# ZOOPLANKTON ENTRAINMENT AT THE SURRY NUCLEAR POWER PLANT, JAMES RIVER, VIRGINIA
Final Report

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## INTRODUCTION

The diverse zooplankton found in marine and estuarine waters serves an important role in food chains, converting phytoplankton and detrital material into protein-rich animal tissues necessary in the nutrition of higher life forms, such as the young stages of decapod crustaceans and fishes. Generally free-floating or only weak swimmers, zooplankters are readily entrained in cooling waters pumped into power plants.

Mortality of entrained organisms can be caused by mechanical abrasion, the length of time and amplitude of temperature increases during plant passage, and from chlorination of the system for fouling control. Estimates of the percent of mortality due to plant passage are difficult to obtain, however, because of the many variables that need to be taken into account.

This project was designed to examine several of these variables as they apply to entrained zooplankton at the VEPCO Surry plant. These variables include seasonal changes in populations, diurnal variation in composition and abundance, and a comparison of techniques for estimating mortality. This report presents final results for the period April 1975 - March 1976.

## METHODS AND MATERIALS

Only two stations were sampled in this subproject, one at the intake forebay and one in the discharge canal. Initial sampling on 7 April 1975 indicated a low current speed and some stratification of the water column at the intake, compared with a turbulent, fast-moving stream in the discharge canal. To offset this difference, we increased the time of tows to 15 minutes in the intake, thereby providing a volume of sampled water roughly equal to that from a 5-min. tow in the discharge canal. As discussed below, adjustments to sampled volume estimates in the intake were necessitated by the low current speed.

Zooplankton collections were made with an eight-inch bongo sampler (18.5 cm inside diameter), equipped with 202 Nitex nets and a General Oceanics flowmeter. The sampler was lowered from a fixed position to just off the bottom, then raised at set intervals in one or two meter steps to the surface (stepped oblique technique). The sampler provided paired net collections that lend themselves to comparative treatments. Our sampling schedule and sample treatment during April 1975 through March 1976 is given in Table 1.

Table 1. Schedule of completed sampling for zooplankton entrainment at the VEPCO Surry Plant, April 1975 - March 1976.

| DATE | PURPOSE | TREATMENT OF COLLECTIONS NET 1 | NET 2 |
|---|---|---|---|
| 7 Apr 75 | Establishment of sampling locations; compariosn of catches with 202 and 571 micron mesh nets; vertical stratification | Preserved, 202 | Preserved, 571 |
| 22-23 Apr | Regular monthly sampling, 24-hr. stations | Preserved | Stained, then preserved |
| 30 Apr | Trial for live examination | Stained, then preserved | Dead organisms counted prior to preservation |
| 14-15 May | Regular monthly sampling, 24-hr. stations | Stained at double dose and time, then preserved | Dead organisms counted prior to preservation, or preserved |
| 4 Jun | Replicate sampling at intake and discharge for statistical estimate of catch variability | Preserved | Not collected |
| 17-18 Jun | Regular monthly sampling, 24-hr. stations | As in 14-15 May | As in 14-15 May |
| 16-17 Jul | " " | " " | " " |
| 13-14 Aug | " " | " " | " " |
| 21 Aug | Replicate sampling at intake and discharge for statistical estimate of catch variability | Preserved | Not collected |

Table 1. cont'd.

| DATE | PURPOSE | TREATMENT OF COLLECTIONS | |
|---|---|---|---|
| | | NET 1 | NET 2 |
| 3-4 Sept | Regular monthly sampling, 24-hr. stations | Stained at double dose and time, then preserved | Dead organisms counted prior to preservation, or preserved |
| 15-16 Oct | " " | As in 3-4 Sept | Preserved only (no live counts) |
| 13-14 Nov | " " | " " | As in 3-4 Sept |
| 9-10 Dec | " " | " " | " " |
| 14-15 Jan | " " | " " | " " |
| 12-13 Feb | " " | " " | " " |
| 16-17 Mar | " " | " " | " " |

## Staining

Live samples were initially stained with neutral red, a vital stain, using the dosage recommended by Dressel et al. (1972). The concentration of stain and the length of time organisms were exposed to stain were doubled beginning with the 24-hour stations in May, to one hour in a concentration of 1:100,000.

## Live Counts

Live samples from the paired net opposite to that used for staining were returned from sampling sites to the VEPCO Surry biological laboratory in gallon jars kept at ambient temperatures. Dead organisms in these collections were counted within an hour of collection. These determinations were also begun in May 1975 and continued throughout the project, except for October 1975 when an abundance of detritus prohibited live counts. This labor-intensive procedure was limited to daylight hours during the 24-hour sampling periods.

## Sorting, Enumeration and Identification

Counts of preserved zooplankters were obtained from either whole samples or from aliquots, in the case of smaller, more numerous taxa. Splitting of samples was accomplished by use of the device described by Burrell et al. (1974). Counts were reduced to numbers per cubic meter, after calibration of flowmeters in a flume (VIMS Physical Oceanography Department). Identification of dominants to species, where possible, was carried out after the initial sorting into major taxonomic groups.

Mortality Estimates

Estimates of mortality due to entrainment were attempted by three methods: 1) vital staining with neutral red stain (Dressel et al., 1972), 2) the method used by Marcy (1971) and 3) that of Davies and Jensen (1974). The last two methods are based on examination of live samples. Results are expressed as percent survival.

Low Speed Calibration of Flowmeter

The flowmeter used in our bongo nets was calibrated in December 1975 in a flume in VIMS Physical Oceanography Department where current speeds could be accurately controlled and measured. This calibration has shown that at low current speeds the flowmeter yields a significantly different calibration number ($m^3$ filtered/1000 counts) than at the higher speeds normally used to calibrate these instruments. Figure 1, comparing the calibration numbers obtained at varying current speeds, shows that at speeds above 50 cm/sec. (or about one knot) the calibration number is fairly constant. Below about 35-40 cm/sec., however, the calibration number rises sharply, becoming over three times as high at 22 cm/sec. as at faster speeds.

