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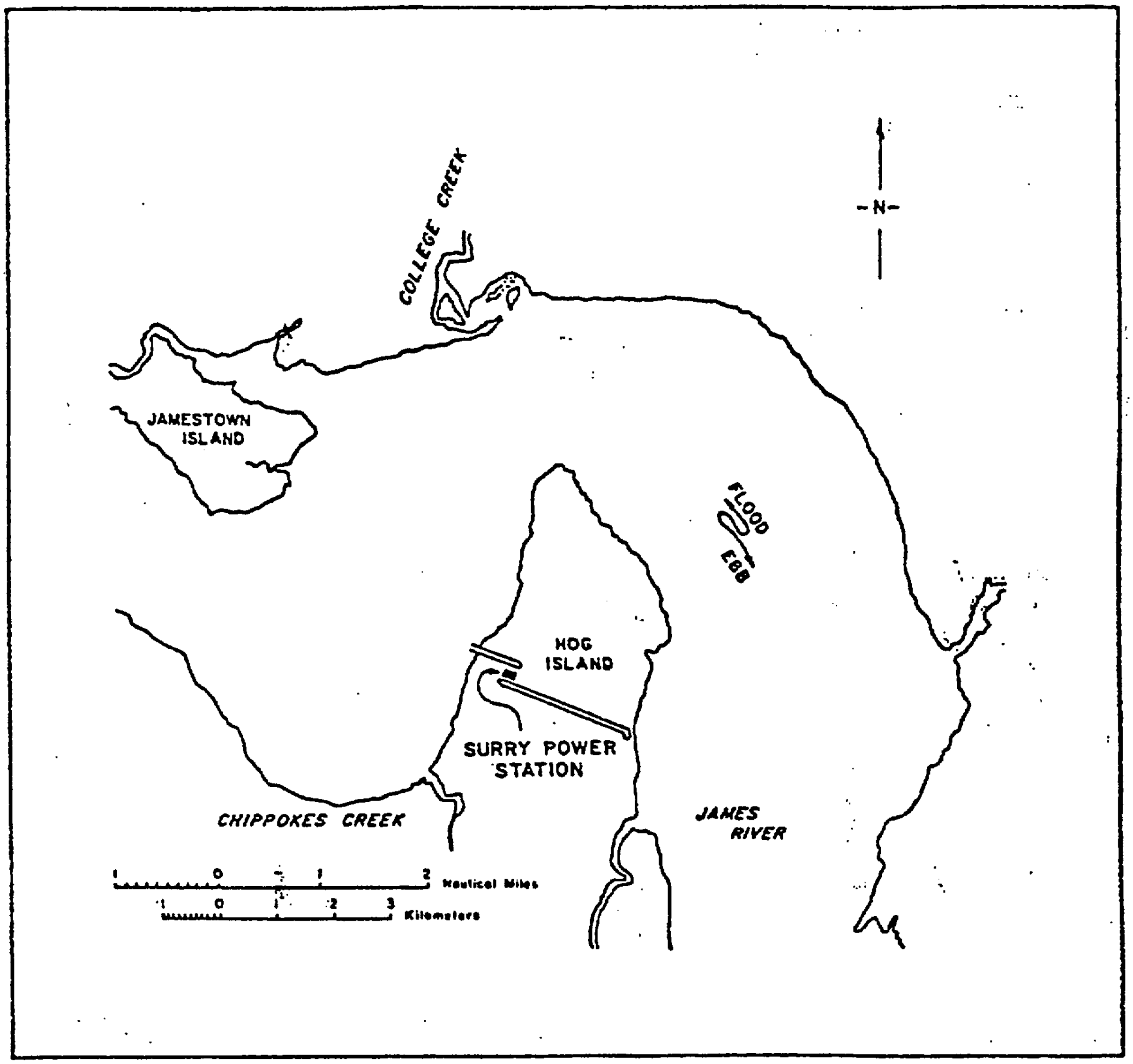

SURRY POWER STATION - UNITS 1 AND 2
COOLING WATER INTAKE STUDIES

ENVIRONMENTAL SERVICES DEPARTMENT
VIRGINIA ELECTRIC AND POWER COMPANY
P.O. BOX 26666
RICHMOND, VIRGINIA 23261

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SURRY POWER STATION
UNITS 1 AND 2
COOLING WATER INTAKE STUDIES

Submitted to

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by

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1.0 INTRODUCTION

1.1 PURPOSE AND ORGANIZATION

The following report constitutes a Section 316(b) demonstration relating to the cooling water intake structure (CWIS) of the Surry Power Station and is submitted in accordance with the provisions of Section 316(b) of P.L. 92-500 and regulations promulgated under Section 316(b). This report also contains impingement and entrainment studies as required by Special Condition No. 1 of NPDES Permit VA 0004090. This report will convincingly demonstrate that the location, design, construction, and capacity of the cooling water intake structure of the Surry Power Station reflect the best technology available for minimizing adverse environmental impact and is therefore in compliance with Section 316(b) of P.L. 92-500.

This report is organized into 9 sections. The first section contains a brief introduction to the purpose and organization of the study, relates the master rationale underlying this report, and concludes with the study history and background. Section 2.0 addresses site characteristics. Section 3.0 describes in detail the condenser cooling water system and discusses several environmentally related modifications to the Surry intake structures. Section 4.0 introduces and describes the various monitoring programs, while Section 5.0 analyzes and discusses the results of these monitoring programs. Several points of comparison between the monitoring programs are provided in Section 6.0. Section 7.0 analyzes and discusses individually the location, design, construction, and capacity of the Surry CWIS, while Section 8.0 presents an overall summary. Section 9.0 contains the major study conclusion. In addition, this report contains numerous tables and figures as well as a list of cited appendices.

1.2 NARRATIVE SUMMARY

This report is a Section 316(b) Demonstration as required by P.L. 92-500 that addresses whether the location, design, construction, and capacity of the CEIS of the Surry Power Station reflect the best technology available for minimizing adverse environmental impact. This Demonstration contains impingement and entrainment studies as required by Special Condition No. 1, NPDES Permit VA 0004090. This report describes, analyzes, and summarizes the impingement, entrainment, and related studies conducted from 1970 through 1978 in the James River in the vicinity of the Surry Power Station and assesses the impacts, if any, of the Surry CWIS upon the finfish community of the area.

This Section 316(b) Demonstration as submitted herein was preceded by a Section 316(a) Demonstration (Appendix 1). On August 31, 1977, Vepco submitted to the Virginia State Water Control Board (SWCB) a Section 316(a) Demonstration (Type 1) for the Surry Power Station, as required by P.L. 92-500 and Special Condition No. 1, NPDES Permit No. VA 0004090. On February 1, 1978, the SWCB, with concurrence from the U. S. Environmental Protection Agency (EPA), approved the Demonstration. The Demonstration was based upon the results of extensive, long-term ecological studies conducted in the James River in the vicinity of the Surry Power Station. Those studies demonstrated convincingly "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" and that the "Surry Power Station operations have had no significant effect on the young fish community of the James River" (Appendix 1). The SWCB and EPA approved these studies and conclusions.

The Surry Power Station is a nuclear powered steam electric generating facility located on Gravel Neck in Surry County, Virginia. Once-through cooling water is withdrawn and subsequently discharged into the James River. The circulating or condenser cooling water system is comprised of a dredged river inlet channel; a "low-lever" intake structure containing eight specially-designed vertical travelling fish screens and eight circulating water pumps; a "high-level" elevated intake canal; a "high-level" intake screen structure with eight conventional travelling screens; a once-through condenser system for each unit; a sea-level discharge canal; and a rock groin mixing structure extending into the James River. Each of these components is described in detail in a subsequent section of this report.

This Section 316(b) Demonstration utilizes data from a variety of sources and investigations. Vepco began funding of investigations by academic and private research organizations in the mid 1960's. In 1969 intensive and wide ranging ecological monitoring and research studies were begun through contracts, by the Virginia Institute of Marine Science (VIMS). Many of these studies continued through 1978. In addition, Vepco has utilized its in-house scientific staff as well as data gathered during other studies.

The various in-house and contracted ecological studies investigated most aquatic floral and faunal communities. The Section 316(a) Demonstration (Appendix) 1) addressed and contained summarizations of stuides of the various communities. The focus of the studies of this Section 316(b) Demonstration, as contained herein, is the ichthyofauna of the James River in the vicinity of the Surry Power Station. In accordance with federal guidelines, no organisms other than finfishes were selected for impact assessment. The Environmental Protection Agency (1977) reported that if "preliminary sampling or prior data does not support special or unique value phytoplankton and zooplankton of the organisms at this site," the faunal groups other than finfishes, specially need not be selected for study. The numerous studies conducted in the area have identified no organisms of "special or unique value."

Therefore, this report describes and analyzes the finfish community of James River in the vicinity of the Surry Power Station and determines whether an adverse environmental impact on this community has been caused by the Surry CWIS.

Based upon the information and studies reported herein, the Surry CWIS have not caused and are not likely to cause an adverse environmental impact upon the ichthyofaunal community of the James River in the vicinity of the Surry Power Station. Furthermore, even if an adverse environmental impact was or is presumed to occur as a result of the CEIS, the location, design, construction, and capacity of the Surry CWIS reflect the best technology available for minimizing adverse environmental impact.

The preceding overall conclusions are fully supported by the results and analyses of five separate finfish studies described and analyzed in this report. These studies are the monthly haul seine, monthly otter trawl, special haul seine, impingement, and entrainment programs. These programs, which were of varying length, intensity, and objective, are fully described and discussed in subsequent sections of this report.

Briefly, however, the shore zone and shelf zone finfish communities were sampled from 1970 through 1978 in the monthly haul seine and monthly otter trawl programs, respectively. Each community was found to exhibit long term stability as gauged by several diversity indice, namely species diversity, richness, and evenness. Studies have shown fluctuations, both increases and decreases, in the relative population levels of some species. These fluctuations, however, are normal and expected and are characteristic of the natural variability inherent in this area and in the occurring species. These conclusions concerning the natural fluctuations of shore zone fish populations were further heightened and illustrated by the results of the special haul seine program. The consistent finding of these studies was that the Surry CWIS have had no detectable adverse environmental impact upon the shore and shelf zone finfish communities.

The impingement program, which provided almost daily sampling data from 1974 through 1978, characterized the number, biomass, and diversity of the finfishes, principally young-of-the year finfishes, impinged by the Surry CWIS. The entrainment program, conducted by VIMS from 1975 through 1978, characterized the number and diversity of finfish eggs and larvae entrained by the Surry CWIS. In both programs the Surry CWIS were found to have had no detectable adverse environmental impact upon the finfish egg and larval populations in the James River in the vicnity of the Surry Power Stations.

In all of the five monitoring programs, no threatened or endangered species was seen or collected. Indeed, based upon an extensive literature review, no threatened or endangered species has been reported to inhabit the James River or Chesapeake Bay during this century.

A holistic rationale is used to determine whether adverse environmental impact was caused by the Surry CWIS. This rationale is simply that if the Surry CWIS, through impingement and entrainment losses, had caused adverse environmental impact on the James River finfish community, that impact would be evident in the degradation and decline of finfish community. However, as determined by the widely-accepted statistical parameters of diversity, evenness, and richness as well as by the long-term overall catches of each species, fish communities, despite impingement and entrainment losses, have remained sound and stable within, of course, the limits of natural variability attributable to the harshness and inconsistency of estuaries. For example, during the many years of investigation, finfishes of the James River were subjected to a wide variety of environmental perturbations. Tropical storm Agnes flooded the lower estuary with record levels of freshwater runoff. Certain species (notably, the alosids or herrings), were seriously overfished by offshore foreign trawlers. Winters were unusually mild or extremely cold. Chemicals, such as Kepone, as well as discharges from sewage treatment plants, resulted in unknown consequences. Nonetheless, the data reported herein show that the finfish communities were resilient to these stresses and, indeed, thrived despite these perturbations.

Undoubtedly, natural compensation, which forms an intergral, if not, the underlying foundation of modern fish management offsets any individual losses from impingement and entrainment by the Surry CWIS. The principle of compensation, or the capacity of a population to ameliorate, in whole or in part, reductions in numbers or density, is an operant reality for fish populations subjected to impingement and entrainment mortalities. In general, when individuals, particularly young individuals and/or eggs or larvae, are removed from a population, the survival and/or reproductive rate among the remaining individuals tends to increase. In this manner the sheer numbers of individuals impinged or entrained by the Surry CWIS is not indicative per se of adverse environmental impact.

As a generalization, the potential (or actuality) of a finfish undergoing impingement typically occurs during only one period of its life history, that being the juvenile stage of its first year. This generalization, coupled with the typically young age and life stage of the removed finfishes (when compensation is most efficient), minimizes the effect of losses due to impingement and entrainment. Furthermore, natural mortality rates are highest during the first year. An unknown but undoubtedly significant percentage of these young finfishes including eggs and larvae would not have survived to adulthood due to natural mortality. Thus, because of the compensatory response of finfishes undergoing impingement or entrainment mortalities and the age at which the vast majority of individuals typically undergo impingement or entrainment, adverse environmental impact does not occur.

The stability of the James River finfish community subjected to natural and man-induced stresses is evidence in itself of the resiliency and compensatory capacity of this community. Changes within the populations of the dominant species, where changes were evident, were found to be the result of natural and/or man-induced perturbations other than the Surry Power Station. It follows that since the finfish community in the James River in the vicinity of the Surry Power Station is stable, robust, and dynamic within the limits of natural variability and that no population or community changes are attributable to the Surry CWIS, the Surry CWIS do not cause any adverse environmental impact.

However, even if adverse environmental impact attributable to the Surry CWIS is presumed to occur, the Surry CWIS reflect the best technology available for minimizing any such impact. This report describes in detail the Surry CWIS and clearly explains why the location, design, construction, and capacity of the CWIS reflect the best technology available for minimizing adverse environmental impact. Importantly, the Surry CWIS incorporates many of the features recommended by Environmental Protection Agency (1976).

The location of the CWIS reflects the best technology available for minimizing adverse environmental impact. The Surry CWIS are located away from major finfish spawning areas. Recirculation of entrained organisms is prevented by the station intake being located approximately 9 km downstream of the station discharge. The low-level intake structure is located flush with the shoreline which tends to prevent finfishes from concentrating or being trapped in embayments and being subject to impingement or entrainment.

The design of the Surry CWIS reflects the best technology available for minimizing adverse environmental impact. The Ristroph travelling fish screens were designed by Vepco and may represent the most successful design for minimizing impingement mortality at CWIS. Based upon intensive impingement sampling, approximately 94 percent of all finfishes impinged upon the Ristroph travelling fish screens were returned alive to the James River. As described by Environmental Protection Agency (1976), this device "might have a positive impact on the impingement problem." At Surry the Ristroph travelling fish screens clearly do.

The construction of the Surry CWIS reflects the best technology available for minimizing adverse environmental impact. All components of the present Surry CWIS except the Ristroph travelling fish screens were in operation prior to enactment of P.L. 92-500, and therefore, the "construction" requirement of Section 316(b) is presumably not applicable. Moreover, the installation of the Ristroph travelling fish screens was a retrofit of material and machinery to an existing concrete structure and involved no disturbance to the river bottom or increase in turbidity levels.

The capacity of the Surry CWIS reflects the best technology available for minimizing adverse environmental impact. The Environmental Protection Agency (1976) reported that if the cooling water flow is small compared to the total river flow, the (assumed) 100 percent death rate may not result in an adverse environmental impact. The capacity of the Surry CWIS is comparatively small and represents only 2.9 percent of tidal river flow. Furthermore, actual 100 percent death rates for total species have never been recorded. Based upon EPA guidelines, the capacity of the Surry CWIS clearly reflects the best technology available for minimizing adverse environmental impact.

This section has provided an overview and summarization of data obtained from years of study and the rationale embodied in the discussion contained in this report. Based upon these data and this rationale, the Surry CWIS have not caused and are not likely to cause an adverse environmental impact. Furthermore, even if an adverse environmental impact was (or is) presumed to occur, the location, design, construction, and capacity of the Surry CWIS reflect the best technology available for minimizing adverse environmental impact.

2.0 SITE CHARACTERISTICS

2.1 SITE LOCATION

The Surry Power Station is located in southeastern Virginia along the south shore of the James River (Figure 1). The site is approximately 71 km southeast of Richmond, 61 km east of Petersburg, 14 km south of Williamsburg and 7 km west-northwest of Fort Eustis, Virginia. The station is situated on a peninsula of land known as Gravel Neck which is located in Surry County, Virginia (Figures 2 and 3). This peninsula occupies the south shore of the James River. The northernmost point of this peninsula is known as Hog Point.

The site traverses in a general southeast-northwest direction bisecting Gravel Neck. The approximate geographic coordinates of the station are 37° 10' north and 76° 42' west.

2.2 STATION DESCRIPTION

The Surry Power Station occupies an 339.9 ha site on Gravel Neck in Surry County, Virginia. The station contains two virtually identical nuclear powered steam electric generating units. Each unit consists of a closed-cycle, pressurized, light-water-moderated nuclear steam supply system, a turbine generator, and auxiliary equipment. A site plan is shown in Figure 2.

The heat generated by each reactor is transferred through 3 separate closed-cycle loops (the primary system) to 3 steam generators. The steam generators in turn utilize the heat from the primary system to produce steam. The steam is transferred through the closed-cycle secondary coolant loops to the steam turbines and drives the generators to produce electricity. After passing through the turbines, the spent steam is condensed with cooling water from the James River and returned to the steam generator to repeat the cycle. Figure 8 is a simplified flow diagram of this process.

2.3 GEOLOGY

The site lies wholly within the coastal plain on a peninsula of land bounded on the east and west by the James River, the south by the upland interior of Surry County, and the north by the marsh-wetlands complex of the Hog Island State Wildlife Refuge (Figure 2). The ground surface at the site is generally flat with steep banks sloping down to the river and to the low level wildlife refuge. Surface and near-surface soil types include brown and mottled brown sand, silty sand, and silt and clay. These soils are included in the Norfolk formation, an estuarine deposit of Pleistocene age. Site elevations range from sea level to approximately +13 m with a mean elevation of approximately +11 m.

2.4 HYDROLOGY

The general hydrology of the James River in the vicinity of the Surry Power Station is fairly well known. Early major studies were begun in 1942 by the Virginia Institute of Marine Science (VIMS)[1] where salinity and temperature data were collected (unpublished data). Pioneer estuarine circulation studies were conducted in the James River in the early 1950's (Pritchard, 1955). A biological and comprehensive chemical study was conducted throughout the tidal James River from May 1965, through May 1966 (Brehmer and Haltwanger, 1966). Studies funded by Vepco characterized the general hydrology of the James River in the vicinity of the Surry Power Station (Pritchard-Carpenter, Consultants, 1966). Extensive pre-operational and post-operational studies monitoring and analyzing the thermal structure of the James River in the vicinity of the Surry Power Station were conducted by several investigators from VIMS (Bolus et al., 1971; Chia et al., 1972; Shearls et al., 1973; Parker et al., 1974; Parker and Fang, 1975; Fang and Parker, 1976). Temperature and salinity were routinely recorded during studies by VIMS and Vepco and are the principle physicochemical parameters discussed in this report.

The James River is the southernmost major tributary of the Chesapeake Bay estuary and traverses through areas of major urban and industrial development. Upstream between the cities of Richmond and Hopewell, Virginia, the river is recipient of heavy sediment and organic and non-organic chemical loading (Brehmer and Haltwanger, 1966). However, natural purification of the river generally occurs by the time the waters reach the power station. Moreover, since the Surry Power Station with-

[1] Formerly Virginia Fisheries Laboratory

draws cooling water from the downstream side of Gravel Neck and discharges it on the upstream side, a distance of approximately 9 km apart (Figure 1), there is additional time for natural purification to occur before the water enters the station.