Current speeds at the Vepco sampling sites can be estimated by comparing counts/sec. with current speed as

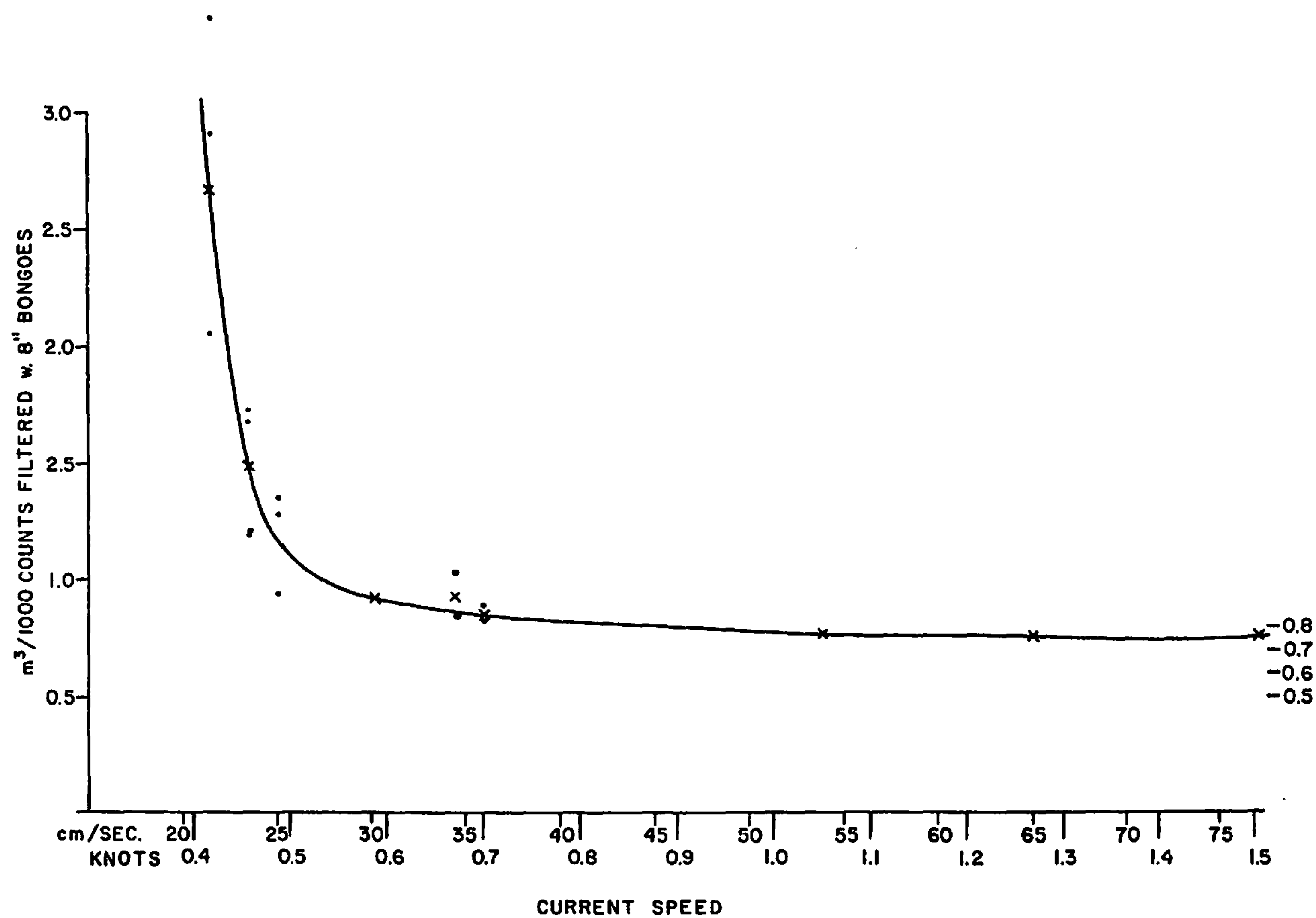


Fig. 1. Relationship of G-O meter calibration to current speed determined in VIMS flume.

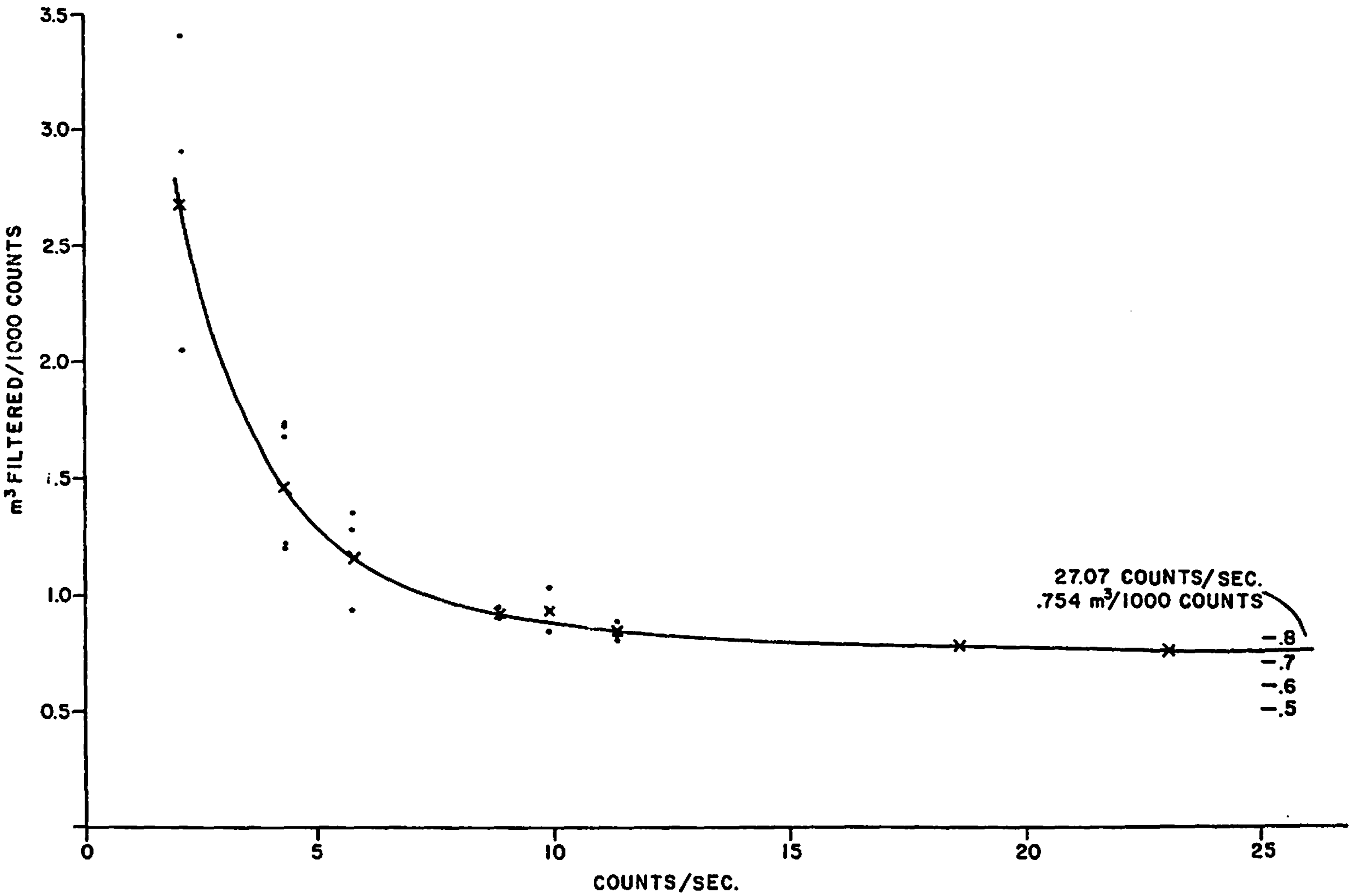


Fig. 2. Calibration curve for G-O meter based on observed current speeds at VEPCO Surry sampling sites.

obtained in the flume (Figure 2). Counts/sec. obtained at Vepco are quite variable, although usually fairly consistent within the same day. Current speed at the intake was about 21-35 cm/sec., while at the discharge its' range was 40-80 cm/sec.