The James River is tidal from its mouth at Old Point Comfort, Virginia, to the falls of the river at Richmond, Virginia. Upstream from the site at Surry, the James River is fed by a drainage area of 26,449 km^2 (Pritchard-Caprenter, Consultants, 1966). Freshwater inflow from this watershed is highly variable. Based upon data from 1934 through 1965 the minimum monthly mean discharge flow at Hog Point was 857 cfs and the maximum monthly mean discharge was 39,778 cfs (Pritchard-Carpenter, Consultants, 1966). The maximum flood of record in the James River caused by the downgraded remnants of Tropical Storm Agnes, occurred in June, 1972 and resulted in a flow of approximately 420,000 cfs. High river flow conditions in the James River occur generally in the colder months with low flows occurring primarily in summer and early autumn.

Salinity concentrations characterize the James River in the vicinity of the Surry Power Station as a transition region between salt water and fresh water. Dependent primarily upon river discharge, salinity concentrations were observed by Pritchard-Carpenter, Consultants (1966) to range from 0.0 ppt (fresh water) to 21.1 ppt at a depth of 8 m located east of the station intakes.

Salinities recorded by Vepco personnel during a program which is described later in this report show a smaller range of from 0.0 ppt to approximately 12.0 ppt (Figure 5). Although various portions of these ranges may be included in the limnetic, oligohaline, mesohaline, and/or polyhaline zones for the purposes of this report, an oligohaline zone classification (salinity range 0.5-5.0 ppt) best characterizes the area (Carriker, 1967). In addition, the estuary proper, which is classically defined as a semi-enclosed body of water which has a free connection with the open sea and within which seawater is measurably diluted with fresh water derived from land drainage (Pritchard, 1967), encompasses Gravel Neck and the site of the Surry Power Station.

Under normal flow conditions, characteristic of most of the year, the upper or inland boundary of the James River estuary proper is located upstream from the western or Cobham Bay side of the site. For example, Pritchard-Carpenter, Consultants (1966) found that at median river flow discharges of about 7,500 to 8,000 cfs, the upstream limit of measurable ocean salt concentration is located near Swann Point, approximately 10 km upstream of Hog Point. At a discharge of 10,000 cfs this limit shifts downstream near Hog Point. At discharges of 14,000 cfs or greater the limit of saltwater intrusion is near or below Deep Water Shoals. However, under all but the most extreme high river flow conditions, the oscillatory ebb and flood of the tide constitute the dominant motion in both the estuary proper and the freshwater tidal river.

The tidal James River is classified as a partially mixed estuary (Pritchard-Carpenter, Consultants, 1966). In an estuary of this type, salinity decreases in a more or less regular manner from higher salinities at the mouth to lower salinities toward the head of the estuary. Salinity also typically increases with depth at any given location. The upper, less saline stratum of river water experiences a net non-tidal downstream motion directed toward the mouth of the estuary. Conversely, the lower, more saline stratum of river water experiences a net non-tidal upstream motion directed toward the head of the estuary. The boundary between the layers is generally sloped across the estuary such that the downstream moving surface layer extends to greater depth on the right side (looking downstream) than on the left side. Conditions can and do exist whereby a net downstream flow on the right side of the estuary coexists and yet partially mixes with a net upstream flow on the left side of the estuary.

As a result of these tidal and non-tidal movements, the net non-tidal flow involves volumes of water that are large when compared to river flow, but small compared to oscillatory tidal flow. Pritchard-Carpenter, Consultants (1966) describe, for example, that in July, 1950, the freshwater discharge at Hog Point was approximately 168 m^3/min. At the same time at Deep Water Shoals (a midstream area of the James River east of the CWIS) the downstream directed flow in the surface strata was approximately 504 m^3/min and the upstream directed flow in the deeper strata was approximately 336 m^3/min. By comparison, the average volume rate of flow (upriver during flood tide and downriver during ebb tide) was approximately 3,640 m^3/min at this same area during this time.

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 (U. S. Department of Commerce, 1978a). 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 0.68 m/sec (1.3 knots) while the average maximum flood current is 0.58 m/sec (1.1 knots).

Spring tides have maximum ebb currents of 0.98 m/sec (1.9 knots) and maximum flood currents of 0.85 m/sec (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.

Pritchard-Carpenter, Consultants (1966) analyzed the computer records of some 3,000 water temperatures recorded in a 16 km stretch of the James River centered on Hog Point between 1942 and 1966 by VIMS and the Chesapeake Bay Institute (unpublished data). Maximum and minimum surface water temperatures were 33.8 C and 1.8 C, respectively. The majority of the summer surface temperatures fell in the range 26-28 C although temperatures in excess of 30 C occasionally occurred. Since the observations were biased toward warmer seasons, lower winter temperatures than 1.8 C probably occurred. Winter river ice is not uncommon in the lower James River.

Water temperatures recorded by Vepco personnel during 1970-1978 in the programs described later in this report correlate with the above temperature (Figure 5). The highest surface water temperature ever recorded by VIMS personnel in their thermal monitoring studies was 37.7 C which was located in the heated discharge waters (Fang and Parker, 1975).

The James River in the vicinity of the Surry Power Station is broad and relatively shallow although depths up to 27.4 m are located east of the station intakes near Deep Water Shoals (Figure 6). A navigation channel is maintained at 7.6 m and generally courses through the middle of the river.

Composition of the river bottom varies with area and includes soft mud and ooze, mud, clay, sand, pebbles, and oyster seed beds. No single bottom type predominates.

2.5 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 influences the local climate in the Surry area. The Atlantic Ocean and 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, thereby, decrease the storms' severity for the Piedmont and Tidewater areas of Virginia in which Surry is located.

Extensive baseline meteorological monitoring began in 1968 at recording stations on the site and on Hog Point. The onsite meteorology has been continuously monitored since March, 1974, by a mini-computer based system which complies with the requirements of the Nuclear Regulatory Commission (NRC) Regulatory Guide 1.23. The meteorological monitoring site is located 1494 m to the southeast of Unit 2. The system includes a 45.7 m tower. Dry bulb temperature, dew point temperature, wind speed, and wind direction are measured at the 10 m level. Wind speed and wind direction are measured at the 45.7 m level. Differential dry bulb temperature is measured between the 10 m level and the 45.7 m level. Precipitation is measured at the surface. The data are processed into one hour averages for historical storage.

Vepco's Environmental Services Department, located in One James River Plaza in Richmond, Virginia, has stored numerous data recorded at Surry from March, 1974 through December, 1978. These data include the following listings:

Monthly joint frequency distributions for wind speed and wind direction at the 10 m and 45.7 m levels.

Maximum 1 hour average wind speed and associated wind direction at the 10 m and 45.7 m levels.

The maximum hourly, minimum hourly, average daily, and diurnal average values of dry bulb temperature, dew point temperature, and differential dry bulb temperature.

The maximum precipitation totals on 1, 6, 12, 18, and 24 hour basis.

Monthly total precipitation.

These data are voluminous and are not included in total in this report. However, specific data can be provided upon request. Selected meteorological data are provided in Table 1.

In general, the prevailing wind at the Surry Power Station during the period 1975-1978 was from the south through the southwest sector. During this same period the average annual onsite wind speed at the 10 m level was 9.16 km/hr. The average annual dry bulb temperature was 14.6 C with a maximum temperature of 36.3 C and a minimum temperature of -12.3 C., both recorded in 1977. Yearly precipitation varied substantially with totals of 150.1, 82.8, 75.7, and 97.3 cm recorded during 1975, 1976, 1977, and 1978, respectively.

The period corresponding to the operation of the cooling water intake structures at Surry Power Station may meteorologically be characterized as an atypical period. During this period Eastern Virginia experienced record extremes and averages of both precipitation and temperature. For example, unusual and unexpected river ice during the winters of 1976-1977 and 1977-1978 inflicted heavy damage to the low-level cooling water intake structure screens.

Despite several unexpected occurrences, the overall meteorology at this site correlates, as expected, with observations made by the National Weather Service at Richmond and Norfolk (Crockett, 1972). Based upon these data, no significant deviations between the onsite meteorology and the general meteorological conditions of eastern Virginia have been experienced or are expected.

3.0 CONDENSER COOLING WATER SYSTEM

3.1 INTRODUCTION

The Surry Power Station is a nuclear powered steam electric generating facility utilizing once through cooling water from the James River to dissipate waste heat from the turbine condensers and from the plant service water system. A simplified flow diagram of the heat dissipation system at the Surry Power Station is shown in Figure 9.

The heat dissipation or circulating water system is designed to provide once-through cooling water for both units. The system is comprised of a dredged river inlet channel, a low-level structure consisting of eight travelling fish screens and eight circulating water pumps, a high-level elevated intake canal, a high-level intake screen structure with eight conventional travelling screens per unit, a once-through condenser system for each unit, a sea-level discharge canal, and a rock groin mixing structure extending into the James River (Figures 10 and 11). Each of these will be described in Section 3.2 of this report.

Water used for cooling is taken from the James River on the downstream side of the site, pumped into the high-level canal, transported by gravity through the station condensers, and discharged into the river on the upstream side. The shoreline distance between intake and discharge points is about 9.5 km while the overland distance across the peninsula is about 3.2 km.

Each unit requires 3,180 m^3/ min of river water to supply condensing and service water needs. The maximum temperature elevation of this water as a result of passage through the condensers is 7.8 C. After passing through the station, the heated water is mixed with river water through a jetting action of 1.8 m/sec at the end of the rock groin and heat dissipation occurs rapidly. Additional details of this system and the thermal discharges may be found in Appendix I.

3.2 STRUCTURES AND OPERATION

3.2.1 RIVER INTAKE CHANNEL

Circulating water is withdrawn from the James River through a channel dredged in the riverbed between the main river channel near river buoy S "J24" and the eastern shore of the site, a distance of approximately 1,737 m. As shown in Figure 12, the channel is roughly L-shaped and was originally dredged to a depth of El. -4.1 m. The bottom width of the channel, exclusive of the L-shaped portion, is approximately 46 m wide with a bank slope ratio of 3 (horizontal) to 1 (vertical). These channel dimensions permit the use of the channel for shipping materials and equipment to a permanent dock located north of and adjacent to the low-level intake structure. Circulating water is then withdrawn through the low-level intake structure.

3.2.2 LOW-LEVEL INTAKE STRUCTURE

The low-level intake structure is an 8-bay reinforced concrete structure located at the shore terminus of the river intake channel (Figure 13). These bays are referred to as the low-level bays. The basic features of each low-level bay include a sloped trash rack, an innovative concept in a continuously operating travelling screen known as the Ristroph travelling fish screen, and a circulating water pump (Figure 14). At the mouth of each low-level bay is a sloped trash rack constructed of a 1.3 cm wide steel bar spaced approximately 8.9 cm apart. Flow between these trash racks at maximum withdrawal capacity averages approximately 0.31 m/s (Table 2). Trash and debris are cleaned off the racks by a mechanical rake.

Because of the unique design of the Ristroph travelling fish screens and its significance in minimizing adverse environmental impact, this device is described and discussed in detail in Section 3.3 of this report.

Each low-level bay houses 1 of the 8 circulating water pumps (Figure 13). These circulating water pumps are rated at 795 m^3/min at 8.5 m total dynamic head when operating at 220 revolutions per min (rpm). The maximum rate of withdrawal of circulating water from the James River is approximately 6360 m^3/min. Each pump is driven by a vertical, solid-shaft induction motor rated at 2,000 horsepower (hp). The discharge conduit of each pump is a 244 cm diameter steel pipe which conveys the cooling water under an access road, up and over the high-level intake canal embankments, and into the high-level intake canal (Figures 10 and 13).

The exposed deck of the low-level structure is El. +3.7 m. The pillbox-like housing for the emergency service water pumps is protected from flooding to El. +6.4 m and from wave run-up to El. +10.2 m. The invert of the low-level structure is El. -7.7 m.

3.2.3 HIGH-LEVEL INTAKE CANAL

The high-level intake canal conveys circulating water by gravity from the low-level intake structure to the high-level intake structure. The canal is approximately 2.8 km long and traverses in a general east-to-west direction, nearly bisecting Gravel Neck (Figures 3 and 7). The canal is lined with concrete for erosion prevention and has an average bottom width of approximately 9.8 m. The side slopes are 1.5 (horizontal) to 1 (vertical). The invert elevation varies from El. +2.1 m at the east or river intake end of the canal to El. +1.5 m at the west or station end of the canal. The berm along each bank of the canal is El. +11.0 m.

The water levels in the canal during different pumping modes are controlled by the piping system friction losses within the power station as well as the prevailing river tide level and will vary between El. +6.4 m and El. +7.0 m, depending upon the tide level in the James River. The minimum capacity of high-level intake canal is maintained at approximately 170,325 m^3 of cooling water.

A minimum freeboard of 3 m is maintained between the canal water surface and the berm during hurricane flooding of the river thereby preventing any spillage from the canal. This freeboard is also adequate to contain surges in the canal which could occur if the station lost power with the river flooded. Freeboard is maintained under these circumstances by progressively reducing the number of pumps in operation by manual control as the river level rises above El. +1.5 m.

3.2.4 HIGH-LEVEL INTAKE STRUCTURE

Two separate reinforced concrete structures, one structure for each generating unit, are located near the terminus of the high-level intake canal (Figure 17). These separate structures, one for each generating unit, are collectively referred to as the high-level intake structure.

Each structure contains 4 high-level bays. Each bay contains a sloped trash rack, a conventional vertical traveling screen, and an inlet to a 244 cm diameter condenser intake pipe which is constructed of reinforced concrete and welded steel incased in concrete.

The trash racks of the high-level structure are identical to racks on the low-level structure. The travelling screens are constructed of 14 gauge wire with 0.95 cm mesh and are designed to rotate once every 24 hours or when a pressure differential of 15.2 cm of water exists across the screen. Water-born debris and aquatic organisms removed from the high-level screens by a high pressure wash water spray are deposited in the station discharge canal via an underground sluice.

3.2.5 IN-PLANT CONDENSER SYSTEM

Circulating water flow from the high-level intake structure into the station condensers is controlled by electric-motor-operated butterfly valves located at the condenser inlets. An "Amertap" condenser tube cleaning strainer is installed in each of 4 condenser discharge lines between the condenser discharge nozzle and the motor-operated condenser discharge butterfly valve. This "Amertap" system mechanically maintains clean and unfouled condenser tubes, thereby eliminating the need for chemical biocidal injection. Following heat exchange and cooling of the station condensers, circulating water enters condenser discharge lines. These discharge lines terminate at the reinforced concrete discharge tunnel which carries the water to the common circulating water discharge canal. A simplified flow diagram of the station's steam-electric system is shown in Figure 8. A simplified flow diagram of the heat dissipation system is shown in Figure 9.

3.2.6 DISCHARGE CANAL AND MIXING STRUCTURE

The station discharge canal receives the flow of condenser cooling water and transports this water to the James River for heat dissipation purposes. The discharge canal is designed to carry the flow of the 2 units at a velocity of approximately 0.7 m/s at mean low water. The depth of the canal is El. - 5.3 m and the sides slope at a grade ratio of 2 (horizontal) to 1 (vertical). The bottom width of the canal varies between 6 m near the head to 20 m near the terminus.

The discharge canal extends approximately 335 m into the James River on the west side of the site (Figure 7) and, from the station to the shoreline, is lined with concrete to prevent erosion of banks and subsurface soil. The 335 m extension has a rock-filled groin along each side to minimize siltation. The terminal opening between the groins is reduced in size to ensure a 1.8 m/s exit velocity for proper mixing with the river. A timber pile trestle having five bays, 3.0 m in width, extends about halfway across the opening in the groin. The timber gates may be installed in this structure using mobile hoisting equipment to reduce the net area of the opening between groins and thereby maintain the 1.8 m/s terminal flow velocity under various operating loads and conditions.

3.3 ENVIRONMENTALLY-RELATED MODIFICATIONS TO INTAKE STRUCTURES

Travelling screens are currently the most commonly used devices for protecting the cooling water intake systems of electric generating facilities. These screens function as a filtering mechanism for the removal of water borne debris and/or aquatic organisms from the source cooling water that may impede flow or render damage to the in-plant condenser cooling system.

At the Surry Power Station this task was initially performed by the high-level intake structure. The high-level intake structure with its conventional travelling screens was included in the station's original design. A low-level travelling screen system was not included in the station's original design. Operation of the high-level intake structure began during the initial cooling water system testing in the latter stages of station construction. The high-level intake structure functioned as the primary fish removal device until May, 1974.

Sampling of impinged fishes on the high-level intake structure was initiated in July, 1972, coinciding with the attainment of criticality status for Unit 1, and continued through May, 1974. Sampling was conducted adjacent to the Unit 1 structure via a common wash water trough that served both Units 1 and 2 structures.

The observations and results of this high-level intake sampling are not included or analyzed in this report. However, these studies did result in an early modification of the high-level intake structure designed to somewhat reduce the mortality of impinged fishes.

The high-level intake screens, like most conventional travelling screens throughout the country, do not rotate continuously. As mentioned in Section 3.2.4 of this report, the normal operating schedule of the high-level screens is to rotate once every 24 hours or whenever a pressure differential of $\overset{6''}{15.2}$ cm exists across the screen. Under this operating regime 100 percent mortality of fishes impinged upon the screens was expected. However, testing revealed survival of some impinged fishes as they were being removed from the water and deposited in a sampling basket.

The first design modification was to extend the high-level wash water trough to the station discharge canal via a $\overset{18''}{\underline{45\text{ cm}}}$ diameter polyethylene pipe. Under normal screen operating conditions, this modification allowed some fishes to survive impingement. Subsequent tests revealed that when the screens were operated continuously (although they were not designed for long-term continuous operation) this transport system minimized mortality during cold water periods but that mortality exceeded desired levels during the warm water periods. Moreover, it was found that mortality was primarily the result of high screen wash water pressure and the repeated reimpingement and subsequent weakening of impinged fishes.

Hydrological studies in the high-level intake canal revealed that the typical time of passage for a unit of water to travel the length of the canal from the low-level intake pumps to the high-level screens was approximately 45 to 60 minutes. However, fishes pumped into the 2.8 km canal were found to normally display an even longer time of passage. It was surmised that an unquantifiable percentage of these fishes, especially of some species, were not ultimately being impinged but rather they continued to live, and indeed, flourish in the canal.

Moreover, relatively large numbers of young-of-the-year and juvenile fishes were found in the high-level canal, a number of which were ultimately being impinged. These situations evidenced the need for an effective fish diversion or fish removal system outboard of the low-level intake pumps.

As a result of this need, two different types of fish diversion systems were installed and tested. These diversion systems were an air-bubbler network and an underwater sound system.

The air-bubbler network was a semicircular configuration of pipe constructed along the bottom of the intake channel in front of the low-level intake structure. Compressed air at 70,310 kg/m^2 was pumped through the pipe and emitted via 0.6 cm diameter holes spaced 10.2 cm apart in the pipe.

The desired result was to produce an artificial vertical barrier screen to prevent fishes from becoming introduced into the high-level intake canal. This system was not as effective as desired.

Following the less than desirable results of the air-bubbler network, a second diversion system, an underwater sound system, was installed and tested. This system consisted of a network of 10 to 14 underwater speakers placed immediately outboard of the trash racks directly in front of the intake pumps at the low-level intake structure. Various levels of sound waves, from "soothing music" to "hard rock" were emitted from the speakers in an attempt to discourage fishes from entering the area of pump influence. This system was also less than successful.