Referring to Figure 1, this means that at the discharge the calibration number is fairly close to the constant value obtained at higher speeds. At the intake, however, the number is from 1.2 to 3 times this constant value, meaning that plankton abundance at the intake may have been overestimated by as much as a factor of 3. Current speeds can be estimated for each sampling by counts/second and the proper calibration number then obtained. The most direct way of doing this is to construct a graph of counts/second versus calibration number, as in Figure 2, and thus estimate the amount of water filtered for each tow. Counts provided in our 3-month interim report have been thus corrected for this final report, and all subsequent counts employ this correction.

## RESULTS

### Hydrography During Sampling

Entrained waters during most of the year fell into the salinity classifications of freshwater to oligohaline

(Table 2), lowest in May and most saline (max. 6‰) in September 1975. Temperatures varied from an observed low of 4.0 C in January 1976 to a high of 29.8 C in August 1975 at the intake station. Temperatures in the discharge canal were elevated above those in the intake by 3 to 8 C, with observed extremes of 12.0-37.5 C.

Ranges of salinity observed in the discharge canal were consistently narrower than those found at the intake. This difference is due to mixing during plant passage of waters that, in the intake forebay, had been vertically stratified.

Vertical stratification and net comparisons

Samples were collected at both stations from surface, midwater and near-bottom waters with paired 202 and 571 Nitex nets of 7 April 1975. Although very variable, most counts of a given taxon were in the same order of magnitude at all depths (Table 3). Considering the inherent variability of plankton catches, these counts were quite close. In any event, a stepped oblique technique of sampling (used subsequently to this preliminary work) integrates populations and densities throughout the water column.

The 571 Nitex net (equivalent to a #0 mesh) was much too coarse for quantitative sampling of zooplankton, especially the typically small estuarine and freshwater forms found at the Surry location, and was tested primarily for

Table 2. Range of temperature and salinity observed at intake and discharge stations during regular monthly samples, April 1975 - March 1976

| DATE | STATION | TEMPERATURE (C) | SALINITY (‰) |
|---|---|---|---|
| 22-23 Apr | Intake (I) | 14.2-16.5 | 1.43-2.05 |
| | Discharge (D) | 16.9-20.5 | 1.53-2.00 |
| 14-15 May | I | 19.5-23.1 | 0.36-0.78 |
| | D | 22.8-26.0 | 0.40-0.73 |
| 17-18 Jun | I | 26.0-29.5 | 3.34-3.99 |
| | D | 30.2-32.2 | 3.40-3.87 |
| 16-17 Jul | I | 26.1-28.2 | 1.27-4.38 |
| | D | 32.1-36.5 | 1.29-1.97 |
| 13-14 Aug | I | 26.3-29.8 | 3.76-5.24 |
| | D | 33.0-37.5 | 4.08-5.05 |
| 3-4 Sept | I | 24.5-27.4 | 5.20-6.03 |
| | D | 31.5-35.4 | 5.17-5.93 |
| 15-16 Oct | I | 20.0-24.0 | 1.22-2.31 |
| | D | 22.3-27.4 | 1.67-2.07 |
| 13-14 Nov | I | 13.0-16.5 | 1.93-3.02 |
| | D | 18.0-21.5 | 2.03-3.22 |
| 9-10 Dec | I | 8.6-10.0 | 3.28-5.76 |
| | D | 16.2-18.0 | 4.35-5.75 |
| 14-15 Jan | I | 4.0-7.2 | 1.18-2.84 |
| | D | 12.0-15.0 | 1.18-2.83 |
| 12-13 Feb | I | 5.5-7.5 | 1.22-1.76 |
| | D | 13.0-15.0 | 1.33-1.71 |
| 16-17 Mar | I | 8.0-12.5 | 1.50-2.56 |
| | D | 12.0-16.5 | 1.37-2.53 |

its efficiency in catching fish larvae (cf. Ichthyoplankton section of this report). The 202 Nitex net has been recommended by Ahlstrom et al. (1969) as one that provides a separation between microzooplankton and mesozooplankton. It is efficient for cladocerans and all but the smallest of adult estuarine copepods (e.g. Oithona), but does not quantitatively retain smaller copepodites or copepod nauplii. Catches of fish larvae were influenced more by sampler size than mesh size. None were caught in intake sampling; the few caught in the discharge canal were unevenly distributed between nets (Table 4). A net with an opening larger than 8 inches was indicated for efficient sampling of fish larvae in the slow currents of the intake forebay.

Smaller holoplanktonic organisms such as copepods and cladocerans exhibit little net avoidance and are efficiently caught in an 8" bongo net constructed of 202 Nitex (Table 4). These organisms, together with polychaete larvae, readily pass through the meshes of a 571 Nitex net. Catch ratios of the two nets are closer to 1:1 for the larger, more active organisms such as amphipods, mysids and fish larvae.

Live staining - interference and specific variation

Vital staining of freshly-caught zooplankton was included in the design of this research as the primary

Table 3. Vertical stratification of dominant major groups of zooplankton, 7 April 1975, as sampled with 202 Nitex nets. Numbers per cubic meter, corrected for low current speeds at the intake.

| Taxon | Intake Surface | Intake Midwater | Intake Bottom | Discharge Surface | Discharge Midwater | Discharge Bottom |
|---|---|---|---|---|---|---|
| Copepoda | 733 | 693 | 669 | 262 | 451 | 381 |
| Cladocera | 109 | 92 | 110 | 67 | 82 | 26 |
| Polychaeta | 47 | 13 | 17 | 3.2 | 3.2 | 12 |
| Amphipoda | 5.8 | 3.3 | 6.1 | 0 | 22 | 17 |
| Mysidacea | 0 | 3.9 | 6.1 | 1.6 | 6.4 | 0.5 |

Table 4. Catch ratio of major zooplankton components from paired tows of 202 and 571 Nitex nets (202:571). Based on log (x+1) transform of catch per cubic meter.

| Taxon | Intake Surface | Intake Midwater | Intake Bottom | Discharge Surface | Discharge Midwater | Discharge Bottom |
|---|---|---|---|---|---|---|
| Copepoda | 98:1 | 190:1 | 161:1 | 146:1 | 107:1 | 66:1 |
| Cladocera | 65:1 | 263:1 | 181:1 | 57:1 | 83:1 | 22:1 |
| Polychaeta | 29:1 | 38:1 | 38:1 | 4.2:1 | 3.5:1 | 11:1 |
| Amphipoda | 5.5:1 | 1:1 | 2.1:1 | 1.7:1 | 4.6:1 | 4.9:1 |
| Mysidacea | ---- | 1.7:1 | 1.4:1 | 1:1.4 | 1.5:1 | 1:1.1 |
| Fish larvae | ---- | ----- | ----- | 1:1.2 | 1:1.6 | 1.3:1 |

means of estimating mortality due to plant passage. Earlier testing of staining with a 1:200,000 concentration of neutral red (Dressel et al. 1972) had indicated good results could be expected with copepods and ctenophores (York River, April 1974). providing that organisms were stained for at least 30 minutes. Poor results in our initial staining during the regular April sampling at the Surry plant were, therefore, unexpected.