As a result of these trials and the ineffectiveness of diverting fishes away from the station intakes, fish removal system were studied. It was determined that the installation of conventional travelling screens outboard of the low-level intake pumps would not significantly reduce impingement levels below those encountered at the high-level intake screens. In addition to the requirement for safely transporting and relocating impinged nekton, a new fish removal system must not jeopardize and/or otherwise impede the flow of cooling water to the condensers. Aware of these restrictions and the inherent handicaps associated with conventional travelling screens, an innovative fish handling device was designed. This device is referred to as the Ristroph travelling fish screen and bears the name of its principal designer, Mr. J. D. Ristroph, the first and former director of Vepco's Environmental Services Department (then, Environmental Control Department).

The Ristroph travelling fish screens were installed in each low-level bay at the low-level intake structure (Figure 14) in May, 1974, and were designed site specific for the Surry Power Station. Significantly different from conventional vertical travelling screens, the Ristroph travelling fish screens were purposely designed to increase the survival of fishes impinged upon it (White and Brehmer, 1976). A schematic of the Ristroph travelling screen is shown in Figure 15.

A typical screen unit contains 47 screen panels, each 4.7 m 15.7'
1.57' wide by 0.6 m high, with a screen mesh size of 0.95 cm. The units rotate continuously at a speed of 3.3 m/min with an alternate capability of .37"
6.1 m/min.

Fish that become impinged upon a Ristroph screen remain on the face of that screen panel for a maximum of 2 minutes as the screen rotates upward or until that panel clears the air-water interface. At this point in the rotation cycle, a conventional vertical travelling screen (unlike the Ristroph travelling fish screen) allows significant mortality to occur as fish can flip back into the water and be repeatedly reimpinged until in a moribund condition and/or they die. By contrast, the Ristroph travelling screen avoids such impacts on fish. The Ristroph travelling screen employs a trough of water 5.1 cm deep by 14.0 cm wide that runs the full width of the screen along the base of each panel (Figure 15). As each panel clears the air-water interface, fish drop into the trough and remain in water until the panel passes over the top of the sprocket. As the panel goes from vertically upward travel to horizontal, fish are out of the water for only a few seconds as they slide down the panel when it becomes vertical going downward, and are gently washed into a backside fiberglass fish sluice trough designed to maintain a water depth of 5.1 cm.

After each panel has rotated over the top of the head sprocket, the screen panels are washed on the backside of the screen structure by water sprayed from two header pipes, one inside the rotating screen and another located outside the screen and above the collection or fish sluice trough. The inside header pipe contains 24 individual spray nozzles, while the outside header pipe contains 48 sprays. Collectively, the nozzles are designed to supply approximately 0.8 m^3/min of washwater at 1,030,000 - 1,380,000 dynes/cm^2 to each of the eight screens. Unlike the high pressure wash spray on the high-level screens, this low pressure spray does not generally result in a debilitating or fatal injury and/or in the descaling of the impinged fishes.

The Ristroph travelling screen system also provides for the safe return of impinged fishes to the James River. The fish return system is an open-top, U-shaped fiberglass trough that contains approximately 0.6 m of water. Screen washwater from each fish sluice trough and special augmentation water safely transport fish and other collected material back to the river. The fish and debris are discharged underwater approximately 305 m downstream from the screens and approximately 91 m offshore, a distance believed sufficient to overcome reimpingement of most discharged fishes.

In addition, the trough is modified to facilitate sampling. The trough is fitted with a Y-shaped section that contains a flop gate whereby the entire washwater flow of approximately 9.5 m^3/min can be diverted for sampling purposes into a 64 m^3 fiberglass holding pool.

4.0 MATERIALS AND METHODS

4.1 INTRODUCTION

In order to assess the adverse environmental impact, if any, of the operations of the Surry Power Station upon the biotic communities of the James River, initial site-specific ecological studies were first begun in May, 1969, in the vicinity of Hog Island on the James River by personnel from VIMS. These studies, funded through a contract with Vepco, characterized various biotic communities of this particular area prior to and during the operation of the Surry Power Station. The various communities investigated included benthos, epibenthos, zooplankton, phytoplankton, finfish, and fouling organisms. These studies continued through 1978.

These studies were analyzed and discussed in detail in Vepco's successful Section 316 (a) Demonstration (Type I) for the Surry Power Station. This demonstration, which found that a balanced indigenous community of shellfish, fish, and wildlife exists in and on the James River in the vicinity of the Surry Power Station and that "the operation of the Surry Power Station has caused no appreciable harm to the fish community", was approved by the SWCB and EPA and is included in this report as Appendix I.

In 1970, programs consisting of monthly haul seines and otter trawls were initiated by Vepco personnel to augment and intensify studies on fish populations in the James River in the vicinity of the Surry Power Station. In addition, a special seine program was instituted in 1973 to supplement and enhance existing data, particularly for possible quantitative purposes. These programs continued through 1978.

Impingement investigations by Vepco personnel began in 1972 at high-level intake structure. In 1974, impingement investigations were initiated at the low-level intake structure following the installation and operation of the Ristroph travelling fish screens in May of that year. These low-level studies continue to date although only those data collected through December, 1978, are discussed in this report. Regular high-level intake studies were discontinued in May, 1974, and are not discussed or analyzed in this report.

Ichthyoplankton entrainment studies were contracted to VIMS and commenced in 1975. These studies continued through 1978.

Data resulting from the various Vepco monitoring programs were analyzed with the Statistical Analysis System (SAS), release 76.6D using an IBM Model 3033 computer (Barr et al., 1976).

The materials and methods utilized in each of these programs are discussed in the remainder of this section. The results of each of these programs are presented and discussed in the following section.

4.2 MATERIALS AND METHODS

4.2.1 MONTHLY HAUL SEINE PROGRAM

The objectives of the monthly haul seine were (1) to characterize the fish populations of the shore zone of the James River in the vicinity of the Surry Power Station in terms of species diversity and relative abundance of collectable fishes and (2) to attempt to relate the effects, if any, of the station's operations upon these populations. Preliminary sampling began in May, 1970, on an irregular basis. Regular monthly sampling commenced in December, 1970, and continued through 1978, except when adverse weather conditions prevented proper sampling.

Seven sampling stations were selected between Jamestown Island and slightly downstream of the low-level intake structure (Figure 16). These stations were selected because (1) they were representative of the shore zone throughout the study area, (2) they presented no significant hazards of conditions, such as snags or deep mud, to preclude proper sampling, and (3) it was felt no significant alteration of these stations, due to shoreside construction, dredging, extensive sedimentation, etc., would occur during the course of a long-term study. Sampled depths ranged from 0 to approximately 1 m. Bottom types were typically sand or firm clay and sand with occasional patches of pebbles and rocks overlying this substrate at Station 0001 and with numerous fossiliferous shells and pebbles at Station 0005.

A single unit of effort consisted of one haul along a 100 m portion of the shore at each sampling station. The haul seine was pulled, when possible, against the tide to maximize the efficiency of this type of gear. The seine was brought ashore after which the collected fishes, except for extremely numerous species, were preserved in a 10 percent buffered formalin solution and returned to the on-site Surry Environmental Laboratory for analysis. For numerous individuals within a species, fifteen individuals were selected for length-weight measurement in the laboratory while the remainder were counted. All other species were similarly weighed to the nearest 0.1 g and measured to the nearest whole millimeter total length (TL). Length-frequency tables presented later in this report reflect only those individuals that were actually measured.

A number of physical parameters and environmental conditions was taken with each sample. Water temperature, conductivity, and salinity were measured with a Beckman RS5-3 salinometer. Dissolved oxygen was measured using the azide modification of the Winkler method (Standard Methods, 1975). In addition, wind speed and direction, weather conditions, time of day, range of depth, average depth, and tidal stage were recorded.

4.2.2 MONTHLY OTTER TRAWL PROGRAM

The objectives of the monthly otter trawl program were (1) to characterize the fish populations of the shelf zone of the James River in the vicinity of the Surry Power Station in terms of species diversity and relative abundance of collectable fishes and (2) to attempt to relate the effects, if any, of the station's operations upon these populations. Preliminary sampling began in May, 1970, on an irregular basis. Regular monthly sampling commenced in December, 1970, and continued through 1978 except when adverse weather conditions prevented proper sampling.

Six sampling stations were selected (Figure 17). The stations were selected in conjunction with and for the same reasons as the sampling stations of the monthly haul seine program (Section 4.2.1). Sampled depths ranged from approximately 1.8 m to approximately 9.8 m with an average sampled depth of around 3 to 4 m. Bottom types include sand, clay-sand, mud, ooze, and shell bottoms.

Generally, all trawls were taken perpendicular to the shore and not along the main river channel. Two exceptions should be noted: (1) trawl station 0010 at the intakes was located in a Vepco constructed channel leading from the main river channel across the shallow shelf zone to the Surry Power Station intakes and dock, and (2) trawl station 009 located at Hog Point south to Hog Point north intersected the river channel during the haul. The main effort, however, focused on the shelf zone on the south side of the river channel.

A single unit of effort consisted of a 10-minute trawl. The effort was standardized in referenced to time of haul and engine revolutions per minute (rpm) rating, although the length of the tow was also dependent on wind and tidal action. Tow lengths averaged approximately 700 m with ranges between 450 and 900 m.

All fishes taken by trawl were treated in the same manner as those taken with the haul seine. Water temperature, conductivity, salinity, and dissolved oxygen were monitored in the same manner as in the monthly haul seine program (Section 4.2.1). Other parameters recorded for each sample included wind speed and direction, weather conditions, time of day, and tidal stage.

4.2.3 SPECIAL HAUL SEINE PROGRAM

A special haul seine program was begun by Vepco personnel in May, 1973, principally to attempt to estimate relative population levels of the various species of fishes inhabiting the shore zone waters between the power station intake and discharge. This program was designed (1) to collect representative samples of the finfishes inhabiting this particular area; (2) to sample an area accessible during most types of weather; and (3) to provide sample replication for statistical analysis.

Three sampling stations, Hog Point West (HPW), Hog Point North (HPN), and Hog Point East (HPE), were chosen (Figure 18) because of their proximity to the power station and their accessibility by land vehicle in all weather conditions. The gear type for this program was adopted from the haul seine program and consequently consisted of a haul seine 15.2 m long by 1.8 m deep with 6.4 mm bar mesh.

A single unit of effort consisted of hauling the seine parallel to the shoreline for a measured distance of 15.2 m after which the outboard or deep water end of the seine was brought to shore. Figure 19 illustrates this sampling technique. After the fishes were collected from this haul, a replicate sample was taken in the adjacent shore zone area. The collected fishes from both hauls were preserved in a 10 percent buffered formalin solution and returned to the on-site Surry Environmental Laboratory for analysis.

Initially, each sample collection was separated by species and the individuals within each species were enumerated. For those species whose total number was less than 50, all individuals were measured to the nearest whole millimeter of total length (TL). For those species whose total number was greater than 50, a total of 50 selected individuals was similarly measured. The program was modified in September, 1973, to include weighing to the nearest 0.1 g and measuring 15 selected individuals within a species, measuring up to 35 individuals, and enumerating any remaining individuals within that species.

All physical parameters and environmental conditions recorded for this program were monitored in the identical manner as the monthly haul seine program (Section 4.2.1).

4.2.4 IMPINGEMENT PROGRAM

The Environmental Protection Agency (1977) defines impingement as "the physical blocking of larger organisms by a barrier, generally some type of screen system in the cooling water intake." This program addresses impingement as the blocking of finfishes upon the Ristroph travelling fish screens. As noted in Section 4.1 of this report, initial impingement studies began at the high-level intake studies. However, due to the uncertainties associated with high-level impingement studies and the shift in research undertaken following completion of the Ristroph travelling fish screens, the high-level studies are not presented in this report. Therefore, impingement studies as they are discussed hereafter in this report pertain only to those studies that utilized the Ristroph travelling fish screens.

Low-level intake impingement sampling was begun by Vepco personnel in May, 1974, immediately following the construction and completion of the Ristroph travelling fish screens. A unique sampling design and methodology was employed at this time. As described in Section 3.3 of this report, the screen wash water trough is fitted with a Y-shaped section that contains a flop gate whereby wash water can be diverted into an in-ground holding pool. This holding pool was initially open and without cover and a later housing was constructed. An impingement sample, that is a single unit of effort, is obtained by diverting the entire flow of screen wash water from the trough into the holding pool for a five-minute time period. The wash water and any impinged fishes remained in the pool for a five-minute period after which the water was slowly drained. When the fishes became visible (generally 5-10 minutes, depending upon turbidity) they were collected in a D-frame dip net and were determined to be either alive or dead. All specimens were then identified to species, measured by 20 mm TL increments, and bulk weighed per species to the nearest 0.1 g. Two consecutive five-minute impingement samples were taken daily, generally Monday through Friday of each week.

Water temperature, conductivity, and salinity of each sample were measured with a Beckman RS5-3 portable salinometer and recorded. In addition, wind speed and direction, weather conditions, time of day, and tide stage were recorded. Dissolved oxygen levels were not determined due to possible fluctuations in wash water concentrations as a result of intake screen operations.

4.2.5 ICHTHYOPLANKTON ENTRAINMENT PROGRAM

The Environmental Protection Agency (1977) defines entrainment as "the incorporation of organisms into the cooling water flow." This program addresses entrainment as the incorporation of ichthyoplankton into the intake cooling water flow and the resulting passage through the power station.

Ichthyoplankton (fish eggs and larvae) entrainment studies were begun in April, 1975 by VIMS, under a funding contract by Vepco. The studies were designed to assess the species and quantities of ichthyoplankton entrained and passed through the facility. An investigatory study was conducted by VIMS to evaluate the best type of gear to be utilized for this project. The most suitable gear type selected was paired 0.5 m diameter conical nets equipped with 505 μ mesh netting. Each net was fitted with a General Oceanics Digital Flowmeter (Model 2030) suspended across the net opening to accurately measure the amount of water filtered. Tows were made at surface, mid-water and bottom depths in the low-level intake forebay and mid-channel in the discharge canal near the roadway bridge at sample times of 1000, 1400, 1800, 2200, 0200 and 0600 hours on any given sample day. Tow time at the low-level intake was 10 minutes per depth and tow time at the discharge was 5 minutes per depth. The difference in tow times was necessary in order to sample approximately equal volumes of water at each sampling station.

All samples were collected and preserved in the field with a 5 percent buffered formalin solution and returned to the VIMS laboratory for identification, enumeration, and further analysis.

Water temperature was measured for each sample with a stem thermometer. Salinity samples were taken for each sample and returned to VIMS, Gloucester Point, Virginia, for analysis with a Beckman RS-7 induction salinometer. Dissolved oxygen samples were taken and fixed at each station and concentrations were determined using the Winkler Titration Method.

5.0 RESULTS AND DISCUSSION

5.1 INTRODUCTION

In order to properly assess the environmental impact, if any, of the Surry cooling water intake structure upon the oligohaline zone of the James River, an acute awareness of the operant natural stresses and interrelationships between the physical and biological components of the estuary is essential. Therefore, before presenting the results and analysis of the studies, this section briefly introduces and discusses several considerations pertinent to the uniqueness of the relationships between cooling water intakes, estuaries, and estuarine organisms.

Foremost in the knowledge of estuarine sciences is an appreciation of the sheer complexity of estuarine systems. Despite many recent advances and refinements in techniques and technology and the costly and exhaustive efforts of numerous investigations, the "estuary," even the much studied Chesapeake Bay estuary, remains essentially a poorly known, labyrinthine system. McHugh (1967) reports that the precise "environment" of an estuarine individual or species is unknown.

A review of the numerous factors governing the physical relations of estuaries and the diverse behavioral manifestations of estuarine biota is beyond the purpose and scope of this report. However, one important biological concept will be presented and discussed, the principle of compensation.

Broadly defined and topically applied, compensation refers to the natural capacity of a fish population to totally or partially offset and/or ameliorate reductions in population numbers caused by deleterious and/or catastrophic, extraneous stresses. Examples of compensatory responses of fish populations are numerous. For example, discussing natural limiting factors in Gulf Coast estuaries, Hopkins and Petrocelli (1977) quote Simmons and Breur (1962) that "Catastrophic freezes occurring about every 10 years have destroyed more fish than have been harvested commercially for the past 50 years" and report that the natural compensatory capacity of the surviving individuals is such that fish catches subsequently returned to normal levels in 2 or 3 years.

Impingement and entrainment at cooling water intake structures effect population responses different from the often cataclysmal results of two classes of problems, the wholesale destruction of environmental resources and the release of exotic toxic substances. McFadden (1977) discusses this:

> "A third class of man-made problems - the imposition on a population of increased mortality that takes a form similar to natural predation - has an entirely different effect upon most species. This is the kind of impact to which the population has been adapted by thousands of years of evolutionary experience. The agent of mortality - predatory fish, commercial or sport fishermen, or power plants - is an indifferent matter from the standpoint of population response. When the population is reduced in numbers, the survival rate or the reproductive rate among the remaining members tends to increase; a compensating response is generated. This is the reality upon which successful management of agriculture, forestry, wildlife, and fisheries is carried on today. The population has a measurable and often impressive capacity to persist in a healthy state in the face of deliberate removals by man. Populations of most species, while fragile when deprived of basic life requirements or exposed to exotic toxicants, are robust in the face of this impingement and entrainment predation-type mortality."

As will be shown and discussed later in this report, the Surry cooling water intake structure entrains relatively few fish eggs and larvae and impinges fewer adult than juvenile fish. Relating the principle of compensation to egg, larval, and juvenile mortality, Ricker (1954) reports:

> ". . . it is clear that any general prejudice against exploiting young fish is unsound. Exploitation that takes fish at an age when natural mortality is still a compensatory means . . . the earlier the better. The removal of such young is at least partly balanced by increased survival and/or growth of the remainder . . . ."

These remarks by Ricker (1954) and, moreover, their underlying principles have remained unchallenged to date.

McFadden (1977) echoes and succinctly phrases this relationship: "Killing some fish during the egg, larval, and juvenile stages (which is what power plants do) is no worse than killing the parents that would have produced these young (which is what fisheries do)."

In short, "the continued existence of fish populations undergoing exploitation is ample evidence for the operation of compensatory mechanisms within the life cycle of those populations" (Goodyear, 1977). As will be shown, the fish populations in the oligohaline zone of the James River are balanced and resilient and have been for several years.

Before the results of each monitoring program can be analyzed and discussed, a few additional factors need to be presented. First, estuaries are characterized by their natural physical and biological variability or inconstancy. This inherent inconstancy of estuaries can be equated with normality (Caspers, 1967). In particular, therefore, the within and between-year inconstancy of the oligohaline zone of the James River during the study period, was normal.

Second, the behavioral manifestations of a fish, on both an individual and population level, are determined by the sum of an unknown complex of environmental factors. While many of these variables may be known, the actual effect upon fishes may not be understood. Other variables, such as the exclusion of certain fishes from shore zones due to ice buildup or rough water, may exert only subtle influences. Still others are, undoubtedly, completely unknown. The synergistic effect of these variables, particularly with regard to estuarine fishes, is less obvious as, for example, evidenced by the unknowns surrounding the effects of Kepone contamination in the James River.

One important example that population responses are determined by the sum of an unknown complex of factors is illustrated by fish kills. A number of fish kills have occurred in the tidal James River during the study period. Some have been attributed to natural causes and some have been attributed to man-made causes. The largest fish kill, which occurred during the spring of 1971, involved "millions" of white perch (Morone americana) and reportedly reduced the James River population to "near extinction" (St. Pierre and Hoagman, 1975). No precise cause was found for this kill although the kill was believed similar to a bacterium-induced white perch epizootic in the Potomac River in 1963. By the end of the present study period in 1978, however, partial, if not total, recovery of the white perch population had occurred.