During our initial 24-hour sampling on 22-23 April 1975, complete failure of staining was experienced at 3 of 11 stations, once at the intake and twice at the discharge. In the remaining collections, the percentage of organisms stained varied widely from 19.3% to 71.4% of the total. Sorters had difficulty in classifying many of the organisms as stained or unstained. Examination of samples revealed large amounts of detrital particles to which an evident adsorption of stain had occurred. A heavy detrital load may, thereby, interfere with staining of zooplankton. Sorting of stained and unstained organisms also showed a specific difference in stain uptake (Table 5A). Only Eurytemora affinis, the dominant calanoid copepod at this time (see below), stained consistently. Other calanoids were few in number, and only occasionally were stained: cyclopoid copepods never stained. Crippen and Perrier (1974) successfully stained calanoid copepods, polychaete eggs and larvae, gastropod eggs, hydrozoan larvae, rotifers and chaetognaths with this concentration of neutral red and a staining time of one hour. By doubling the stain concentration and increasing the staining time (1-6 hours), they were able to increase the effectiveness of staining. Calanoid copepods and polychaete larvae required the shortest staining period, barnacle larvae and decapod zoea the longest.

A staining time in excess of one hour was undesirable in our research for two reasons: 1) the schedule of sampling each of two stations every four hours and 2) the liklihood of mortality due to holding for lengthy periods. We therefore increased staining time in subsequent sampling to only one hour, and doubled stain concentration to 1:100,000. This change resulted in vividly stained organisms from our regular monthly May sampling. Preserved samples were still stained one month after collection (in 5% formalin). Results in May (Table 5B) were improved considerably, with no indecision on the part of sorters, good stain retention for up to one month after collection, and an expansion of the list of those taxa that are consistently stained. Cyclopoid copepods were the only abundant organisms that largely failed to stain. Amphipods and gastropods rarely stained and results with cladocerans and hydroids were mixed. The list of organisms consistently staining was extended from E. affinis to all calanoids, harpacticoids, polychaete larvae, and the few brachyuran larvae.

Table 5. Relative success in staining of zooplankton with neutral red at a concentration of A) 1:200,000 for 1/2 hour, Surry plant, 22-23 April 1975, B) 1:100,000 for 1 hour, Surry plant, 14-15 May 1975.

| | Consistently stained | Occasionally stained | Not stained |
|---|---|---|---|
| A. | *Eurytemora affinis* | *Acartia tonsa* | cyclopoid copepods |
| | | *Diaptomus birgei* | amphipods |
| | | polychaete larvae | gastropods |
| | | | fish larvae |
| B. | *Eurytemora affinis* | cladocerans | cyclopoid copepods |
| | *Diaptomus birgei* | hydroids | hydrachnids |
| | *Acartia tonsa* | amphipods | |
| | harpacticoids | gastropods | |
| | brachyuran zoea | | |
| | polychaete larvae | | |

Staining results in June, with a changing fauna, were similar, with the exceptions of the now more abundant decapod larvae, which did not stain and the barnacle nauplii which consistently stained. Obviously, staining alone cannot be relied upon as an estimate of plant mortality unless a distinction is made between those organisms that consistently stain well and those that either rarely stain or stain unevenly. Examination of freshly caught collections for dead specimens was incorporated into our regular sampling in May 1975 as an alternative and comparative method, and the doubling of stain concentration and exposure time was continued.

## Variation in Replicate Tows

A series of replicate tows (5 discharge, 4 intake) was taken on 4 June 1975 in an initial assessment of catch variation. Data for total copepods per cubic meter were as follows:

| Tow No. | Discharge | Intake |
|---|---|---|
| 1 | 2238 | 581 |
| 2 | 2092 | 786 |
| 3 | 3379 | 386 |
| 4 | 1457 | 182 |
| 5 | 2312 | |
| $\bar{x}$: | 2295.6 | 483.8 |
| st.dev.: | 693.2 | 259.1 |
| c.v.: | 0.30 | 0.54 |

With such wide variation, especially at the intake, the number of replicates was insufficient for a good estimate of variation. In order to more accurately estimate between-tow variability, a second series of 10 tows at each station was taken on 21 August 1975. Tows were five minutes in length and all samples at each station were taken within one hour. Numbers per cubic meter of some of the more consistently encountered groups are given in Tables 6 and 7.

The variances of these samples with very different means can be compared using the coefficient of variance (C.V. = standard deviation divided by samples mean). The coefficient is quite variable for scarce animals, such as fish larvae and medusae, ranging between 0.3 and 1.0 for groups such as barnacle nauplii and decapods, and is near 0.2 for the abundant copepods.

Sampling error thus decreases for more abundant organisms until the standard deviation is about 20% of the sample mean for the most abundant organisms, assuming that the degree of patchiness remains consistent throughout our sampling period.

Faunal Composition and Abundance of Entrained Zooplankton

All samples were sorted into major taxonomic groups, such as copepods, amphipods, fish larvae, etc., and counts of these groups placed on sorting sheets under the appropriate aliquot size. Calanoid copepods and cladocerans were usually

Table 6. Variation in replicate tows, intake, 21 Aug 1975.

Intake

| TOW | fish larvae | amphipods | decapods | barnacle nauplii | medusae | copepods |
|---|---|---|---|---|---|---|
| 1 | 0 | 4.5 | 8.9 | 51 | 8.9 | 2735 |
| 2 | 0 | 1.1 | 31 | 67 | 11 | 1264 |
| 3 | 0.6 | 2.2 | 14 | 80 | 2.2 | 1814 |
| 4 | 0 | 0 | 38 | 19 | 0 | 1825 |
| 5 | 0 | 0 | 36 | 24 | 0 | 2330 |
| 6 | 0.6 | 2.3 | 53 | 160 | 13 | 2391 |
| 7 | 0 | 0 | 110 | 247 | 2.3 | 1618 |
| 8 | 0 | 0 | 55 | 118 | 0.6 | 1517 |
| 9 | 4.5 | 0 | 27 | 22 | 0 | 1769 |
| 10 | 0.6 | 0 | 32 | 4.6 | 0 | 1998 |
| $\overline{x}$ | 0.63 | 1.01 | 40.47 | 79.26 | 3.8 | 1926.1 |
| st. dev. | 1.39 | 1.54 | 28.43 | 76.48 | 5.11 | 445.6 |
| C.V. | 2.21 | 1.55 | 0.70 | 0.97 | 1.34 | 0.23 |

Table 7. Variation in replicate tows, discharge, 21 Aug 1975.

Discharge

| TOW | fish larvae | amphipods | decapods | barnacle nauplii | fish eggs | copepods |
|---|---|---|---|---|---|---|
| 1 | 1.8 | 70 | 70 | 164 | 43 | 6236 |
| 2 | 1.5 | 59 | 70 | 174 | 46 | 8255 |
| 3 | 3.1 | 130 | 33 | 76 | 76 | 6563 |
| 4 | 1.1 | 192 | 34 | 102 | 124 | 7825 |
| 5 | 2.6 | 237 | 21 | 52 | 62 | 7257 |
| 6 | 1.8 | 21 | 16 | 34 | 50 | 5769 |
| 7 | 1.6 | 114 | 22 | 73 | 59 | 7722 |
| 8 | 1.4 | 91 | 65 | 169 | 78 | 7750 |
| 9 | 2.3 | 132 | 46 | 119 | 68 | 3963 |
| 10 | 1.1 | 98 | 68 | 45 | 68 | 6933 |
| $\bar{x}$ | 1.83 | 114.4 | 44.5 | 100.8 | 67.4 | 6827.3 |
| std. dev. | 0.65 | 63.41 | 22.08 | 53.42 | 23.21 | 1274.8 |
| C.V. | 0.36 | 0.55 | 0.50 | 0.53 | 0.35 | 0.19 |

dominant and have been identified to species. Other specific identifications are limited to those groups of special interest, such as fish larvae. Identifications and estimates of abundance are given in Tables 8-19. Tabulated values are in numbers per cubic meter, corrected for low flows at the intake station.

Zooplankton throughout the sampled year was, as expected numerically dominated by copepods. The calanoid copepods contributed the dominant species in all months. Eurytemora affinis was dominant at the start of sampling in April, and again in May 1975. Acartia tonsa was present in low numbers in April, along with the cold-water A. clausi, decreased further in the freshened conditions of May, then dramatically increased to dominance in June. It remained the dominant species through the summmer months of July, August and September, then decreased to co-dominance with E. affinis in October and November. E. affinis was dominant through the remainder of the year, December - March.

Other calanoids included a species of Diaptomus, possibly D. birgei, which occurred only in the coldest months, January - May, and Pseudodiaptomus coronatus, present in low numbers throughout much of the year. Other calanoids were limited to rare occurrences and included Centropages hamatus, C. typicus, Paracalanus crassirostris, P. quasimodo, Temora turbinata and Labidocera aestiva.

Cyclopoid and harpacticoid copepods were caught most abundantly in freshened conditions, especially during the



(text continued on page 40)

Table 8. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), April 22-23, 1975. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bongo sampler using 202 Nitex nets.

| Taxon | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | D | I | D | I | D | I | D | I | D | I | D |
| Cnidaria | | | | | | | | | | | | |
| hydroids | 1.2 | 1.6 | | 1.0 | 0.3 | 1.4 | | 0.5 | 1.5 | | pr. | |
| Mollusca | | | | | | | | | | | | |
| gastropods | 0.6 | 11 | 0.5 | | 1.0 | 8.4 | 66 | 0.9 | 2.8 | | pr. | |
| Annelida | | | | | | | | | | | | |
| polychaete larvae | | | | | 0.2 | | | | | 1.6 | | |
| leeches | | | | | | | | | 0.3 | | | |
| Crustacea | | | | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| *Leydigia quadrangularis* | 0.6 | 0.2 | | | | | | | | | | |
| *Daphnia ambigua* | | | | | 0.2 | | | | | | | |
| Copepoda | | | | | | | | | | | | |
| *Eurytemora affinis* | 32 | 44 | 20 | 38 | 30 | 20 | 100 | 41 | 87 | 161 | pr. | |
| *Acartia tonsa* | 2.4 | 1.6 | | | 0.9 | | 2.8 | 0.5 | 1.8 | | pr. | |
| *A. clausi* | | | | 0.8 | | | | | | | | |
| *Diaptomus birgei* (?) | 0.6 | 0.8 | 0.9 | 0.8 | 1.3 | 0.3 | 3.5 | | 3.6 | | pr. | |
| Non-calanoids | 18 | 14 | 24 | 15 | 15 | 5.9 | 59 | 18 | 51 | 61 | pr. | |
| cyclopoids | | | | | | 4.5 | | | | | | |
| harpacticoids | | | | | | 1.4 | | | | | | |
| Amphipoda | 0.2 | 4.3 | 1.9 | 6.3 | 6.2 | 1.4 | 15 | 20 | 22 | 18 | pr. | |
| Mysidacea | | | | | | | | | | | | |
| *Neomysis americana* | | 0.2 | | | 0.2 | | | | 1.3 | 0.2 | pr. | |
| Insecta and Hydrachnida | | | | 3.1 | | | | 1.8 | 2.1 | | | |
| Pisces (larvae) | | | | | | | | | | | | |
| *Brevoortia tyrannus* | | | | | 0.2 | | | | | 0.4 | | |

Table 9. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), May 14-15, 1975. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bongo sampler using 202 Nitex nets.

| Taxon | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | D | I | D | I | D | I | D | I | D | I | D |
| Cnidaria | | | | | | | | | | | | |
| hydroids | | 5.5 | | | | | | | | | | |
| Mollusca | | | | | | | | | | | | |
| gastropods | 2.3 | 0.5 | 0.1 | 2.8 | | 1.2 | | 32 | 37 | 27 | | |
| bivalve larvae | | | | | | 1.8 | | | 0.6 | 0.8 | | |
| Annelida | | | | | | | | | | | | |
| polychaete larvae | | | | | | | 3.3 | | 0.5 | 0.4 | | |
| leeches | 0.6 | | | | | | | | | | | |
| Crustacea | | | | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| *Bosmina longirostris* | 8.2 | 2.8 | 1.0 | 1.7 | 18 | 12 | 24 | 35 | 35 | 28 | 1.4 | 2.5 |
| *Daphnia parvula* | | | 0.2 | | 0.3 | | | | | | | 0.4 |
| *Diaphanosoma brachyurum* | | | | | 0.1 | | | | | | | |
| Cirripedia | | | | | | | | | | | | |
| barnacle nauplii | | | | | | | | | 0.6 | 0.8 | 0.1 | |
| Copepoda | | | | | | | | | | | | |
| *Eurytemora affinis* | 343 | 94 | 29 | 30 | 230 | 104 | 584 | 268 | 104 | 117 | 59 | 148 |
| *Acartia tonsa* | | 0.5 | | | | | | 0.6 | | 1.7 | | |
| *Diaptomus birgei* (?) | | | 2.4 | | 2.0 | 1.2 | 5.2 | 0.6 | 0.6 | | 2.0 | 1.4 |
| *Centropages hamatus* | | 0.5 | 0.6 | | | | | | | | | |
| Non-calanoids | 95 | 20 | 48 | 14 | 96 | 15 | 579 | 152 | 139 | 63 | 27 | 21 |
| cyclopoids | | 18 | 48 | | | 15 | 490 | 87 | 79 | 34 | 25 | 21 |
| harpacticoids | | 1.4 | --- | | | --- | 89 | 65 | 60 | 29 | 2.0 | --- |
| Amphipoda | 4.1 | 6.9 | 3.3 | 19 | 1.4 | 29 | 115 | 161 | 50 | 70 | 12 | 31 |