Moreover, fish kills, especially the "small-scale" kills, often yield unquantifiable influences upon the relative abundance and population structures of present and future fish populations. Year-class failures are often not evident until an affected year-class enters the commercial or sport fishery, sometimes several years after the failure.

Third, sampling gear selectivity represents an often yet sometimes largely unquantifiable variable that is inherent in virtually all fish sampling programs. The selective nature of seines and trawls are well-known and will be further discussed later in each appropriate section. The selectivity of the Ristroph travelling fish screen, due to the newness of the design, is not known.

Fourth, in order to observe fish population trends over time for the purpose of detecting and assessing the impact, if any, of a cooling water intake structure upon these populations, a method of comparison is needed. Species diversity analyses have recently been used to assess estuarine fish communities in Georgia (Dahlburg and Odum, 1970) and Maryland (Mihursky and McErlean, 1971). Species diversity analysis is widely recognized to represent a relatively simple but informative approach to measure community stability, and specifically in this report, stability of the estuarine fish community in the James River in the vicinity of the Surry Power Station. Three indices, species diversity (H'), evenness (J), and richness (D) have been selected for inspection of the monthly haul seine and otter trawl data. These indices are useful analyses for determining long-term community trends. Since wide variability exists within and between samples, sampling data were pooled into monthly and seasonal composites and fish communities were analyzed by these composites. Data pooled in this manner enabled a more realistic observation of fish community changes and provided a dampening effect on the within and between station variability.

O'Conner and McErlean (1975) summarize the rationale underlying species diversity analysis:

> "The concept of species diversity is based upon the relationship between the number of species present in a community (species richness) and the distribution of individual organisms among species (evenness or equitability). If an environment contains a large number of species, each represented by a few individuals, the diversity is high. Conversely, if an environment contains few species, each represented by many individuals, species richness and evenness are low. For some groups of organisms, including benthos and nekton, the diversity of a community reflects environmental conditions. Adverse or stressful conditions will reduce species diversity because some species will be unable to survive the stress and will be lost from the community, while other species will survive and increase in number because of decreased predation or decreased competition for food."

Thus, in order to detect population stability over the length of the study period, species diversity (H'), evenness (J), and richness (D) analyses were performed. It was felt that if the integrity of the population as measured by these variables remained fairly constant with natural variability, then the population was suitably resilient to extraneous influences, including the Surry cooling water intake structure.

Finally, and perhaps most importantly, the apparent success of the Ristroph travelling fish screens cannot be overemphasized. The high survival rate of impinged fishes is convincing evidence that the Ristroph travelling fish screens are the best technology available (BTA) for minimizing adverse environmental impact.

5.2 MONTHLY HAUL SEINE PROGRAM

A total of 126,653 fishes was collected in 681 haul seines at 7 sampling stations during the 8 1/2-year program. These fishes comprised 63 species and 27 families (Table 3). No threatened or endangered species was seen or collected (U. S. Department of the Interior, 1979). Of note, however, a single bonefish (*Albula vulpus*), a tropical species, was collected at sampling station 0003 on July 20, 1972, representing the second known record of this species in the Chesapeake Bay estuary.

During the study period 5 species comprised over three-fourths or 75.5 percent of the total number of fishes collected in the monthly haul seine program (Table 4). These species were Atlantic menhaden (*Brevoortia tyrannus*), blueback herring (*Alosa aestivalis*), tidewater silverside (*Menidia beryllina*), bay anchovy (*Anchoa mitchilli*), and spottail shiner (*Notropis hudsonius*).

The most numerous species was Atlantic menhaden which represented 26.7 percent of the total catch. Blueback herring, which were most abundant in 1970, comprised 14.1 percent of the total catch. Tidewater silverside accounted for 13.1 percent of the total catch. Bay anchovy exhibited widespread annual variation in total numbers collected and comprised 13.1 percent of the total catch. Spottail shiner, despite a decline in total catch in the last 3 years of the study, represented 8.4 percent of the total catch. Several of these species will be discussed individually in varying detail later in this section.

In terms of abundance and frequency of occurrence, many of the remaining species were seldom collected. A total of 11 species were represented by only a single individual (Table 4). Eight species were collected during only a single year of the study (Table 4). A total of 15 species was recorded in only 1 sample (Table 5). Interestingly, of 681 samples, 13 of these samples (1.9%) yielded no fish (Table 5).

The most frequently occurring species in the monthly haul seine collections was spottail shiner which occurred in 60.1 percent of the samples (Table 5). Other frequently occurring species included tidewater silverside (54.2%), bay anchovy (49.5%), spot (Leiostomus xanthurus) (34.4%), and blueback herring (33.6%).

Several species exhibited notable fluctuations in relative abundance as gauged by monthly haul seine sampling. The most striking fluctuation involved a resident species, white perch. As discussed in Section 5.1 of this report, a major kill of James River white perch occurred in 1971, prior to the commercial operation of the Surry Power Station. White perch ranked fourth in relative abundance in 1970 and was markedly reduced in following years (Table 4). However, in 1978, this species ranked sixth in relative abundance for that year indicating at least partial and possibly total recovery of white perch population levels.

The factors precipitating the dearth of white perch possibly reflected a similar decline in young striped bass (Morone saxatilis) population levels during this same pre-operational period. However, the data in Table 4 suggest that some recovery had occurred by the end of 1978.

Blueback herring (Alosa aestivalis) and alewife (Alosa pseudoharengus) experienced several poor year-classes in recent years that are unrelated to the operation of the Surry Power Station (Hoagman and Kriete, 1977). Although the 1975 blueback herring year-class was believed strong, alewife levels remained low. Increased inshore stock levels will require favorable environmental conditions in the nursery zones to subsequently improve recruitment. Indeed, the earliest substantial stock increase is not expected until 1979 when the strong 1975 year-class enters the Virginia fishery (Loesch and Kriete, 1976). It should be noted that the alosine nursery zone in the James River lies well upstream from the Surry Power Station.

An excellent illustration typifying a correlation, and in this case, a probable cause-and-effect relationship, between a single environmental parameter and relative abundance may be found in Table 4 and Figure 5. Fluctuations in relative abundance between two closely related species, tidewater silverside (_Menidia beryllina_) and Atlantic silverside (_Menidia menidia_), correspond with salinity levels. Although both species occupy similar ecological niches, tidewater silverside generally prefer a more freshwater, lower salinity habitat than Atlantic silverside. When salinities were "high" during 1970 and 1977, Atlantic silverside was the dominant atherinid in the James River in the vicinity of the Surry Power Station. When salinities were "low" during 1971 through 1976, tidewater silverside was the dominant atherinid in the same area. Spottail shiner (_Notropis hudsonius_), a freshwater resident, shows similar salinity-related abundance trends.

The haul seine is a highly selective collecting gear type. As such, certain species and certain sizes of fish would characteristically not be expected to occur in the haul seine samples. The major components of the haul seine collection totals are shallow water, schooling, and young-of-the-year species including adult small size fishes such as the cyprinids, atherinids, or engraulids. The ability of a fish to escape capture is generally related to the size of the individual since the larger the fish, the greater its net or screen avoidance capability. Coupled with the inherent and unavoidable bias resulting from sampling site selection, this resulted in sampling a limited size range of the fish community generally 40 mm TL to 100 mm TL. Thus, as shown for selected species in Table 6, seine samples were comprised primarily of fishes in this size range.

Since some of the species captured are adults within this size range, their populations were believed to be adequately sampled. The majority of the haul seine samples, however, were represented by young-of-the-year or juvenile forms and thereby yielded some indication of the relative current year-class strength.

In order to attempt to detect and/or assess the impact, if any, of a cooling water intake structure (or any extraneous stress) upon estuarine communities, species diversity analysis was performed. As noted in Section 5.1 of this report, species diversity analysis represents a relatively simple but informative approach to measure population stability, and specifically in this report, stability of estuarine fish populations.

Three indices, species diversity (H'), evenness (J), and richness (D), were calculated for the monthly haul seine data. These values are shown in Tables 7, 8, and 9, respectively. Calculation of these variables follow the formulae of others as used and described by Dahlberg and Odum (1970) except that all calculations are based upon the use of logarithms to the base 2 ($\log_2$). Additional discussion of these analyses is contained in Appendix I.

In order to detect any significant changes in the overall structure of the fish community, these data were subject to regression analysis over time. The distribution of these parameters was assumed normal. The regression equation estimates were calculated by PROC GLM (Barr et al., 1976) and are given below:

H' - Diversity

$H' = 2.202 + 0.002t$ $R^2 = 0.001$ (slope not significant)

D - Richness

$D = 1.744 + 0.006t$ $R^2 = 0.025$ (slope not significant)

J - Evenness

$J = 0.499 + 0.0004t$ $R^2 = 0.002$ (slope not significant)

where t is the grouped data by season beginning with spring, 1970 and ending with fall, 1978.

The regression slopes indicate that the calculated diversity parameters, H', D, and J, were not changing (not significant) during the course of the study period. In short, these regression analyses disclose that young fish populations in the shelf zone of the Surry area have remained generally stable over the past 8.5 years. It follows, therefore, that no effect has been realized upon the shelf zone fish populations as a result of the operation of the Surry CWIS. In this manner no adverse environmental impact has been caused by the Surry CWIS. Furthermore, even if an adverse environmental impact was presumed to occur, the Surry CWIS, as shown in Section 7.0 of the report, reflect the best technology available for minimizing adverse environmental impact.

The present Surry cooling water intake structure with Ristroph screens began operation in 1974. The shore zone fish populations in the area have shown no reaction (adverse or otherwise) to the operation of the intake structure.

As can be observed in Table 4 certain shore zone species have exhibited fluctuations in relative abundance, both increases and decreases. However, these variations are due primarily to a number of factors such as naturally occurring annual and/or year-class variations, possible epizootic fish kills, hydrologic and meteorologic changes. In essence, therefore, no effect has been realized upon the shore zone fish populations as a result of the operation of the Surry CWIS. In this manner no adverse environmental impact has been caused by the Surry CWIS. Furthermore, even if an adverse environmental impact was presumed to occur the Surry CWIS, as shown in Section 7.0 of this report, reflect the best technology for minimizing adverse environmental impact.

5.3 MONTHLY OTTER TRAWL PROGRAM

A total of 33,953 fishes was collected in 540 otter trawls at 6 sampling stations during the 8 1/2-year program. These fishes comprised 42 species and 22 families (Table 10). No threatened or endangered species was seen or collected (U.S. Department of the Interior, 1979).

During the study period 5 species comprised over four-fifths or 80.4 percent of the total number of fishes collected in the monthly otter trawl program (Table 11). These species were hogchoker (Trinectes maculatus), spot, channel catfish (Ictalurus punctatus), Atlantic croaker (Micropogon undulatus) and bay anchovy.

The most numerous species was hogchoker which represented 26.9 percent of the total catch (Table 11). Spot, which was especially abundant from 1975 through 1978, comprised 22.3 percent of the total catch. Channel catfish accounted for 13.4 percent of the total catch and displayed an abundance trend related to salinity fluctuations roughly analagous to the trend described for the silverside in Section 5.2 of this report. Atlantic croaker comprised 9.5 percent of the total catch of which over one-half were collected in 1976. The ubiquitous bay anchovy represented 9.1 percent of the total catch and were particularly abundant in 1977. These species will be discussed individually in varying detail later in this section.

In terms of low abundance and low frequency of occurrence, many species were seldom collected. Eight species were represented by only 1 individual while 25 species collectively comprised approximately 1.0 percent of the total catch (Table 11). Furthermore, 9 species occurred in only 1 sample while no fish were taken in 7 (1.3% of all samples) samples (Table 12).

The most frequently occurring species in the monthly otter trawl collections was channel catfish which occurred in 70.4 percent of the samples (Table 12). Other frequently occurring species included hogchoker (66.5%), white catfish (Ictalurus catus) (54.1%), bay anchovy (46.5%), and spot (46.5%).

As may be observed in Table 11 and as expected, several species underwent fluctuations in relative abundance. A further indication of the extent of recovery by white perch from the 1971 fish kill is evidenced by these data, particularly the 1978 totals. Hogchoker displayed considerable variability in relative abundance levels and apparently were particularly abundant in 1971, 1977, and 1978.

The data in Table 11 may provide a relative index of spawning success and year class strength. For example, Atlantic croaker were particularly abundant in 1976. These data agree with current findings by VIMS that 1976 was a strong year class for this species and that unusually cold winters essentially destroyed the 1977 and 1978 year classes (unpublished data).

The dynamic and unpredictable nature of the oligohaline zone of the James River estuary is typified in Tables 11 and 13. For example, in late 1974, 1975, and early 1976, threadfin shad (Dorosoma petenense) underwent a marked increase and decline of abundance in the James River near the Surry Power Station that was unattributable to the operation of the Surry Power Station. Population levels increased in 1975 such that threadfin shad represented the second most numerous species collected in the monthly otter trawl program for that year. Examination of Tables 11 and 13 and Figure 5 indicate that threadfin shad may have moved downstream from their presumably usual upstream habitats as a result of low salinity levels in the study area during cold water periods of 1974, 1975, and 1976.

However, low salinity levels occurred in late 1977 and early-to-mid 1978 and no corresponding "bloom" of threadfin shad resulted.

The selectivity of the otter trawl as a sampling gear type was evident in the lower abundance and diversity totals compared to the haul seine (Tables 4 and 11). The otter trawl is selective for demersal, bottom-dwelling, and bottom feeding species such as the catfishes (*Ictalurus* species), spot, Atlantic croaker, and hogchoker. Surface and/or pelagic species such as blueback herring and Atlantic menhaden would not be expected in representative numbers.

Not unexpectedly, the otter trawl program resulted in fewer numbers of fish and a lower diversity of species as compared with the results of the monthly haul seine program. In addition to possible but likely differences in catch efficiency between the otter trawl and the haul seine, this relationship was due in a large degree to the general body size differences between the species that are usually available and collectable by the respective gear types. Fishes which typically inhabited the shelf zone, were, as a generalization, larger in size than the typical shore zone inhabitants and can therefore more easily escape capture. With the exceptions noted in Section 4.2.2 of this report, the otter trawl generally sampled the relatively shallow shelf zone of the James River.

The size selectivity of the otter trawl is evident from Table 13. Except for the 6.4 mm bar mesh in the cod end of the trawl net, small fishes may extrude or pass through the larger-sized mesh of the nest of the trawl net. Comparisons of data in Tables 6 and 13 partially illustrate this situation. Importantly, however, with the exception of certain species, such as channel catfish and hogchoker, most species collected by the otter trawl were young-of-the-year and/or juvenile individuals.

The data resulting from the otter trawl program were analyzed in the same manner as the haul seine program data (Section 5.2). Seasonal diversity (H'), evenness (J), and richness (D) values for the otter trawl samples are shown in Tables 14, 15, and 16, respectively. In order to detect any significant changes in the overall structure of the fish community, these data were subjected to regression analysis over time. The regression equation estimates were calculated by PROC GLM (Barr et al., 1976) and are included below:

H' - Diversity

$H' = 2.395 - 0.006t$ $R^2 = 0.017$ (slope not significant)

D - Richness

$D = 1.741 - 0.012t$ $R^2 = 0.118$ (slope significant) ($p < 0.05$)

J - Evenness

$J = 0.608 - 0.002t$ $R^2 = 0.019$ (slope not significant)

where the t is the grouped data by season beginning with spring, 1970, and ending with fall, 1978.

During inspection of these trends, it should be noted that a sharp decline in H' values may either be indicative of the influx and subsequent capture of a single schooling species or may be related to a reduction in the number of species.

The above regression slopes indicate that the calculated diversity parameters were either not changing (not significant) for H' and J or were decreasing slightly ($p < 0.05$) for D over the time of the investigations. The instability reflected in the D parameter may represent variability associated with salinity fluctuations. In short, these regression analyses indicate that young shelf zone fish populations in the James River near the Surry Power Station have remained generally stable.

5.4 SPECIAL HAUL SEINE PROGRAM

As described in Section 4.2.3 of the report, Vepco initiated a supplemental haul seine program in May, 1973, in an attempt to assess population levels of the various fishes inhabiting the shore zone of the James River between the station cooling water intake and discharge structures. This program was instituted as a response to guidelines set forth in the Technical Specifications for the Surry Power Station, Units 1 and 2. Furthermore, this program subsequently satisfied (and even exceeded in terms of effort) the qualitative and quantitative objectives required by the NRC as stated in the Technical Specifications.

Three sampling stations were located in the shore zone between the low-level intake structure and the station discharge structure (Figure 18). In order to ascertain "realistic" population estimates of shore zone fishes at this site, certain assumptions were necessary. The assumptions were:

(1) the habitats selected and sampled are equal in their ability to attract and maintain fish populations;

(2) the sampling stations are representative of the entire shoreline from the station intake to the discharge;

(3) the estimates made are only of those fish which primarily inhabit the shore zone and do not occur in equal numbers at the same time in channel or shelf zone waters;

(4) the shore zone fishes are uniformly distributed from the shoreline to approximately 12 m out from the shoreline, i.e., the area sampled by the seine;

(5) the haul seine samples each replicate with equal efficiency.

It should be readily obvious that these assumptions impose strict limitations upon the natural-state validity of any calculated population estimates simply due to the often random and nearly always unpredictable movements of estuarine fish populations. However, these assumptions were statistically necessary.

In addition to these assumptions, the inherent limitations of haul seine sampling often renders the shore zone difficult to sample effectively even with sample duplication. No single gear type or sampling method collects 100 percent of the fish. However, while considered by some to be relatively efficient, the catch efficiency of the haul seine has been found to approximate only 50 percent (Derickson and Price, 1973).

The method used to calculate population estimates is an area-density method. Basically, an area-density method consists of sampling a plot of known area and capturing all or some of the fish present (Kjelson, 1977). The average number of fish per unit of area is calculated and multiplied by the total area to obtain an estimate of the size of the population (Cochran, 1963).

The rationale underlying the development of the formula used in this program was as follows:

(1) each replicate haul seine samples a 22.9 m portion of the shoreline;

(2) the distance between the station intake and discharge is approximately 9,144 m, thereby providing approximately 400 possible 22.9 m sampling stations;

(3) the number of possible sampling stations (400) is divided by the number of replicates taken during a sampling period (usually 6) to obtain a multiplicand of 66.7;

(4) the total number of fish collected in all replicates on a given sampling day is then multiplied by 400 (the number of possible samples) and divided by the number of samples taken to obtain the population estimated for that date.

Specifically, the formula used was:

$$TP = N\bar{y}$$

where TP = the estimated total number of individuals of the population; N = the total number of sample units for the given area; and $\bar{y}$ = the mean number of fish per sample unit.

In order to measure the variability of the population estimates, the standard deviation was calculated for each estimate. The formula used was:

$$S_e = \frac{N}{n} s$$

where S_e = the standard deviation of the estimate; N = the number of possible sample units (400); n = the actual number of samples taken (usually 6); and S = the square root of the variance of the sample. In addition, the coefficient of variability was calculated using the following formula:

$$CV = \frac{\bar{y}}{s} 100$$

where CV = the coefficient of variability; $\bar{y}$ = the mean number of fish per sample unit; and s = the standard deviation of the sample.

These formulae were used to obtain estimates of fish populations and measure the variability associated with these estimates. An example of these calculated estimates and their related variability parameters is shown in Table 17. As can be seen in this table, the coefficients of variability of the special haul seine samples during the selected time period ranged from 41 percent to 174 percent. The coefficients of variability are indicative of the greatly reduced confidence limits that could be assigned to the estimates.

An indirect but illustrative gauge of the tenuous nature of determining estuarine fish population estimates may be found by calculating the number of actual samples required to obtain a desired level of precision. To obtain this number of samples a Stein's two-stage sample procedure was used as shown below:

$$n = \frac{t_1{}^2 S^2}{d^2}$$

where n = the number of samples required for the desired level of precision; t_1 = the tabulated t value for the desired confidence level; S = the standard deviation; and d = the half-width of the desired confidence level.

At a desired level of confidence of 90% ($p = 0.1$) and utilizing the data for July 6, 1973 (Table 17), it was found that 171 samples were necessary to reliably estimate the size of the shore zone fish populations for that day. Obviously, this is not practical or feasible.

Shore zone populations constantly fluctuate in size by the hour, day, month, season, and year. An example of relative day-to-day variations in population size is illustrated by the parameters calculated in Table 17 for August 13-16, 1973.

No actual estimates over time are provided due to the extreme variation in the population estimates and the resulting unrealistic nature of these estimates. This special haul seine program constituted an attempt to quantify fish populations in estuaries. In essence, this was found to be impossible and merely confirms what unfortunately is a major handicap of estuarine sciences.

The above data, and the aforementioned host of ecologically unrealistic assumptions necessary for computing these estimates, simply point out the dubious and indeterminate nature of quantifying estuarine fish populations. Indeed, with the present-day state-of-the-art of estuarine sciences, McHugh (1967) reported that it is not possible to reliably estimate the total or even relative magnitude of biomass or numbers of fishes present throughout the year in an estuary such as the James River.

Despite the limitations found in attempting to quantify estuarine fish populations, the special haul seine program did provide useful data further characterizing the shore zone fish community between the station intake and discharge structures in terms of diversity, relative abundance, and frequency of occurrence.

From May, 1973, through December, 1978, a total of 76,819 fishes representing 50 species and 20 families was collected in the special haul seine program (Table 18). No threatened or endangered species was recorded (U.S. Department of the Interior, 1979). However, this program did yield the first Chesapeake Bay record of bay whiff (Citharichthys spilopterus).

The most abundant species collected, representing 49.6 percent of the total catch, was Atlantic menhaden (Table 19). In addition to this species, four others, Atlantic silverside (12.9% of the total), bay anchovy (7.8%), spot (6.7%), and tidewater silverside (6.0%), collectively comprised 83.0 percent of the total catch of the program.

The majority of the species did not occur in high numerical abundance (Table 19). Thirty-two species individually accounted for 0.1 percent or less than 0.1 percent of the total catch.

The most frequently occurring species in the special haul seine samples was Atlantic silverside which occurred in 541 of 1,065 (50.6%) samples (Table 20). Other frequently occurring species include spottail shiner (50.1%), tidewater silverside (44.7%), spot (41.1%), and bay anchovy (37.2%). Conversely, five species taxa occurred in only one sample while no fish were taken in eighteen (1.7%) samples.

In short, because the results of the special haul seine program to quantify shore zone fish populations and to derive population size estimates displayed such high variability and imprecision, no absolute and reliable measure of population size is presented. This program did provide informative and comparative measures of between species or relative abundance with population trend fluctuations for most species somewhat analogous to those found in the monthly haul seine program (Tables 4 and 19). Finally, the special haul seine program was useful in demonstrating and confirming the natural and expected phenomena of estuarine fish populations, namely spatial and temporal variability over both short and long periods of time.

5.5 IMPINGEMENT PROGRAM

5.5.1 INTRODUCTION

As noted in Section 4.2.4 of this report, initial investigations of intake screen impingement rates began in July, 1972, at the high-level intake structure. With the installation of low-level screens in May, 1974, regular impingement sampling at the high-level structure was discontinued and supplemented by regular sampling at the low-level intake structure. Analysis and discussion of impingement in this report shall focus only on the data obtained from sampling at the low level intake structure, specifically the Ristroph travelling fish screens. These data are probably more reliable than the data for the high-level intake screens. Data from the high-level screens may be influenced by the time lag in the 1.8 km long high-level canal between pumping and impingement as well as the uncertainty as to whether all fish pumped were being impinged.

The low-level impingement program provided almost daily (Monday through Friday) sampling data from May, 1974 through December, 1978. The only significant gaps in the sampling continuum occurred as a result of unexpected intake screen outages during January 14 - May 1, 1977 and February 8 - March 6, 1978, when damage to the Ristroph travelling fish screens by river ice prevented sampling.

The results and discussions included in the following section of this report will incorporate data and analyses previously reported in Appendix I and by White and Brehmer (1976). In addition, updated data and further analyses will be presented.

The results, analyses, and discussions of the impingement program, which follow , will focus on several major aspects of impingement at this site. The major topics discussed include the general results and the estimates of impingement, the seasonal movements of fishes in relation to impingement, the survival and mortality of impinged fishes, and finally, the overall impact of impingement mortality. For the sake of clarity and simplicity and because the bulk of the impingement totals are represented by only a few species, the following discussions will concentrate primarily upon the 5 major impinged species, spot, Atlantic menhaden, blueback herring, threadfin shad, and bay anchovy.

5.5.2 RESULTS AND DISCUSSIONS

5.5.2.1 GENERAL RESULTS AND ESTIMATES OF IMPINGEMENT

A total of 136,624 fishes, representing 73 species and 39 families was collected during sampling from the Ristroph travelling fish screens at the low-level intake structure from May, 1974, through December, 1978 (Table 21). No threatened or endangered species was collected (U. S. Department of the Interior, 1979). A totally unexpected species, rainbow trout (Salmo gairdneri) was collected during impingement sampling on May 21, 1974. This individual weighed 144.3 g and measured 252 mm TL. A second individual, 189.4 g and 268 mm TL, was observed and subsequently captured in the wash water trough on the following day. Investigation later showed these specimens to be possible March or April escapees from the Harrison Lake National Fish Hatchery, located approximately 55 km upstream.

To attempt to quantify (and more realistically discuss) impingement on an annual or other time period basis, estimates based upon mathematical expansions of actual sampling results were derived. These estimates were calculated using the general formula:

$$Y = N \bar{y}$$

where Y = the estimate of the number of impinged fishes per specified unit of time; N = the number of possible samples per specified unit of time; and $\bar{y}$ = the mean number of fish collected per sample.

Actual sampling data collected in a specified number of 5-minute replicate samples (occasionally more than 2 replicate samples were taken) were expanded into hourly, daily, and weekly estimates of impingement. Annual estimates as reported and discussed in this report represent the sum of the calculated weekly estimates for that particular year. Specifically, weekly estimates were obtained by calculating:

$$Y_w = \sum_{d=1}^{7} Y_d = \sum_{d=1}^{7} (N_d \bar{y}_d)$$

where Y_w = the estimated number of fishes impinged per week, Y_d = the estimated number of fishes impinged per day, N_d = the number of possible samples per day, and $\bar{y}_d$ = the mean number of fish collected per day. Yearly or annual estimates were obtained by calculating:

$$Y_y = \sum_{i=1}^{52} \sum_{j=1}^{7} Y_{d_{ijy}}$$

where Y_y = the yearly estimate and Y_d is the daily estimate. It should also be noted that the annual estimates for 1974, 1977, and 1978 are slightly underestimated. The low-level impingement program began in May, 1974, while ice damage to the intake screens during portions of winter and spring of 1977 and 1978 precluded sampling.

While it is generally accepted that direct enumeration and/or quantitative estimates of estuarine fish populations is virtually impossible (McHugh, 1967), except under very specific circumstances or in very localized areas estimates resulting from sampling with gear types, specifically intake screens can and do provide useful measures of relative levels of abundance. Indeed, the use of travelling screens as a valid biological sampling gear type was proposed to a meeting of the American Fisheries Society (AFS) in 1975 at Las Vegas, Nevada (paper presented before AFS by White, 1975). No adverse criticism or comments were heard or subsequently received from the biologists in attendance.

Annual estimates of impingement are provided using data obtained from sampling the Ristroph travelling fish screens from May 1, 1974, through December 31, 1978 (Table 22). Based upon the calculated estimates the most abundant species during the study period was spot which accounted for 21.8 percent of the estimated total. In addition to spot, 4 other species, Atlantic menhaden (18.7% of the estimated total), blueback herring (11.1%), threadfin shad (11.0%), and bay anchovy (7.4%) accounted for 70.0 percent of all fishes estimated impinged from May, 1974 through December, 1978.

Many species did not occur in large numbers. The individual abundance per species of 47 species collected during the study period was 0.1 percent or less (Table 22).

Frequency analysis of the low-level impingement data was conducted by treating weekly estimates as discrete samples. In this manner the most frequently occurring species was Atlantic menhaden which occurred in 212 of 224 (94.6%) weekly estimates (Table 23). Other frequently occurring species include bay anchovy (86.6%), spot (85.7%), gizzard shad (84.8%), and Atlantic croaker and white perch (75.0% each). Fifteen species occurred in only one sample. Fish were collected in all 224 samples.

An important factor in impingement analysis involves the overall size/age of the impinged fishes. As discussed previously in Section 5.1 of this report, populations of young fishes (which are readily distinguished by size frequencies) are better able to compensate for mortalities (natural and man-made) than are older fish populations. In other words, adverse environmental impact is minimized if small, young-of-the-year individuals are impinged as opposed to larger year Class I, year Class II, etc. individuals.

The majority (51.4%) of the measured fishes impinged upon the low-level intake screens ranged in size between 55-94 mm TL which was generally intermediate in degree between the majority size ranges of fishes collected in the monthly haul seines (35-69 mm) and monthly otter trawls (45-109 mm) (Figure 20).

The majority of the most numerous or "major" impinged species except for bay anchovy would generally be young-of-the-year, juvenile individuals in 55-94 mm TL size range. Bay anchovy is a small-sized fish and many individuals in the 55-94 mm TL size range would be adult fish.

It is also important to note that the 5 major species, spot, Atlantic menhaden, blueback herring, threadfin shad, and bay anchovy are all primarily schooling species. When these species enter the proximate areas of the Surry low-level intake structure, they occur in abundance in these schools. Thus, relatively large numbers associated with impingement are not unexpected.

5.5.2.2 SEASONALITY OF SELECTED IMPINGED SPECIES

The presence of many species in the vicinity of Surry Power Station is seasonal in nature. The seasonality of the species was analyzed such that monthly estimates of abundance were grouped into seasonal estimates. The seasons were defined as follows:

spring - March, April, May
summer - June, July, August
fall - September, October, November
winter - December, January, February

Thus, seasonal data begin with spring, 1974 although only one month of data can be reported. Data labeled winter, 1974 include December, 1974, and January and February, 1975. Winter, 1978 reflects only December, 1978 data. As previously noted, no low-level impingement data are available from January 14-May 1, 1977, and February 8-March 6, 1978, and seasonal estimates which incorporate these time periods reflect underestimates.

The seasonal nature of many species is evidenced by the impingement data. The following discussion will focus upon the seasonality of the 5 major species.

Spot was the most numerous fish impinged during the study period. As shown in Table 24, spot was included in the relative abundance rankings of the five most numerous species collected per year during each year of the study period. Spot was ranked fourth in 1974, third in 1975, second in 1976, and first in 1977 and 1978.

The overall seasonal movements of spot in Virginia are generally well understood (Hildebrand and Schroeder, 1928; Pacheco, 1962; Massmann, 1962; Joseph, 1972; Chao and Musick, 1977). Following late fall and winter ocean spawns, young-of-the-year spot enter the nursery grounds of Virginia's estuaries typically in late March and early April. Rapid growth ensues, and with the onset of declining water temperatures in late fall, most exit the low salinity nursery grounds. Overwintering primarily occurs at sea although some may remain in the deep channels and join returning yearlings in the following spring.

The seasonal patterns of impingement of spot are shown in Figure 21. Abundance is greatest during the summer and least during the winter. These winter data, however, do indicate that spot do not reside solely in deep channel or offshore areas. Rather, a few spot may enter shallow water and near shore zones as evidenced by the records of winter impingement. Similarly, warm temperatures during winter, 1975, may have caused many individuals to overwinter near Surry as evidenced by impingement data for this period.

On a yearly basis, impingement of spot was least during 1974 and greatest during 1977. A total of 1,355,584 spot (31.6% of the total) was estimated impinged during 1977 (Table 22), despite the absence of sampling during portions of winter and spring. These data lend additional support to a supposition presented in Vepco's 316(b) demonstration for the Yorktown Power Station. In that report, it was advanced that the magnitude of the number of young-of-the-year spot estimated impinged at the Yorktown Power Station during 1977 may be an indication of a highly successful ocean spawn during the winter of 1976-1977. The relative percentage and rate of impingement of young-of-the-year spot at Surry, principally during summer and fall, 1977, similarly may indicate a highly successful spawn during the previous winter.

Atlantic menhaden was the next numerically dominant fish impinged during the study period. The seasonal movements of this prolific commercial species are generally well-known (Hildebrand and Schroeder, 1928; Kinnear, 1973; Nicholson, 1978; Wang and Kernehan, 1979). Atlantic menhaden spawn in spring and late fall off the mid-Atlantic seaboard during annual coastal migrations (Wang and Kernehan, 1979). The eggs hatch at sea and the larvae move inshore to oligohaline and freshwater nursery areas.

Inshore migrations of these newly hatched populations are not thoroughly understood. Water temperatures of 3°C or less appear to prevent entry of larvae into estuaries and to restrict those present to areas with salinities near 15 ppt (Kinnear, 1973). However, when critical temperatures are not a factor, larval menhaden ascend the estuaries to oligohaline and limnetic zone nursery areas. Rapid development from larvae to juvenile occurs in the nursery areas during the spring and summer. Juveniles exit the nursery grounds in the fall. Some may overwinter in the more saline portions of larger estuaries or may migrate south along the coast and enter the commercial fishery in Florida.

The seasonal patterns of impingement of Atlantic menhaden are shown in Figure 22. As a generalization, the species was impinged throughout the study period and was least abundant during the winter and most consistently abundant during summer. The data in Figure 22 suggest that populations entered the nursery grounds earlier in spring, 1976, than in other years, probably due to favorable temperature and salinity regimes during this time. Colder temperatures in spring, 1978, may have delayed inshore movements while warmer temperatures in fall, 1977, may have extended the duration of occupation of the nursery areas.

Furthermore, despite the absence of data from January through April, comparatively fewer Atlantic menhaden were impinged in 1974 indicating a possible poor year-class for that year. This indication is partially substantiated by commercial fisheries statistics for 1973-1976 (U. S. Department of Commerce, 1975, 1976, 1977, 1978). Virginia landings of Atlantic menhaden in 1973, 1974, 1975 and 1976 were as shown below:

1973 - 485,227,863
1974 - 369,760,840
1975 - 305,826,843
1976 - 329,140,194

The poor 1974 year class is evidenced by the relatively lower harvest. According to Henry (1971), in the Chesapeake Bay more Age I fishes traditionally comprise the fishery than any other year class. Fortunately, there appear to be no disturbing annual trends for this species and the Virginia fishery remains productive.

Blueback herring ranked third in the estimated total number of fishes impinged. This species is important commercially and is subjected to an intensive offshore fishery as well as a brief sport and commercial fishery during annual spawning migrations. Blueback herring enter the James River in spring and spawn at or near the upstream limits of tidal influence after which newly hatched larvae are quickly carried downstream by currents (Wang and Kernehan, 1979). Young juveniles remain in freshwater until the temperature drops in

October and November (Davis, 1973). The primary nursery grounds for this species are usually located well upstream from the Surry Power Station. Burbidge (1974) noted that young-of-the-year blueback herring remained upstream in generally freshwater regions of the James River during spring and summer, and that a downstream movement was evident by November.

It has historically been believed that most young-of-the-year blueback herring exit the freshwater and low salinity nursery areas of estuaries in late autumn and winter. This supposition may be argued in light of winter impingement rates of this species (Figure 23). Although cold-induced sluggishness may be a factor, maximum or near maximum impingement rates occurred during winter possibly indicating a significant delay in movements beyond that previously believed.

The seasonal relations of impingement of this species, as shown in Figure 23, suggest possible poor spawning success in 1976 and 1977 although reduced sampling due to intake screen outages may have masked the magnitude of this occurrence. Low abundance of juvenile blueback herring in the James River in 1976, which may be attributable to high salinities in the nursery grounds, has been documented (Loesch and Kriete, 1976). In 1977, low impingement rates may be due to the scarcity of individuals in the downstream portions of their traditional nursery area. The juvenile blueback herring population in the James River in 1977 was concentrated well upstream of the Surry cooling water intake structure (Loesch and Kriete, 1977). These suggestions as related to impingement are rather tenuous, however, since there is a data gap in late winter. This species may have passed the intake structure en masse during these screen outages resulting in underestimations.

Threadfin shad was the fourth most numerous species impinged during the study period. Compared with the available information on the previously discussed species, relatively little is known about the ecology of threadfin shad in estuaries. Lippson (1974) provides some information relative to spawning habits in the Potomac River. She reports that the species is rare in the Potomac River and that spring-early summer spawning occurs in shallow, freshwater areas.

The species is typically regarded as a freshwater fish although incursions into low salinity waters may occur. During the period of maximum impingement recorded for this species, salinities at Surry in December, 1974, averaged slightly over 4.0 ppt while January and February, 1975, salinities averaged approximately 1.0 and 0.5 ppt, respectively.

Threadfin shad populations have historically been found to be intolerant of cold water temperatures and mass mortalities have been observed during severe winters or during periods of sudden temperature decline (Griffith, 1978). Specifically, maximum impingement rates of threadfin shad have occurred during the winter when intake temperatures dropped below 10 C (Loar et al., 1977). Seasonal estimates of impingement are shown in Figure 24.

Low temperatures may have precipitated the impingement peak during winter, 1974. The two preceding years were mild and may have represented favorable conditions for the species. It is possible that these apparently favorable conditions allowed the threadfin shad population to either increase in size or move and relocate downstream near the Surry intakes or both. It can also be speculated that the threadfin shad population increase during this period is related to a possible abatement of competitive exclusion pressures as a result of low population levels of blueback herring. Whatever the causative factors involved, threadfin shad were abundant in the vicinity of the Surry intake structure during winter, 1974. Average water temperatures for December, 1974, January, 1975, and February, 1975, were approximately 6.5 C, 4.5 C, and 5.5 C, respectively. Griffith (1978) found a lower lethal temperature of approximately 5.0 C for this species. Despite the 93.3 percent impingement survival recorded for the species throughout the study period (Table 25), significant mortalities would likely have ultimately occurred as a result of low temperatures. Subsequently, declining temperatures and salinities in January and February, 1975, may have imposed stresses upon the threadfin shad that resulted in the increased level of impingement during that time. It should be noted that while the winter of 1974-1975 was the only time that this species made a significant contribution to the screen samples, numbers were high enough to enable threadfin shad to account for 11 percent of the fish impinged in five years. Finally, there is no evidence to attribute the dramatic increase and decrease of threadfin shad abundance in the James River in the vicinity of the Surry Power Station to the CWIS.

Bay anchovy was the fifth most numerous species impinged during the study period. The spawning habits and seasonal movements of bay anchovy are well documented (Hildebrand and Schroeder, 1928; Massmann, 1962; McHugh, 1967; Dovel, 1971; Wang and Kernehan, 1979). McHugh (1967) terms the species "the most abundant of all Atlantic fishes." Furthermore, McHugh (1967), citing manuscripts and personal communication from Massmann, labels bay anchovy "the most abundant species in Chesapeake Bay."

The species spawns from late spring to early fall in mid-Atlantic estuaries (Wang and Kernehan, 1979) with maximum abundance occurring in July in the upper Chesapeake Bay (Dovel, 1971). Peak spawning activities probably occur at salinities of 10.0-20.0 ppt (Wang and Kernehan, 1979). Thus, the Surry cooling water intake structure is usually well upstream of the major spawning grounds.