Table 9 (continued)

| Taxon | 1000 I | 1000 D | 1400 I | 1400 D | 1800 I | 1800 D | 2200 I | 2200 D | 0200 I | 0200 D | 0600 I | 0600 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crustacea (continued) | | | | | | | | | | | | |
| Decapoda (larvae) | | | | | | | | | | | | |
| *Crangon septemspinosa* | | | 0.1 | | | | | | | | | |
| *Rhithropanopeus harrisii* | | | 0.3 | 0.2 | 1.0 | 0.6 | | | | | | |
| Insecta and Hydrachnida | 0.6 | | 0.1 | | 0.1 | | | 0.6 | 3.7 | 3.3 | | |
| Pisces | | | | | | | | | | | | |
| unknown fish larvae | 0.2 | | | 0.2 | | | | | | | | |
| *Dorosoma cepedianum* larvae | | | | | 0.3 | | | 0.6 | | | | |

Table 10. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), June 17-18, 1975. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bongo sampler using 202 Nitex nets.

| Taxon | 1000 I | 1000 D | 1400 I | 1400 D | 1800 I | 1800 D | 2200 I | 2200 D | 0200 I | 0200 D | 0600 I | 0600 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cnidaria | | | | | | | | | | | | |
| medusae | 0.6 | | | | 0.7 | | | | | | 0.3 | |
| Mollusca | | | | | | | | | | | | |
| gastropods | 0.8 | 1.0 | | | 15 | 15 | 14 | | | 0.5 | 36 | 44 |
| bivalve larvae | 1.1 | 1.0 | | | | | 0.3 | | | | 1.7 | 1.8 |
| Annelida | | | | | | | | | | | | |
| polychaete larvae | | | | | | 0.5 | | | | | 0.3 | |
| Crustacea | | | | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| *Evadne tergestina* | 5.8 | | | | | | | | | 5.0 | 0.3 | |
| *Penilia avirostris* | 5.8 | | | | | | | | | | | |
| *Moina micrura* | | | | | | 1.0 | | | | | | |
| Cirripedia | | | | | | | | | | | | |
| barnacle nauplii | 409 | 66 | 349 | 77 | 41 | 41 | 122 | 13 | 595 | 114 | 176 | 88 |
| barnacle cypris larvae | | | | | | | | | | | | 1.8 |
| Copepoda | | | | | | | | | | | | |
| *Eurytemora affinis* | 58 | 57 | | 2.1 | 3.4 | | 21 | 29 | 470 | 148 | 11 | 80 |
| *Acartia tonsa* | 2,061 | 474 | 2,368 | 306 | 135 | 247 | 1,401 | 328 | 5,113 | 882 | 3,989 | 1,900 |
| *Pseudodiaptomus coronatus* | | | | | 0.3 | | 2.6 | 1.6 | 5.1 | | | |
| *Paracalanus crassirostris* | | | | | | | | | | | 5.7 | |
| Non-calanoids (total) | | | | | 0.7 | | 8 | 4.8 | 20 | | | 22 |
| cyclopoids | | | | | 0.7 | | | 1.6 | 20 | | | 22 |
| harpacticoids | | | | | | | 8 | 3.2 | | | | |
| Amphipoda | | 85 | 1.6 | 91 | 3.1 | 133 | 25 | 143 | 9.6 | 183 | 4 | 25 |
| Isopoda | | | | | | 0.5 | | | | 1.0 | | 0.3 |

Table 10 (continued)

| Taxon | 1000 I | 1000 D | 1400 I | 1400 D | 1800 I | 1800 D | 2200 I | 2200 D | 0200 I | 0200 D | 0600 I | 0600 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crustacea (continued) | | | | | | | | | | | | |
| Mysidacea | | | | | | | | | | | | |
| *Neomysis americana* | | | | | 0.2 | 0.5 | 4.1 | 4.6 | 12 | 3.5 | | |
| Decapoda (larvae) | | | | | | | | | | | | |
| *Crangon septemspinosa* | | | | | | | 0.1 | | | | | |
| *Palaemonetes* sp. | 3.3 | 9.2 | 0.4 | | 1.0 | 0.5 | 3.8 | 7.0 | 7.7 | 4.0 | 2.8 | 3.7 |
| *Rhithropanopeus harrisii* | 7.5 | 10 | 12 | 14 | 0.3 | 2.5 | 6.6 | 1.0 | 22 | 14 | 20 | 21 |
| *Uca* sp. | 1.8 | 1.1 | | | 0.7 | 0.5 | 3.3 | 0.2 | | 0.5 | 0.7 | |
| Insecta and Hydrachnida | | 2.0 | 0.4 | 2.1 | | 2.5 | 0.7 | | 0.6 | 21 | | |
| Pisces | | | | | | | | | | | | |
| *Anchoa mitchilli* - eggs | 4.4 | | 0.8 | | 0.9 | | | | 0.6 | | | |
| " " - larvae | 2.0 | 1.0 | | | | 0.5 | | 1.0 | | | | 1.1 |
| *Gobiosoma bosci* - larvae | | | | 1.0 | | 0.5 | 1.3 | | | 1.5 | 1.0 | 4.3 |
| Unid. fish larvae | | | | | | | | | 3.2 | | 2.0 | |

Table 11. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), July 16-17, 1975. Numbers per cubic meter based on stepped oblique tows with an 18.5 cm bongo sampler using 202 μ Nitex nets.