Following hatching, larvae and young move upstream to low salinity nursery areas. Young-of-the-year apparently overwinter in warmer, deep water areas. Dovel (1971) reports that the species has a short life span and assumes all bay anchovy are sexually mature at age I. In addition, he reports that individuals hatched early in the year may reproduce late in that year. Thus, the species is highly prolific.

As shown in Figure 25, bay anchovy impingement was highly variable. The data suggest that the 1975 spawning population experienced a highly successful spawn as evidenced by the relatively high impingement rates in winter, 1975 and spring, 1976. Fewer bay anchovy were impinged during the winters of 1976, 1977, and 1978. Although reduced sampling efforts are undoubtedly reflected, cold water temperatures may have restricted some bay anchovy to deeper waters.

The seasonality of impingement of all species is presented in Figure 26. These data illustrate two important characteristics underlying some relations of impingement and estuaries. First, accepting that intake screens constitute a valid sampling device for gauging relative population levels of nekton, fishes were found to be abundant in the James River estuary throughout the year. These studies at Surry provide additional support for the relations expounded by McHugh (1967):

> "In a temperate zone estuary like Chesapeake Bay large numbers of fish are certainly present at all seasons. There is little doubt that the number of species is least in winter and greatest in fall. Biomass also probably varies greatly with season, because very small young predominate in winter and spring and adults in summer and fall. However, there may not be a very great seasonal variation in numbers of individuals, which may be held relatively uniform by the influx of young and out-migration of adults in winter."

Second, and perhaps foremost, the inherent, normal characteristic of estuaries like the James River - variability - is amply illustrated in Figures 21 through 26. After nearly 5 years of almost daily impingement sampling with the Ristroph travelling fish screens at the Surry Power Station, no precise and consistent seasonal and/or annual trends in the number of fishes impinged are readily discernible. This masking of trends of total numbers may bear some, although likely a minor, association with the intake screen outages in 1977 and 1978. However, the absence of these consistent trends in impingement abundance merely underscores the uncontrollable (and, for the most part, unpredictable) natural fluctuations of population levels of many species of estuarine fishes. These population fluctuations, as reported herein, represent the normal, recurrent state of the fishes of the James River estuary.

5.5.2.3 SURVIVAL OF IMPINGED FISHES

Paramount to the conclusion that the Surry CWIS cause no adverse environmental impact and that even if adverse environmental impact was presumed to occur the Surry CWIS reflect the best technology available for minimizing any such impact, is the unqualified success of the Ristroph travelling fish screens in minimizing the mortality of impinged species. No installed and commercially operated intake screening system for major electric generating facilities is known to achieve as high a survival rate of impinged fishes as the Ristroph travelling fish screens.

White and Brehmer (1976), in their eighteen-month evaluation of the Ristroph travelling fish screens, reported that 52 of the 58 species collected by that time had greater than 80 percent survival. Moreover, the majority of these species experienced a survival rate in excess of 90 percent. As shown in Table 23 for data through 1978, 68 of the 73 species collected exhibited greater than 80 percent survival while 61 of the 73 species had a survival rate exceeding 90 percent. Based upon almost daily sampling from May, 1974, through December, 1978, approximately 94.4 percent of all sampled fishes survived and were returned alive to the James River (Table 25).

Examination and analysis of Table 25 revealed several major pertinent characteristics of impingement and survival of the sampled fishes. First, those species with low survival rates are represented by relatively few individuals. Only 5 species, hickory shad (Alosa mediocris), spotted seatrout (Cynoscion nebulosus), Spanish mackerel (Scomberomorus maculatus), blackcheek tonguefish (Symphurus plagiusa), and Atlantic cutlassfish (Trichiurus lepturus), displayed survival rates of less than

80.0 percent. The only species with a 0.0% survival rate, Atlantic cutlassfish, was represented by only 2 individuals collected in over 4.5 years of low-level impingement sampling. Significantly, none of these species, except possibly hickory shad which is uncommon in the James River, occur with any degree of expected abundance or regularity in the study area.

Second, certain major species displayed a greater relative susceptibility to impingement mortality than other species. Bay anchovy and blueback herring are major species with survival rates less than 90 percent (83.6 and 89.8%, respectively). Their comparatively lower survival rate may be simply related to body shape and body size of the individual. The fusiform body of bay anchovy and the small size of both species may have occasionally resulted in the fatal entrapment of the individual within the 0.45 cm wire cloth mesh of the screens.

Continuing with this second point, the obvious must be reported in that all fish are not equal. Despite the absence of empirical data in terms of "fragileness" of a species, the difference in survival rates between the major or other numerous species indicates that some species are simply hardier and more robust than others when subjected to the rigors of impingement.

Third, in terms of sheer number of fishes, most of the dead fishes were comprised of only a few species. The 5 major species, with an average survival rate of 91.9 percent, not surprisingly accounted for over three-fourths or 79.1 percent of all the dead fishes collected at the low level intake structure. As shown in Table 25, these species and their respective percent totals were bay anchovy (21.3% of all dead fishes), blueback herring (20.0%), Atlantic menhaden (16.3%), threadfin shad (13.2%), and spot (8.3%).

Fourth, delayed mortality of impinged fishes was not found to be significant. As described in Section 4.2.4 of this report, a five-minute "rest" or "still water" period is allowed in the sampling methodology to enable the collected fishes to equilibrate and, if needed, recover from the impingement experience for the purposes of survival assessment. A series of on-site experimentations in the fish sampling pool investigated the effect of varying recovery periods upon the survival of the collected fishes. Recovery periods up to four days in duration revealed no significant change in the survival of the fishes. Interestingly, biologists conducting these impingement studies routinely observed very active, opportunistic individuals feeding upon others during the recovery and collecting periods. The significance of these experimentations is that the Ristroph travelling fish screens function as a "gentle" transporter of fish and that the collected fish are returned to the James River alive and in a manner that minimizes adverse environmental impact.

The dual efficiency of the Ristroph travelling fish screens as both a trash removal and, particularly, a fish protection device cannot be overemphasized. The estimated number of dead fishes, if equally divided for each year of impingement sampling yields an average annual mortality of approximately 248,000 fishes. It is important to note that some of these fish were likely dead or moribund prior to impingement and that mortality reflected in this figure (and other figures in this section) may not be solely attributable to the Surry CWIS. More importantly, however, these data reveal an annual average survival of approximately 4 million fishes. The inescapable result and benefit of the Ristroph travelling fish screens is that had this device not been installed and operated, approximately 19.7 million fishes would have been removed and ultimately eliminated from the James River by the Surry Power Station. Clearly in this manner, the Surry CWIS has minimized adverse environmental impact.

Finally, based upon the discussion and rationale in this section, no adverse environmental impact has been caused by the Surry CWIS. Furthermore, even if an adverse environmental impact was presumed to occur, the Surry CWIS, as shown in Section 7.0 of this report, reflect the best technology available for minimizing adverse environmental impact.

5.5.2.4 IMPACT OF IMPINGEMENT MORTALITY

In order to better realize and appreciate the impact, if any, of the impingement mortality of fishes by the Surry CWIS upon the overall James River fishery, impingement losses may be evaluated relative to known fish population data and commercial stock data. Of the 5 major species, blueback herring, Atlantic menhaden, and spot will be evaluated and discussed. Sufficient data are not available to analyze the impact, if any, of threadfin shad or bay anchovy impingement losses. Both species are primarily forage fishes with little or no direct commercial value.

The impact of the impingement losses of blueback herring from the James River population is, at most, minimal. To illustrate and substantiate this statement, statistics for 1975 will be compared. According to Hoagman and Kriete (1975), a standing crop estimate of young-of-the-year blueback herring in the James River in 1975 was 1.9 billion. These VIMS investigators reported their estimate to be conservative and sampled the James River only between river kilometers 56-129 which they denote as the major nursery zone for blueback herring. Significantly, the Surry Power Station is located downstream of this area at approximately river kilometer 40. In 1975, a total of 609,864 blueback herring were estimated impinged (Table 22). Based on a survival rate of 89.8 percent (Table 23), 62,206 blueback herring may reasonably be considered to represent the impingement mortality for the species during 1975. Assuming these dead blueback herring were all young-of-the-year individuals, and the majority were, the loss of 62,206 individuals represents a loss of 0.0033% of the conservatively estimated James River standing crop of blueback herring in 1975.

Although this example only illustrates 1 year for this species, other years could be evaluated with more or less the same results. The James River alosine populations including the blueback herring population have been monitored by VIMS since 1969. VIMS attributed fluctuations in the alosid population levels to a number of causes such as offshore foreign fishery exploitation, meteorological occurrences, and cyclic mechanisms. In these investigations by VIMS, the Surry Power Station in any of its operations including the withdrawal of cooling water has not been reported, implicated, or even intimated to affect these populations.

The effect of impingement losses of Atlantic menhaden upon commercial stocks is, at most, minimal. To illustrate and substantiate this statement, impingement losses in 1976 will be compared on a weight basis with commercial fishery data for that year which at the time of writing this report was the most recent year with final statistics available.

In 1976 a total of 974,560 Atlantic menhaden were estimated impinged by the Surry CWIS (Table 22). Utilizing a survival rate of 95.1 percent (Table 23), 47,753 Atlantic menhaden were determined to represent the impingement mortality for the species during 1976. The mean size of impinged Atlantic menhaden was 105 mm TL based on data incorporated in Figure 20. According to length-weight tables compiled by Hildebrand and Schroeder (1928) for Atlantic menhaden in the Chesapeake Bay, an individual 105 mm TL may be expected to weigh approximately 11.3 g. Calculating with these data, the total number of dead Atlantic menhaden weighed approximately 540 kg. In 1976, 194,657,992 kg of Atlantic menhaden were commercially landed in Virginia (U. S. Department of Commerce, 1978). The removal of 540 kg of Atlantic menhaden represents to the loss of approximately 0.0003% of the total Virginia landings of this species. This number clearly does not constitute an adverse environmental impact.

The impact of this loss is further minimized by the age and size of the fish that succumbed to impingement. The majority of the dead fish were not of commercially harvestable size and had not entered the commercial fishery. In addition, many of these individuals would not have survived to maturity further minimizing adverse environmental impact.

The impact of the impingement losses of the most numerous species, spot, is again, minimal. To illustrate and substantiate this statement, impingement losses in 1976 will be compared in the same manner as Atlantic menhaden. At the time of writing this report, 1976 data were the most recent data for which final statistics were available. The necessary data are listed below:

1. 950,688 spot estimated impinged in 1976 (Table 22)
2. 97.9% survival rate (Table 25)
3. 19,964 dead spot calculated for 1976
4. 96 mm TL = mean size of impinged spot (incorporated in Figure 20)
5. 0.034 kg = typical weight of mean size (Hildebrand and Schroeder, 1928)
6. 678.8 kg = weight of dead spot
7. 528,644.5 kg = weight of spot landed in Virginia in 1976 (U. S. Department of Commerce, 1978)
8. impingement losses at Surry = 0.1% of Virginia landings

Importantly, losses equivalent to 0.1% of the Virginia landing are not significant for highly variable and prolific species such as spot. Moreover, at an average size of 96 mm TL, the majority of the individuals were young-of-the-year and had not entered the commercial fishery. Again, many of these individuals would, naturally, not have survived to maturity.

In any case, findings by Joseph (1972), as stated below, suggest that impingement losses for this species may not be critical to the overall abundance of the species:

> "The (Spot) post-larvae at about four months of age enter the estuarine nursery grounds, at which time the strength of the year class seems to have been determined. We have never been able to detect any large-scale mortalities of juveniles once the nursery grounds has been occupied.
>
> This pattern would suggest that the factors responsible for the non-periodic year-to-year fluctuations are most likely environmental differences that prevail on the spawning grounds."

From both an aesthetic and ecological viewpoint, the loss of fish from an aquatic system is generally unfortunate and seldom desirable. However, as shown, the loss of various estimated numbers of the 3 most numerous species, blueback herring, Atlantic menhaden, and spot, is, at most, minimal. These species accounted for over half (51.5%) of all impinged fishes and nearly half (44.6%) of all dead fishes.

As determined in Section 5.5.2.3 of this report, approximately 248,000 fish are permanently removed from the James River annually. The effect upon a resilient, compensating estuarine community of any mortality of this magnitude, on predominately young fishes, especially when distributed among many species, is so low as to be not measurable or discernible with present technological capabilities. Therefore, the

Surry CWIS could not be causing adverse environmental impact.

Based upon the examples and discussion of this and the previous impingement sections, no adverse environmental impact has been caused by the Surry CWIS. Furthermore, even if any such impact is presumed, the Ristroph travelling screens would clearly minimize any adverse environmental impact attributable to losses of fish. Therefore, the Surry CWIS reflect the best technology available for minimizing adverse environmental impact.

5.6 ICHTHYOPLANKTON ENTRAINMENT PROGRAM

5.6.1 INTRODUCTION

Under a funding contract by Vepco, ichthyoplankton entrainment studies at the Surry Power Station were conducted by VIMS from April, 1975 through December, 1978. The objective of these studies was to assess the kinds and amounts of ichthyoplankton being entrained from the James River near Hog Island and passed through the Surry Power Station.

The semi-annual and annual "Nonradiological Environmental Operating Reports," as required by the U. S. Nuclear Regulatory Commission (NRC), include the appropriate progress reports pursuant to these ichthyoplankton entrainment studies. These documents, which are not included in total, are voluminous and are available in NRC Public Document Rooms and the Swem Library of the College of William and Mary, Williamsburg, Virginia. However, portions of the 1977 and 1978 annual operating reports, the ichthyoplankton entrainment studies, have been reproduced and attached to this report as appendices. Appendix III contains the ichthyoplankton entrainment studies conducted by VIMS during 1977 while Appendix IV contains the 1978 studies. Appendix II is extracted in total from a VIMS special scientific report (No. 84) and contains the 1976 ichthyoplankton entrainment studies.

The initial sampling period, beginning April, 1975 and continuing through December, 1975 was used primarily to investigate various sampling gear and techniques, standardize techniques, and acquire a familiarity with the area. The data discussed in this report cover the January, 1976 through December, 1978 time span except where noted.

The remainder of Section 5.6 of this report will present the general results of the ichthyoplankton entrainment program along with a discussion by year of the seasonality and abundance of the most numerous species. In addition, the impact of ichthyoplankton entrainment upon the James River will be discussed.

SPECIAL NOTE

Subsequent to the writing of this report, VIMS issued a final technical report (Appendix V) covering ichthyoplankton entrainment studies from 1975 through 1978. Since Appendix V is a synopsis of Appendices II, III, and IV, the latter three have not been included as attachments to this report. Instead, Appendices II, III, and IV are available to interested parties at Vepco headquarters in Richmond.

5.6.2 RESULTS AND DISCUSSION

5.6.2.1 GENERAL RESULTS

Depending upon a number of environmental conditions, notably salinity, the composition of ichthyoplankton at and subsequently entrained by Surry CWIS can vary to include classically freshwater species, estuarine species, and marine strays. The oligohaline zone of the James River is utilized by a number of species both separately and simultaneously as a spawning ground, nursery ground, and/or migration route. The majority of the species found in this area do not spawn in the vicinity of the cooling water intake structure, rather most occur as juveniles or adults.

While certain young forms possess some degree of locomotory potential related usually to size, fish eggs and larvae are generally pelagic and transported into the area by water currents. In this manner, the pelagic nature of many fish eggs and larvae renders them susceptible to entrainment.

From 1976 through 1978 a total of 1,080 ichthyoplankton entrainment samples were taken by VIMS investigators in the forebay area of the low-level intake structure. These entrainment samples yielded 45 taxa of ichthyoplankton, 38 of which were identified to species, 5 were identified to genus, and 2 were identified to family (Tables 26 and 27). Certain species, especially at the young stages of life, were extremely difficult to identify and occasionally an individual was damaged by the sampling net and could not be recognized to species.

No threatened or endangered species was recorded (U. S. Department of the Interior, 1979). Interestingly, a total of 17 Stage II leptocephali of the ladyfish (Elops saurus) was collected during May, June, and July, 1976. These specimens represented the first Chesapeake Bay record and the first recurrent record north of Cape Hatteras of this life stage of this species (Govoni and Merriner, 1978).

Bay anchovy and naked goby (Gobiosoma bosci) were the most abundant species collected throughout the study period (Table 28). Collectively, these species comprised approximately 91.1 percent (64.5% - bay anchovy, 26.6% - naked goby) of all ichthyofauna collected from 1976 through 1978. Both eggs and larvae of bay anchovy were collected while naked goby eggs were rarely taken due to their demersal and adhesive nature.

Although bay anchovy and naked goby were the dominant species during the study period, other species were regularly collected. Most common of these included Atlantic croaker, spot, Atlantic menhaden, Atlantic silverside, tidewater silverside, rough silverside (Membras martinica), striped bass, and white perch. The seasonality and abundance of these species will be discussed in the following section.

Species of direct economic and/or recreational value generally did not comprise a significant portion of the total collected ichthyofauna. Spot, Atlantic croaker, and Atlantic menhaden were the most abundant of these. As will be discussed later, each was collected seasonally and in low abundance during its residence in the James River.

5.6.2.2 SEASONALITY AND ABUNDANCE

5.6.2.2.1 INTRODUCTION

This section will examine the seasonality and relative abundance of selected species of ichthyoplankton entrained by the Surry CWIS during each complete year of sampling. Because the annual reports by VIMS detailing the results of the ichthyoplankton entrainment program differed each year in the manner of discussion and the presentation of data, the following yearly discussions will include few tabular data. Complete tabular and raw data underlying the analysis and conclusions reported in this section may be found in Appendices II, III, and IV. Following these yearly discussions, overall trends during the study period as a whole will be presented.

5.6.2.2.2 SEASONALITY AND ABUNDANCE DURING 1976

During 1976 the abundance of fish larvae increased from January to March, declined to the year's minima in mid-April, increased to the year's maxima in July, and steadily declined through December. The abundance of eggs peaked in mid-May and decreased slowly. No eggs were recorded before May or after August. Greatest concentrations of both eggs and larvae were at midwater and bottom depths.

During 1976 bay anchovy and naked goby were the dominant species collected. Anchovy were taken in both life stages while goby were primarily taken as larvae. Eggs and larvae of both species were collected from April through September.

These 2 species comprised approximately 92 percent of the total yearly calculated catch for both larvae and eggs (Table 28). Of this total bay anchovy represented approximately 59 percent and naked goby represented approximately 33 percent.

Maximum concentrations of larvae occurred in late July. Naked goby was the most abundant larvae and attained a maximum density of $27/m^3$ in late July (Table 29). The abundance of bay anchovy larvae also peaked in late July at $14/m^3$ (Table 29).

Maximum concentrations of eggs occurred in mid-May. Bay anchovy eggs were the single most abundant ichthyoplankter during 1976 with concentrations peaking at $51/m^3$ in mid-May (Table 29).

Other species were regularly collected although in low concentrations and seldom at levels approaching those of bay anchovy and naked goby. Postlarval and juvenile spot and Atlantic croaker were collected seasonally. Spot were taken in low concentrations during spring. Atlantic croaker were taken from late winter through spring and again during fall. A late winter spawning of Atlantic croaker was evidenced by 2 distinct size modes in the spring catches. No eggs were entrained as these species are offshore spawners.

Postlarval and juvenile Atlantic menhaden were fairly common in late winter-early spring samples. Concentrations, however, never exceeded $1/m^3$. No eggs were entrained as Atlantic menhaden are oceanic spawners.

The eggs, larvae, and juveniles of the atherenids, Atlantic silverside, tidewater silverside, and rough silverside, were occasionally numerous during spring and summer with maximum concentrations $> 2/m^3$. Only juveniles and a few adults were collected in fall and winter. The eggs of these species, which are normally demersal and attached to submerged objects, were collected presumably as a result of dislodgement by wave and current action.