| Taxon | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | D | I | D | I | D | I | D | I | D | I | D |
| Cnidaria (medusae) | 0.6 | | | | | | | | 0.6 | | 1.2 | |
| Mollusca | | | | | | | | | | | | |
| Gastropoda | 11 | | 82 | 135 | | 92 | | 50 | 236 | | 246 | 237 |
| Bivalvia | | | | | | | | | | | | 0.6 |
| Polychaeta | | | | | | | 2.6 | 1.0 | | 1.1 | | |
| Crustacea | | | | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| *Diaphanosoma brachyurum* | 3.9 | | | | | 1.0 | 7.0 | 2.1 | 15 | | 7.12 | 2.4 |
| *Moindaphnia macleayi* | | | 0.6 | | | | | | | | | |
| *Bosmina longirostris* | | | | | | | | 0.5 | | | 0.6 | |
| Copepoda | | | | | | | | | | | | |
| *Acartia tonsa* | 783 | 435 | 366 | 315 | 73 | 148 | 387 | 163 | 522 | 327 | 579 | 568 |
| *Eurytemora affinis* | 179 | 120 | 156 | 216 | 3.8 | 4.2 | 76 | 33 | 396 | 147 | 178 | 242 |
| Non-calanoids | | | | | | | | | | | | |
| cyclopoids | 4.4 | | 2.4 | 13 | | | | 8.3 | 63 | 27 | 43 | 22 |
| harpacticoids | 2.2 | | 2.4 | 13 | | | 51 | 6.2 | 4.9 | | | |
| Amphipoda | 5.5 | 184 | 12 | 216 | 7.6 | 151 | 11 | 187 | 20 | 92 | 5.9 | 64 |
| Mysidacea | | | | | | | | | | | | |
| *Neomysis americana* | | | | | | | 1.3 | | | | | |
| *Mysidopsis bigelowi* | | | | | | | | | 0.6 | | | |
| Cirripedia | | | | | | | | | | | | |
| barnacle nauplii | 34 | | 30 | 2.3 | 2.2 | 20 | 17 | | 31 | 2.1 | 36 | 15 |
| Decapoda | | | | | | | | | | | | |
| *Rhithropanopeus harrisii* | 10 | 3.9 | 10 | 19 | 6.7 | 10 | 17 | 14 | 7.3 | 7.9 | 7.7 | 3.6 |
| *Uca* sp. | | | | | 0.6 | 2.1 | | | | 0.5 | 0.6 | 0.6 |
| *Palaemonetes* sp. | 8.8 | 3.9 | 0.6 | | | | 50 | 1.6 | 1.8 | 1.6 | 3.0 | |
| *Sesarma* sp. | | | | | | | | | | 0.5 | | |
| *Crangon septemspinosa* | | | | | | | | 0.5 | | | | |

Table 11 (continued)

| Taxon | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | D | I | D | I | D | I | D | I | D | I | D |
| Insecta | | | | | | | | 0.5 | | | | |
| Pisces | | | | | | | | | | | | |
| *Anchoa mitchilli* | 0.1 | | 0.2 | 0.1 | | 0.1 | 0.4 | 1.0 | 0.3 | 1.1 | 0.3 | 0.3 |
| *Gobiosoma bosci* | | 0.3 | | | | | | | | | 0.3 | 1.1 |

Table 12. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), August 13-14, 1975. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bongo sampler using 202 Nitex nets.

| Taxon | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | D | I | D | I | D | I | D | I | D | I | D |
| Cnidaria | | | | | | | | | | | | |
| hydromedusae | 17 | | | | 8,5 | 3.3 | 6.6 | 6,9 | 35 | 35 | 28 | 2,7 |
| Mollusca | | | | | | | | | | | | |
| gastropods | | | | | | | 1,610 | | | | | |
| Crustacea | | | | | | | | | | | | |
| Cirripedia | | | | | | | | | | | | |
| barnacle nauplii | 161 | 123 | 26 | 21 | 30 | 156 | 415 | 119 | 160 | 188 | 2,9 | 21 |
| Copepoda | | | | | | | | | | | | |
| *Acartia tonsa* | 1,903 | 1,148 | 1,307 | 613 | 987 | 703 | 3,294 | 1,643 | 12,100 | 3,620 | 1,690 | 1,100 |
| *Eurytemora affinis* | | | 3.1 | 5.1 | | | 7,5 | 6.9 | 29 | | | |
| *Temora turbinata* | 2.5 | | | | | | | | | | | |
| *Pseudodiaptomus coronatus* | | | | | | | | | | 9,9 | | |
| cyclopoids | | | | | | | 38 | 4.6 | | | | |
| harpacticoids | | | | | | | 23 | 6.9 | | 5,0 | | |
| Amphipoda | | 123 | 0.8 | 31 | 11 | 72 | 5,6 | 300 | 14,6 | 327 | 0,6 | 75 |
| Mysidacea | | | | | | | | | | | | |
| *Neomysis americana* | | | 0.8 | | | | 0,9 | 1,4 | 1,8 | | 0,3 | 0.7 |
| Decapoda (larvae) | | | | | | | | | | | | |
| *Rhithropanopeus harrisii* | 57 | 37 | 0.4 | 17 | 4,3 | 2.2 | 21 | 44 | 43 | 94 | | 17 |
| *Uca* sp. | | | | 4.2 | | | 20 | | | | 7,0 | |
| *Crangon septemspinosa* | | | | | | | | 11 | | | | |
| *Palaemonetes* sp. | | | | | | | | | 10 | | 7,0 | |
| Insecta and Hydrachnida | | | | | | | | | | | | |
| water mites | 4,5 | | 3,9 | 2,1 | | | | | | | | |

Table 12 (continued)

| Taxon | 1000 I | 1000 D | 1400 I | 1400 D | 1800 I | 1800 D | 2200 I | 2200 D | 0200 I | 0200 D | 0600 I | 0600 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pisces (larvae) | | | | | | | | | | | | |
| *Anchoa mitchilli* | 0.1 | 0.1 | | | 1.6 | 0.5 | 0.7 | 0.6 | 3.6 | 0.3 | 0.3 | 1.2 |
| *Gobiosoma bosci* | 0.3 | 0.4 | | | | 0.5 | 0.2 | 1.2 | 11 | 4.3 | 0.1 | 0.3 |
| *Micropogon undulatus* | | | | | | | 0.1 | 0.1 | 1.8 | | | |

Table 13. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), September 3-4, 1975. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bongo sampler using 202 Nitex nets.