Striped bass and white perch were collected occasionally in spring. No eggs of either species were taken. Only larvae and juvenile of striped bass and larvae of white perch were recorded.

5.6.2.2.3 SEASONALITY AND ABUNDANCE DURING 1977

During 1977 the abundance of fish larvae increased from February to March, declined from March to mid-May, and increased to the year's maxima in late July. Abundance declined sharply through August and September, remainded low but generally stable through October and November, and increased slightly in December. No sampling was conducted in January, 1977, due to river ice.

Fish eggs were collected only from March through September. The abundance of fish eggs was low until mid and late May. The sharp increase was attributed to increased bay anchovy spawning. The abundance of eggs fluctuated from late May to July but remained relatively high compared to other months. Maximum egg abundance occurred in late June and steadily declined through September.

The abundance of both eggs and larvae was stratified with regard to depth. Abundance of both was greatest at the bottom.

Bay anchovy and naked goby continued to be the dominant ichthyoplankters. All stages of bay anchovy were collected while naked goby were taken primarily as larvae and postlarvae.

Collectively, these 2 species comprised 91.7 percent of the total yearly calculated catch for both eggs and larvae (Table 28). Of this total bay anchovy represented 68.5 percent, of which 10.6 percent were larvae and 57.9 percent were eggs, while naked goby represented 23.2 percent. From April through September, the period of abundance of these species, bay anchovy accounted for 67.8 percent of the total calculated catch, of which 4.9 percent were larvae and 62.9 percent were eggs, while naked goby accounted for 25.2 percent.

Maximum concentrations of larvae occurred in late July. Naked goby was the most abundant larvae and attained maximum concentrations of $37/m^3$ in late July (Table 29). The abundance of bay anchovy larvae also peaked in late July at $2/m^3$ (Table 29).

Maximum concentrations of eggs occurred in late June. Bay anchovy eggs were the single most abundant ichthyoplankter during 1977 with concentrations peaking at $52/m^3$ in late June.

Other species were regularly collected although in low concentrations. Postlarval and juvenile spot and Atlantic croaker were collected seasonally. Spot occurred in concentrations of $< 1/m^3$ during spring. Atlantic croaker were taken in fall and early winter in concentrations of $< 2/m^3$. No eggs were entrained as these species are offshore spawners.

The atherinids, Atlantic silverside, tidewater silverside, and rough silverside, were collected in all life stages with the latter species the most abundant. Eggs, larvae, and juveniles occasionally reached concentrations $> 3/m^3$ during spring and summer. Only juveniles and a few adults were collected in fall and winter. The eggs of these species are normally demersal and adhesive and were collected presumably as a result of dislodgement from submerged objects by wave and current action.

Catches of larval and postlarval Atlantic menhaden were significant during April. No eggs were entrained as Atlantic menhaden are oceanic spawners.

Striped bass were collected on only 3 occasions as only 1 egg, 1 larva, and 1 juvenile were recorded. Larval white perch were absent in 1977. White perch eggs were collected from mid-April to mid-May in concentrations of $< 1/m^3$.

5.6.2.2.4 SEASONALITY AND ABUNDANCE DURING 1978

During 1978 the abundance of fish larvae was low but stable from January through March. Small increases in abundance occurred in both mid-April and mid-May with each increase of short term duration. The increase in mid-April was primarily attributable to catches of white perch and striped bass larvae while the mid-May increase was primarily attributable to larval river herring, *Alosa* species. Sharp increases occurred in June followed by a slight decline in July. The annual maxima occurred in August with a rapid decline ensuing for the remainder of the year. This peak was primarily composed of bay anchovy and naked goby larvae.

Fish eggs were collected from April through September. The abundance of fish eggs was low until late June during which the annual maxima was reached. A decline occurred in July, followed by a moderate increase in August and a decrease to near absence in September. The abundance of fish eggs during the summer months is primarily attributable to the spawning of bay anchovy during this period. Maximum concentration of fish eggs was $156/m^3$ which occurred in late June.

The abundance of both eggs and larvae was stratified with regard to depth. The abundance of both was greatest at the bottom.

Bay anchovy and naked goby continued to be the dominant species of ichthyoplankters. All life stages of bay anchovy were collected while naked goby were taken primarily as larvae and post-larvae.

Collectively, these 2 species comprised 89.6 percent of the total yearly calculated catch for both eggs and larvae (Table 28). Of this total bay anchovy represented 66.0 percent, of which 7.5 percent were larvae and 58.5 percent were eggs, and naked goby represented 23.6

percent. From April through September, the period of abundance of these species, bay anchovy accounted for 66.0 percent of the total calculated catch, of which 7.3 percent were larvae and 58.7 percent were eggs, and naked goby accounted for 23.7 percent.

Maximum concentrations of larvae occurred in mid-August. Naked goby was the most abundant larvae and attained maximum concentrations of $15/m^3$. The abundance of bay anchovy larvae also peaked in mid-August at $5/m^3$.

Maximum concentrations of eggs occurred in late June. Bay anchovy eggs were the single most abundant ichthyoplankter during 1978 with recorded concentrations peaking at $95/m^3$ in late June.

Other species were regularly collected although seldom in concentrations approaching the levels of bay anchovy and naked goby. Postlarval and juvenile spot and Atlantic croaker were collected seasonally. Spot occurred in concentrations of $< 1/m^3$ in spring. Atlantic croaker were taken in fall and early winter in concentrations of $< 1/m^3$. No eggs were entrained as these species are offshore spawners.

The atherinids, Atlantic silverside, tidewater silverside, and rough silverside, were collected in all life stages. Of these species, tidewater silverside was the most common. Eggs, larvae, and juveniles were collected in spring and summer at concentrations of $< 1/m^3$. Only juveniles and adults were collected in fall and winter. The eggs of these species are demersal and normally attached to submerged objects and their occurrence was presumably the result of dislodgement by wave and current action.

Larval and postlarval Atlantic menhaden occurred in concentrations of $< 1/m^3$ during late winter and early spring. No eggs were entrained as Atlantic menhaden are oceanic spawners.

Striped bass larvae and white perch eggs and larvae were common during spring. However, concentrations of both species never exceeded $1/m^3$.

5.6.2.2.5 OVERALL TRENDS DURING STUDY PERIOD

With few exceptions ichthyoplankton entrainment by the Surry CWIS from 1976 through 1978 was seasonal in nature. Depending on life stage, entrainment of ichthyoplankton was generally found to either not occur or occur at low levels during early spring, fall, and winter and to be greatest during mid-to-late spring and summer. For example, based upon studies by VIMS, no larvae were entrained in February, 1977. No eggs were entrained during January through April and September through December, 1976, during February through March and October through December, 1977, and during March and October through December, 1978.

Maximum entrainment concentrations of larvae occurred in late July in 1976 and 1977 and in mid-August in 1978. Maximum entrainment concentrations of eggs occurred in mid-May in 1976, late July in 1977, and late June in 1978.

Bay anchovy and naked goby were the dominant taxa throughout the study period. Collectively, these species comprised 91.1 percent of all ichthyoplankton collected and determined entrained from 1976 through 1978 (Table 28). Of this percentage bay anchovy and naked goby represented 64.5 and 26.6 percent, respectively.

Yearly maximum egg and larval concentrations per m^3 for the dominants are shown in Table 29. Maximum period of peak concentrations of the ichthyoplankton forms of bay anchovy and naked goby were early to mid-summer except the peak for bay anchovy eggs which occurred in mid-spring in 1976. The periods of peak concentrations for the dominants coincided and resulted in the periods of peak abundance of eggs and larvae of all species.

Bay anchovy eggs were the dominant single ichthyoplankter during the study period. Maximum bay anchovy egg concentrations averaged $62.6/m^3$ for the 3-year study while maximum larval concentrations averaged $7.0/m^3$ (Table 29). Maximum naked goby larval concentrations during this period averaged $25.7/m^3$ (Table 29).

Other species were regularly collected but seldom in concentrations approaching the levels of bay anchovy and naked goby. Postlarval and juvenile Atlantic croaker and spot were collected seasonally. Spot were consistently captured in concentrations $<1/m^3$ during the spring. Atlantic croaker were found during fall and early winter in concentrations of $<2/m^3$ except $<1/m^3$ during 1978.

Postlarval and juvenile Atlantic menhaden commonly occurred in late winter and early spring but consistently at concentrations $<1/m^3$.

The atherinids, Atlantic silverside, tidewater silverside, and rough silverside (Membras martinica), were collected in all life stages. Eggs, larvae, and juveniles were taken in spring and summer, while in fall and winter only juveniles and adults were taken. Eggs, larvae, and juveniles occasionally exceeded $3/m^3$ in 1976 and 1977, while 1978 maximum concentrations were $<1/m^3$.

The percichthyids, striped bass and white perch, were collected primarily in the spring. Larvae and juveniles of striped bass were taken in 1976, 1977 (only one larvae and one juvenile), and 1978. Only 1 striped bass egg was collected in 3 years of sampling, occurring in spring, 1977. Larval white perch were taken in 1976 and 1978 while white perch eggs were taken in 1977 and 1978.

Although maximum concentrations of all forms of both white perch and striped bass never exceeded $1/m^3$, both species were more abundant in 1978 than in 1977 or 1976.

5.6.2.3 IMPACT OF ICHTHYOPLANKTON ENTRAINMENT

The Surry CWIS, as discussed in previous sections, do entrain and remove varying numbers and kinds of ichthyoplankton from the James River. This section will set forth and detail information concerning whether the Surry CWIS cause any adverse environmental impact on the major species entrained by the Surry CWIS and whether the Surry CWIS reflect the best technology available for minimizing adverse environmental impact.

Because two species, bay anchovy and naked goby, dominated the entire study, detailed discussion and analysis is necessary to place proper perspective on the data and to realistically assess the impact, if any, of entrainment upon their respective populations. As shown in Table 28, these species accounted for 91.1 percent of all ichthyofauna collected and entrained during the study period.

Bay anchovy with the possible exception of Atlantic silverside, is probably the most abundant fish species in the Chesapeake Bay and lower James River estuaries. Hildebrand and Schroeder (1928) stated:

> "*Anchoa mitchilli*, bay anchovy, is a small forage fish with a low fecundity rate. However, they have a prolonged spawning period, extending from April to September. They are one of the most abundant fish wherever they occur . . . this species is not at all utilized by man in the Chesapeake region, yet it is undoubtedly of very great indirect commercial importance, as it appears to enter into the food of the larger predatory species more frequently than any other species."

The bay anchovy is present in the Chesapeake Bay throughout the year (U. S. Fish and Wildlife Service, Vol. 1, 1978). The adults and larvae are euryhaline in nature. Jensen (1974) reported bay anchovy adults as far upstream as Vepco's Chesterfield Power Station on the James River. Massmann (1954) found larvae approximately 64 km above brackish water in Virginia rivers.

Stevenson (1958), working in the Delaware Bay, reported that the fecundity of bay anchovy in that region was approximately 26,500 eggs per individual. In addition, he postulated that an apparently prolonged spawning season (April through September in the James River) is the result of successive spawns of different size groups of individuals rather than multiple spawnings by the same individuals.

Peak spawning activities probably occur at salinities of 10.0-20.0 ppt, with little successful spawning occurring at salinities less than 5.0 ppt (Wang and Kernehan, 1979). During the ichthyoplankton entrainment program at Surry, intake salinities were typically well below 10.0 ppt during the major spawning season. Dovel (1971) collected bay anchovy eggs at salinities ranging from 1.0 to 22.0 ppt in Chesapeake Bay while peak densities were found at salinities of 13-15 ppt. Intake salinities exceeded 13.0 ppt only during late September and late October, 1977 (Appexndix II, III, and IV).

As a result of low salinity levels, it is likely that most bay anchovy eggs in the vicinity of Surry were either dead prior to entrainment sampling or would soon have died. Wang and Kernehan (1979) found that higher percentages of live eggs (80-90%) were collected in higher salinity waters (20-30 ppt) of the Indian River estuary in Delaware than were found in the oligohaline waters (<15 ppt) of the upper portions of the Delaware estuary. Moreover, they report that egg viability was generally higher at salinities greater than 8.0 ppt.

These data indicate the major spawning ground of bay anchovy in the James River lies in more saline waters than are typically found at the Surry Power Station. Thus, the major spawning area is normally well downstream from the Surry Power Station, and as such, the Surry CWIS do not cause adverse environmental impact to the areal spawning population. In addition, the likelihood exists that significant mortality of bay anchovy eggs had occurred prior to entrainment as a result of low salinity levels.

Finally, if ichthyoplankton entrainment of bay anchovy at Surry resulted in an adverse environmental impact, it follows that this impact would likely be reflected in reduced relative abundance of juvenile and/or adult bay anchovy. As gauged by haul seine, otter trawl, and intake screen sampling reported herein, the abundance of bay anchovy has not declined or been adversely impacted. Rather bay anchovy population levels have fluctuated within the expected limits of natural variability, as have, incidentally, all the major species.

As described by VIMS in Appendix III:

> "Sharp changes in abundance of adult anchovy may occur from year to year. These are natural fluctuations that are a part of the biological attributes of any fish population. VIMS winter trawl data (Hoagman and Kirete, (1975) and VEPCO data (White, 1976) indicate relatively stable bay anchovy populations over the long term."

Naked goby has been termed "abundant" (U. S. Fish and Wildlife Service, Vol. V, 1978), "common" (Wang and Kernehan, 1979), and "common to abundant" (Wass et. al., 1972). The species typically inhabits shallow flats, weed and oyster beds in spring, summer, and fall and deeper channel edges and channels in high salinity waters in winter. Naked goby are seldom collected in trawl or seine sampling as they typically reside in crevices and other protected shelters.

Spawning is known to occur from late spring to early fall in Chesapeake Bay (Hildebrand and Schroeder, 1928). However, peak spawning times are during May through August along the Atlantic coast (Dahlberg and Conyers, 1974). Naked goby eggs are demersal and adhesive, explaining their near absence from entrainment samples.

Spawning occurs in mesohaline and polyhaline (10.0-30.0 ppt) waters (Wang and Kernehan, 1979). Hatching occurs in approximately 4 days at 26-28 C (Wang and Kernehan, 1979, citing others) whereupon a general up-estuary movement to lower salinity nursery areas begins. Dawson (1966) found most 7-11 mm larvae at 14.8-24.7 ppt salinity and most 11-22 mm young at 0.3-4.7 ppt.

During the ichthyoplankton entrainment program at Surry intake salinities ranged from 0.1 to 14.3 ppt (Appendices II, III, and IV). Maximum salinity occurred in September, 1977, which is after the peak spawning times as reported by Dahlberg and Conyers (1974). Intake salinities were typically well below the minimum value of 10.0 ppt as reported by Wang and Kernehan (1979). Furthermore, salinities greater than 10.0 ppt occurred during only 6 sampling surveys during the study period.

These data indicate that the major spawning ground of naked goby in the James River lies in more saline waters than are typically encountered at the Surry Power Station. Thus, the major spawning area is normally well downstream from the Surry Power Station, and, as such, the Surry CWIS do not cause adverse environmental impact to the areal spawning population.

The ecology and life histories of several other numerous species indicate that the Surry CWIS do not cause adverse environmental impact. For example, the major sciaenids found at this site, spot and Atlantic croaker, are oceanic spawners. Postlarvae and juvenile spot and Atlantic croaker subsequently move into the estuaries such as the James River which serve as nursery grounds for these species. Because these species are oceanic spawners, no spot or Atlantic croaker eggs were entrained.

Moreover, as reported by Joseph (1972) and noted in Section 5.5.2.4 of this report, by the time the postlarval spot occupies the estuarine nursery ground, the strength of the year-class has already been determined, most likely by environmental differences that prevail on the oceanic spawning grounds. Concerning Atlantic croaker, Joseph (1972) reported:

> "The most likely explanation for the fluctuations in abundance that have occurred in Atlantic croaker populations over the past 30 years is, in my opinion, their relationship to a facet of the natural environment, namely temperature."

In the case of both species, spot and Atlantic croaker, the spawning success and ultimately the abundance of these populations are related to factors other than entrainment by the Surry CWIS.

The entrainment of Atlantic menhaden is similar to the entrainment of spot and Atlantic croaker in several aspects. First, no Atlantic menhaden eggs were entrained as they are oceanic spawners. Second, having occupied the nursery grounds in the vicinity of the Surry Power Station, postlarvae and juvenile individuals were entrained in low numbers, consistently at concentrations $<1/m^3$. Third, Atlantic menhaden are extremely populous and prolific. It is highly unlikely that the loss of the postlarval and juvenile individuals removed by the Surry CWIS could be significant or even detected in a population as large as the Atlantic menhaden population in Chesapeake Bay.

The occurrence and abundance of the atherinids, Atlantic silverside, tidewater silverside, and rough silverside, was closely tied with salinity. For example, during 1977, salinities were relatively "high" on the areal spawning and nursery grounds resulting in rough silverside being the dominant atherinid. In 1978 salinities were comparatively lower and the typically upriver, fresher-water species, tidewater silverside was the dominant atherinid.

More importantly, however, the atherinids are extremely populous species. Hildebrand and Schroeder (1928) report that all atherinids are "common" and/or "abundant" and that Atlantic silverside may vie with bay anchovy as being the most abundant fish in Chesapeake Bay. While their spawning and nursery grounds included the area near the Surry CWIS, eggs and larvae of the various species were entrained only during spring and summer and only occasionally in concentrations exceeding $3/m^3$. Of these concentrations, few eggs were entrained as explained in previous sections.

As in the case of Atlantic menhaden, it is highly unlikely that the loss of the silverside individuals entrained by the Surry CWIS could be significant or even detected in the large and dynamic populations of these species in the James River and Chesapeake Bay.

Striped bass and white perch, the percichthyids, occurred primarily in the spring and in low concentrations, never exceeding $1/m^3$. All stages of striped bass were uncommon. Only 1 striped bass egg was taken in 3 years of study while only 1 larvae was taken in 1977.

White perch eggs were found only in 1977 and 1978 while larvae were found only in 1976 and 1978. The primary spawning and/or larval nursery grounds of white perch and particularly striped bass, as these data indicate, are not located in the vicinity of the Surry CWIS. Both species typically spawn upriver from the Surry CWIS, especially during periods of relatively elevated salinities in this vicinity. In this manner and in the case of these species, as the data convincingly demonstrate, the Surry CWIS do not cause adverse environmental impact upon the ichthyoplankton populations of striped bass and white perch.

To place a real-world perspective on the impact of ichthyoplankton entrainment at Surry, the natural, steady-state complexities of a continually fluctuating, dynamic ecosystem, estuaries, and the resultant stresses upon estuarine ichthyoplankters cannot be overlooked or overemphasized. Conclusions reported by VIMS in their 1978 ichthyoplankton entrainment studies (Appendix IV) which reflect, in part, a summary of information applicable for the entire program, aptly characterize ichthyoplankton entrainment at Surry. The following statements are excerpts from Section 3.5.2 of Appendix IV:

> "... Natural fluctuations of considerable magnitude do occur in fish populations and these fluctuations reflect changes in natural mortality. Natural mortality from the egg to juvenile stage is 99 percent or more (Pearcy, 1962; Ahlstrom, 1954). Success of a given year-class is correlated with natural mortality and conditions on the spawning and nursery grounds. Thus, from year to year there may be natural fluctuations in species abundance of one or more orders of magnitude similar to those we have observed at Vepco Surry.

> ... The James River has been subjected to numerous stresses in recent years, i.e., organic and inorganic pollutants, siltation, flooding, etc. To extract any one stress (e.g., Vepco Surry) from such a combination is extremely difficult, especially when the effects of other stresses have not been analyzed. Coupled with sampling variability, natural population fluctuations, biological attributes of ichthyoplankton, environmental factors, and other sources of variability inherent in any sampling program, any changes other than those of catastrophic proportions are difficult to assess."

From a holistic viewpoint, the realistic assessment of the impact on the planktonic life stages of fish (eggs and larvae) by the Surry CWIS is significantly augmented and strengthened by an examination of the juvenile and adult populations and the effect of entrainment losses upon them. As was noted previously in this section for bay anchovy, no effect was detected. Regarding the other major species, losses due to entrainment have resulted in no detectable effect upon juvenile and adult fish populations in the vicinity of the Surry Power Station. Indeed, white perch population levels have actually increased despite entrainment losses.

Finally, as noted and discussed in Section 3.4 of this report, the Surry CWIS incorporates many of the features and technologies suggested by the EPA to be desirable in minimizing adverse environmental impact (Environmental Protection Agency, 1976). In particular, the physical location of the Surry CWIS minimizes adverse environmental impact to the spawning populations of the dominant ichthyoplankters, bay anchovy and naked goby, owing to the siting of the CWIS well upstream of the normal breeding grounds of these two species. In this manner, the Surry CWIS reflect the best technology available for minimizing adverse environmental impact.

In summary, the Surry CWIS do entrain fish eggs and larvae from the oligohaline zone of the James River. However, no impact, adverse or otherwise, has been detected in the ichthyofaunal community. Based upon the data and discussion of this and previous sections of this report no adverse environmental impact has been caused by the Surry CWIS. Furthermore, even if such an impact is presumed, the Surry CWIS reflect the best technology available for minimizing adverse environmental impact.

6.0 COMPARISON OF MONITORING PROGRAMS

The previous sections of this report have introduced, described, and analyzed the consortium of nonradiological environmental studies conducted at the Surry Power Station from 1970 through 1978. In particular, this report has focused upon the low-level impingement and entrainment programs.

In order to gain greater insight into the effectiveness of the various sampling programs at Surry, other than the ichthyoplankton entrainment program, this section presents a brief comparison of these programs (monthly haul seine, monthly otter trawl, special haul seine, and impingement). Despite the inherent selectivity and use limitations of all fish sampling gear, it is widely recognized that only with a variety of collecting gear types can an in-depth analysis of the population structure and movements of fishes be readily obtained. Unfortunately, the divergent nature of ichthyoplankton and larger nekton do not lend themselves to ready comparisons.

With all gear types, a total of 90 species of fishes representing 47 families from the James River near the Surry Power Station was collected and identified (Table 30). In terms of diversity, the intake screen was the most effective sampling device, taking 74 species which represented 39 families (Table 21). This is due in part to the daily sampling schedule (greater sampling frequency), but could also be equally due to the efficiency of this device as a sampling tool. The monthly haul seine program resulted in 63 species representing 27 families (Table 3). The special haul seine program resulted in 50 species representing 21 families (Table 18). The monthly otter trawl program resulted in 42 species representing 22 families (Table 10). The ichthyoplankton entrainment program resulted in 28 species representing 19 families (Table 26).

A total of 31 species was common to all nekton sampling gear types. Table 31 lists the relative abundance ranking of the five most numerous species per nekton gear type. Table 32 lists the relative catch by percent for all fish species by gear type. One species, bay anchovy was ranked a dominant species by each gear type. Spot was absent from only the monthly haul seine rankings although the species did rank sixth. Atlantic menhaden, a pelagic species, was absent only from the monthly trawl rankings. This is to be expected as the otter trawl is principally selective for demersal and deepwater fishes. Blueback herring and spottail shiner each appeared in two ranking lists. Both were predominant in monthly haul seine samples while the former also appeared in the low-level screen rankings and the latter appeared in the special haul seine rankings.

Importantly, the similarity of these rankings underlies the comparable nature of the intake screens as a sampling device. As discussed earlier and shown in Figure 20, the sizes of fishes collected with this gear type were generally intermediate between the sizes typically collected by the haul seine and otter trawl. The number of fishes taken by the screens generally appears to be in proportion to the numbers within dominants actually residing in this vicinity of the river. In terms of sampling costs and effort as well as the actual quality of the data, there is growing evidence that intake screens, especially continually operative screens, represent the "best" gear type for monitoring estuarine fish populations. It appears that the screens sample an unquantifiable percentage of the most abundant fishes naturally available to be sampled. Conversely, small numbers of a given species indicate that relatively few of that species are present in the area. It must be noted that there are obvious exceptions to the above relationships. For example, naked goby may be extremely abundant in this area as indicated by larval entrainment numbers, but its habitat preference (oyster shells, metal cans, etc.), small adult size, limited home range, and secretive habits generally preclude its impingement and/or sampling with conventional methods.

As discussed in previous sections of this report, one particularly useful indicator for gauging the stability of populations and ultimately ecosystems, is diversity analysis. Data resulting from the monthly haul seine and monthly otter trawl programs were analyzed in terms of diversity (H'), evenness (J), and richness (D). Figure 27 contains graphs of the seasonal composites of these variables during the study period. These data aptly illustrate two basic but important characteristics of the James River estuary. First, short-term variability, especially seasonal variability, represents the normal state of the estuary. As expected, fish populations were typically less diverse in winter and more diverse in spring and summer. Second, long-term stability, as evidenced by the absence of significant slopes of the variables, represents the normal state of the estuary. It is important to reiterate that had the graphed or numerical slope of these variables declined over time, then these data would have signaled degradation and adverse stress or impact of the fish populations and ultimately of the entire ecosystem. As inspection and trend analysis of these data in Figure 27 reveals no adverse environmental impact occurred during the study period.

The various monitoring programs, recognizing, of course, the inherent sampling selectivity between gear types, were similar in several aspects:

1. No threatened or endangered species were collected by any gear type.
2. All gear types were effective collectors of organisms.

3. All gear types effectively established, monitored, and, for the most part, concurrently detected changes in the relative abundance of the dominant species.
4. All gear types effectively established, monitored, and, for the most part, concurrently detected changes in the temporal and spatial distributions of the dominant species.
5. All monitoring programs employed collecting schedules with high sampling frequency, either daily, weekly, or monthly, which was frequent enough to record unexpected and uncommon species.

Finally, the baseline comparison of the various monitoring programs is two-fold. First, except for the inability of the special haul seine program to accurately and realistically quantify in absolute numbers the population size of shore zone fishes, all the monitoring programs were successful in their original purpose. Second, all the monitoring programs yielded essentially the same result. That result is that over time the fish populations of the oligohaline zone of the James River are resilient to extraneous stresses, structurally sound and diverse, and have not been subjected to _any_ uncompensated or irrepairable manmade or natural adverse environmental impact.

7.0 SURRY COOLING WATER INTAKE STRUCTURES AS BEST TECHNOLOGY AVAILABLE

7.1 INTRODUCTION

As noted in Section 1.2 and as demonstrated in detail in Section 5.0 of this report, the Surry CWIS do not cause an adverse environmental impact upon the overall fish community in the James River in the vicinity of the Surry Power Station. Furthermore, even if an adverse environmental impact is presumed to occur as a result of the CWIS, the location, design, construction, and capacity of the Surry CWIS reflect the best technology available (BTA) for minimizing adverse environmental impact. This section, therefore, discusses these four characteristics and relates how these characteristics reflect the BTA for minimizing adverse environmental impact.

These intake characteristics incorporate many of the features and technologies suggested by the EPA to be desirable in minimizing adverse environmental impact of intake structures (Environmental Protection Agency, 1976). Moreover, this section convincingly demonstrates that the Surry CWIS reflect the best technology available for minimizing adverse environmental impact.

7.2 LOCATION, DESIGN, CONSTRUCTION, AND CAPACITY AS BEST TECHNOLOGY AVAILABLE

As discussed in Section 1.2 of this report, the location, design, construction, and capacity of the Surry CWIS reflect the best technology available for minimizing adverse environmental impact. This section will discuss individually the location, design, construction, and capacity of the Surry CWIS. These intake criteria will be shown to incorporate at this site many of the features and technologies suggested by the EPA to be desirable in minimizing adverse environmental impact of intake structures (Environmental Protection Agency, 1976). Moreover, this section will demonstrate convincingly that the Surry CWIS reflect the best technology available for minimizing adverse environmental impact.

7.2.1 LOCATION

"Plant siting and the location of the intake structure with respect to the environment can be the most important consideration relevant to applying the best technology available for cooling water intake structures" (Environmental Protection Agency, 1976). As listed and discussed below, several factors indicate the Surry CWIS is suitably located in order to minimize adverse environmental impact.

1. Intake location with respect to plant discharge - the low-level cooling water intake structure is located 9 river km downstream of the station discharge thereby minimizing warm water recirculation.

2. Intake location with respect to the shoreline - the low-level intake structure at Surry is located flush with the shoreline. Shoreline intakes reduce the likelihood of eddy currents which may disorient fishes. Furthermore, there are no open-ended canals or embayments to concentrate fishes.

3. Inlet location with respect to source water - the water inlet is located well upstream of major spawning areas in the James River as was discussed in Section 5.6.2.3 of this report. The Surry CWIS is located in an area where no threatened or endangered aquatic species, except possibly the shortnose sturgeon (*Acipenser brevirostris*) which was last reported in the Chesapeake Bay estuary in the late 1800's (Smith and Bean, 1899), are indigenous. The degree of source water involvement is minimized because of the following factors. First, the James River near the low-level intake structure is approximately 6.0 km wide with depths up to 27.4 m recorded in the natural river channel (Figure 6). And second, at

a maximum cooling water withdrawal rate of 106.2 m^3/s, the Surry Power Station utilizes approximately only 2.9 percent of the river tidal flow rate, which at Hog Point is in excess of 3.681.6 m^3/s (Pritchard - Carpenter, Consultants, 1966).

7.2.2 DESIGN

The design and technologies incorporated in the Surry cooling water intake structure and especially the Ristroph travelling fish screen, are among the most advanced in the electric utility industry. The following is quoted from the Environmental Protection Agency (1976):

> "There is evidence to conclude that all new intakes should incorporate a fish handling and/or bypass system which will allow for safe return of fish to the water source ... The use of fish bypass facilities at existing intakes where fish impingement has been documented may improve the performance of these intakes ... One type of bypass system can be incorporated in the conventional intake using the traveling (sic) water screen. This system assumes impingement but minimizes its effect in the following manner:
>
> - Impingement time is reduced by continuous operation of the screens
> - It provides a means for a gentle separation of the fish from the screen mesh.
> - It provides a passageway for safe return of fish to the water way.
>
> ... the progress of this type of facility should be closely followed in the future because the system appears to have attractive environmental features".

The above design features are incorporated in the Surry low-level fish bypass system, namely, the Ristroph travelling screens. Interestingly, the Environmental Protection Agency (1976) further reports "One disadvantage of this system may be a lack of acceptance on the part of some of the regulating agencies."

Other design features are pertinent in considering the BTA designation for the Surry cooling water intake structure.

1. Approach velocities - approach velocities at the Surry low-level intake structure which average approximately 0.31 m/s (Table 2) are not excessive

and are generally less than tidal current velocities in the James River. Average maximum current velocities in the James River average 0.67 m/s on the ebb tide and 0.57 m/s on the flood tide at Hog Point (U. S. Department of Commerce, 1978).

2. Screen mesh size - screen mesh size is generally selected in order to provide a clear opening of no more than one half of the inside diameter of the station condenser tubes and in the electric utility industry, usage of 0.95 cm mesh size is generally standard.

3. Control of fouling or corrosion - biological fouling of the condenser cooling water system is usually controlled in the electric utility industry by the injection of chlorine at the intake structure such that organisms incorporated and/or potentially incorporated into the cooling water flow may be additionally stressed or killed. However, as noted in Section 3.2.5 of this report no chlorine or other chemical biocides are used to clean and maintain condenser tubes at the Surry Power Station. The Surry Power Station utilizes an "Amertap" system which mechanically prevents fouling of condenser tubes. Mihursky (1977) reports that the "use of mechanical cleaning devices such as recycled sponge or brush balls in condenser systems are decidedly to the advantage of the biota."

Paramount to the acceptance of the Surry cooling water intake structure as the BTA for minimizing adverse environmental impact is the Ristroph travelling fish screen. Several design features of this device were described in this section. The basic operation of this device is described in Section 3.3 of this report. In addition, several other intake design features were discussed which convincingly demonstrate that the design of the Surry CWIS represents the best technology available for minimizing adverse environmental impact.

7.2.3 CONSTRUCTION

"The adverse environmental impact of the construction of cooling water intake structures consists almost entirely of the effects on the aquatic population of {sic} the turbidity increases created by the various construction activities" (Environmental Protection Agency, 1976).

All components of the present Surry CWIS except the Ristroph travelling fish screens were in operation prior to the enactment of P.L. 92-500 and, therefore, those components are presumably rendered exempt from this portion of the requirements of the legislation. The installation of the Ristroph travelling fish screens was a retrofit of machinery and material to an existing concrete structure and involved no disturbance to the river bottom or increase in turbidity levels.

7.2.4 CAPACITY

The fourth characteristic, capacity or volume of flow through CWIS, concerns potential adverse environmental impact largely due to entrainment. As stated by the Environmental Protection Agency (1976):

> "Certain potentially significant adverse environmental impacts are related to intake flow volume (capacity) of cooling water intake structures. These impacts are caused by damage to organisms which are entrained in the cooling water flow and other indirect effects such as damage to habitats. The effect of capacity in relation to entrainment loss should be considered in terms of the damage to significance {sic} of the organisms and the degree of adverse environmental impacts that result."

The Surry CWIS do entrain aquatic organisms, principally ichthyoplankters, in the cooling water flow. As discussed in Sections 1.2, 4.2.5, and 5.2.6, detailed environmental studies were conducted to determine whether entrainment losses have an adverse environmental impact. Based upon those studies this report concludes that the losses do not have such an impact. However, even if the CWIS did cause adverse environmental impact, this report convincingly demonstrates that the location and design features of the Surry CWIS minimize any such impact. The EPA, as is outlined in its report "stepwise thought process," agrees that modifications other than volume reduction of the cooling water flow should be employed before undertaking the extreme step of reducing capacity (Environmental Protection Agency, 1977). In addition, the EPA recognizes that existing CWIS may be or reflect the BTA (Environmental Protection Agency, 1977).

Furthermore, the Environmental Protection Agency (1976) reported:

> "The death rate of sensitive forms of aquatic biota that pass through a cooling water intake structure can approach 100 percent. However, if the cooling water flow is small relative to the total stream flow, the 100 percent may not result in an adverse environmental impact."

As noted earlier in Section 3.4.1 of this report, the withdrawal capacity of the Surry CWIS represents only 2.9 percent of the river flow associated with tidal motion.

Since (1) entrainment at the Surry CWIS does not cause an adverse environmental impact (as noted in Section 1.2 and was demonstrated in Section 5.6 of this report), (2) other characteristics and features of the Surry CWIS minimize any possible or presumed adverse environmental impact, and (3) the withdrawal volume of the Surry CWIS is small relative to the James River flow, the capacity of the Surry CWIS reflect the best technology available for minimizing adverse environmental impact.

No such section
exists!

8.0 SUMMARY

This report culminates over eight years of the most intensive and comprehensive assessments of the fish community in the James River to date. To introduce the site and to provide the background information necessary for impact assessment, this report has described the overall area near the Surry Power Station, the power station and site per se, and the source body of cooling water, the James River. The components of the condenser cooling water system have been described in detail. In addition, several environmentally related modifications to the CWIS have been described.

This report has discussed and convincingly demonstrated that:

1. Shore zone fishes were sampled from 1970 through 1978 in the monthly haul seine program and, as gauged by several diversity indices, were found to exhibit long term stability. Studies have shown fluctuations in the relative population levels of some shore zone fishes. These fluctuations, however, are normal and expected and are characteristic of the variability inherent in this area and in the species. As such, these fluctuations are not attributable to the Surry CWIS. Therefore, the Surry CWIS has had no detectable impact upon the shore zone fish community of the James River in the vicinity of the Surry Power Station.
2. Shelf zone fishes were sampled from 1970 through 1978 in the monthly otter trawl program and, as gauged by several diversity indices, were found to exhibit long term stability. Studies have shown fluctuations in the relative population levels of some shelf zone fishes. These

fluctuations, however, are normal and expected and are characteristic of the variability inherent in this area and in the species. As such, these fluctuations are not attributable to the Surry CWIS. The Surry CWIS has had no detectable impact upon the shelf zone fish community of the James River in the vicinity of the Surry Power Station.

3. Shore zone fishes were further investigated from 1973 through 1978 in the special haul seine program. This program aptly demonstrated the tenuous, and indeed, unrealistic nature of quantifying estuarine fish populations and underscored the normal spatial and temporal variability of estuarine fish populations. Moreover, this program additionally and effectively gauged shore zone fishes and provided further evidence that the Surry CWIS has had no detectable impact upon the shore zone fish community of the James River in the vicinity of the Surry Power Station.
4. The impingement program provided almost daily sampling data from 1974 through 1978. These studies provided valuable insight into the seasonality of many species in the James River in the vicinity of the Surry Power Station. More importantly, these studies demonstrated that the Ristroph travelling fish screens returned alive to the James River an average of 94.4 percent of all sampled fishes. No other installed and commercially operated intake screening system for major electric

generating facilities is known to achieve as high a survival rate of impinged fishes as this device. Owing to a large degree this high survival effectiveness of the Ristroph travelling fish screens, impingement losses have not caused adverse environmental impact. Furthermore, the Ristroph travelling fish screens unquestionably reflect the best technology available for minimizing adverse environmental impact.

5. The Surry CWIS has had no detectable impact upon the ichthyoplankton populations of the James River in the vicinity of the Surry Power Station. Ichthyoplankton populations were sampled from 1975 through 1978 in the ichthyoplankton entrainment program. Spawning grounds for most entrained species were located either upstream or downstream of the Surry CWIS. Two species, bay anchovy and naked goby, both of which have no commercial market value, were consistently the dominant species, averaging 91.1 percent of all ichthyoplankton entrained from 1976 through 1978. Salinity was identified to be a significant determinant factor in terms of abundance. Studies have shown fluctuations in the relative abundance of some species. These fluctuations are not imputable to the Surry CWIS.

6. The areas investigated in the James River in the vicinity of the Surry Power Station, as gauged by all gear types, were found to support stable, resilient, and diverse populations of fishes. All gear types were effective as

collectors of fish and monitors of changes in the diversity and relative abundance of fish populations. No threatened or endangered species was collected with any gear type. All the monitoring programs independently derived essentially the same assessment which was that over time the fish populations that each gear type sampled was found to be resilient to extraneous stresses, structurally sound and diverse, and have not been subjected to any uncompensated or irrepairable man-made or natural adverse environmental impacts.

7. The location, design, construction, and capacity of the Surry CWIS were analyzed and discussed. These characteristics were found to incorporate many of the features reported and recommended by the EPA to be desirable for minimizing adverse environmental impact at CWIS. Thus, the location, design, construction, and capacity of the Surry CWIS reflect the best technology available for minimizing adverse environmental impact.

9.0 CONCLUSION

The foregoing report constitutes Vepco's Section 316(b) demonstration for the Surry Power Station and is submitted in accordance with the provisions of and the regulations promulgated under Section 316(b) of P.L. 92-500. This report convincingly demonstrates that the Surry CWIS do not cause adverse environmental impact. Furthermore, even if an adverse environmental impact is presumed the location, design, construction, and capacity of the cooling water intake structures of the Surry Power Station reflect the best technology available for minimizing adverse environmental impact and is therefore in compliance with Section 316(b) of P.L. 92-500.

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