| Taxon | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | D | I | D | I | D | I | D | I | D | I | D |
| Cnidaria (medusae) | 42 | 2.5 | 4.3 | 2.0 | 1.8 | 0.8 | 3.1 | | 2.4 | 0.5 | | 1 |
| Mollusca | | | | | | | | | | | | |
| Gastropoda | | | | | | | | | 3.4 | | | |
| Bivalvia | 2.3 | | | 2.6 | | | | | 1.3 | | | |
| Polychaeta | | | | 3.3 | 2.2 | | | | 0.6 | 1.6 | | 6. |
| Crustacea | | | | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| Cirripedia | | | | | | | | 2.2 | | | | |
| barnacle nauplii | 216 | 104 | 28 | 70 | 113 | 62 | 43 | 1.3 | 66 | 88 | 2.5 | 27 |
| barnacle cypris | | | 1.1 | | 18 | 22 | | | | 6.1 | | |
| Copepoda | | | | | | | | | | | | |
| *Acartia tonsa* | 1214 | 921 | 641 | 576 | 279 | 505 | 620 | 60 | 666 | 631 | 120 | 129 |
| *Pseudodiaptomus coronatus* | | 1.3 | | | | | | | 0.5 | | | |
| cyclopoids | | | | | | | 2.9 | | | 2.6 | | |
| harpacticoids | | | 1.1 | | 6.6 | 1.6 | 5.8 | | 2.7 | 2.6 | | |
| Branchiura | | | | | | | | | | | | |
| *Argulus alosae* | | | 1.1 | | | | | | | | | |
| Amphipoda | | 110 | 8.1 | 153 | 9.7 | 560 | 1.1 | 13 | 1.2 | 225 | 3.8 | 213 |
| Mysidacea | | | | | | | | | 0.6 | | | |
| *Neomysis americana* | | | | | | | 0.2 | | | 5.2 | | 1.3 |
| Ostracoda | 2.3 | | | | | | | | | | | |
| Decapoda | | | | | | | | | | | | |
| *Rhithropanopeus harrisii* | 16 | 30 | 12 | 7.2 | 7.1 | 30 | 1.6 | 3 | 5.0 | | 0.5 | 7.2 |
| *Palaemonetes* sp. | | | | | | | | | 2.5 | 28 | | |
| Insecta | | | | | | | | | 0.1 | | | |
| Pisces | | | | | | | | | | | | |
| *Anchoa mitchilli* | 0.3 | 0.2 | | 0.5 | | | | | | 0.2 | | |
| *Gobiosoma bosci* | | 0.3 | | | | | 0.2 | | | 0.2 | | 0.2 |
| *Menidia* sp. | | | 0.1 | | | | | | | | | |
| fish eggs | | 16 | | 17 | | 6.5 | | | | 7.4 | | 34 |

Table 14. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), October 15-16, 1975. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bongo sampler using 202 Nitex nets.

| Taxon | 1000 I | 1000 D | 1400 I | 1400 D | 1800 I | 1800 D | 2200 I | 2200 D | 0200 I | 0200 D | 0600 I | 0600 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mollusca | | | | | | | | | | | | |
| bivalves | 1.0 | | | | 0.4 | | | | | | 0.2 | |
| gastropods | | | | | 0.2 | | 0.9 | 0.5 | | | 5.7 | 0.3 |
| Polychaeta | | | | | | | | 0.5 | 0.1 | | | |
| Crustacea | | | | | | | | | | | | |
| Ostracoda | 9.3 | 0.9 | 0.1 | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| *Bosmina longirostris* | | | | | | | | | | | 1.0 | 0.3 |
| *Diaphanosoma brachyurum* | | | 0.1 | | | | | | | | | |
| Cirripedia | | | | | | | | | | | | |
| barnacle nauplii | | 0.9 | | | | | | | | | | |
| Copepoda | | | | | | | | | | | | |
| *Acartia tonsa* | 188 | 121 | 61 | 8.1* | 49 | 81 | 90 | 161 | 213 | 249 | 248 | 517 |
| *Eurytemora affinis* | 43 | 43 | 32 | 3.6 | 138 | 50 | 109 | 245 | 250 | 384 | 119 | 232 |
| *Paracalanus quasimodo* | 2.6 | | | | | | | | | | | |
| cyclopoids | | 0.9 | 0.6 | 1.3 | 2.6 | 5.8 | 56 | 161 | 106 | 112 | 112 | 157 |
| harpacticoids | | 0.9 | 0.6 | 0.5 | 0.4 | 1.9 | 0.9 | 55 | 2.1 | | 2.3 | 2.1 |
| Amphipoda | 3.2 | 9.2 | 0.4 | 8.5 | | 39 | 0.7 | 16 | 0.5 | 12 | 0.6 | 4.9 |
| Isopoda | | | | | | 0.2 | 0.2 | | | | | |
| Mysidacea | | | | | | | | | | | | |
| *Mysidopsis bigelowi* | | | | 0.5 | | | 0.2 | 0.2 | 0.2 | 0.6 | 1.0 | 1.0 |
| Decapoda | 0.3 | | | | | | | | | | | |
| Insecta | | | | | | | | | | | 0.2 | |
| Arachnida (Acari) | | | | | 2.2 | 1.9 | | | | | | |
| Pisces | | | | | | | | | | 0.2 | 0.2 | |
| *Anchoa mitchilli* | | | | | | | | 0.2 | | | | |
| *Micropogon undulatus* | | | | | | | | | 0.1 | | | |
| fish eggs | | 3.7 | 0.3 | | | | 0.2 | | | 7.6 | | |

* Sample choked with detritus. Bottom was stirred up at intake by tugboat. Probably many organisms missed.

Table 15. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), November 13-14, 1975. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bongo sampler using 202 Nitex nets.

| Taxon | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | D | I | D | I | D | I | D | I | D | I | D |
| Mollusca | | | | | | | | | | | | |
| bivalves | 0.2 | | | | | | | | | | 0.3 | 3.5 |
| gastropods | | | | 0.1 | 1.4 | 3.0 | 3.9 | | 7.9 | 0.3 | 2.9 | 2.6 |
| Polychaetes | | 0.9 | | 0.1 | | 0.5 | 0.4 | 1.2 | | | 0.7 | 1.3 |
| Crustacea | | | | | | | | | | | | |
| Ostracoda | | | | | | 0.5 | | | | 0.3 | | |
| Cladocera | | | | | | | | | | | | |
| *Bosmina longirostris* | | | | | | | | | 1.3 | | 0.3 | 0.4 |
| Chydoridae | | | | | | | | | | | 1.7 | 1.3 |
| Copepoda | | | | | | | | | | | | |
| *Acartia tonsa* | 12 | 69 | 2.9 | 5.3 | 34 | 52 | 37 | 42 | 122 | 28 | 83 | 33 |
| *Eurytemora affinis* | 16 | 25 | 4.5 | 9.8 | 20 | 38 | 12 | 9.2 | 146 | 66 | 41 | 31 |
| *Labidocera aestiva* | 0.5 | 0.5 | | | | | | | | | | |
| cyclopoids | | 1.4 | | 0.1 | 0.9 | 3.3 | 4.3 | 1.0 | 13 | 10 | 4.9 | 3.0 |
| harpacticoids | 0.5 | 0.5 | 0.3 | | 0.3 | 1.9 | 0.5 | 0.2 | 0.4 | 0.2 | 0.8 | 0.9 |
| Amphipoda | 0.5 | 24 | 0.8 | 7.1 | 3.1 | 17 | 3.07 | 20 | 1.1 | 9.5 | 0.5 | 4.3 |
| Mysidacea | | | | | | | | | | | | |
| *Mysidopsis bigelowi* | | 1.8 | | | 0.2 | 0.9 | 0.1 | | | 0.3 | | |
| *Neomysis americana* | | | | | | | | 0.2 | 1.3 | 0.3 | 0.3 | 0.4 |
| Arachnida (Acari) | | | | | 0.2 | | 0.1 | | 0.2 | 0.3 | | 0.4 |
| Pisces | | | | | | | | | | | | |
| *Micropogon undulatus* | | | | | | | | | | | | 0.4 |

Table 16. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), December 9-10, 1975. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bongo sampler using 202 Nitex nets.

| | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | I | D | I | D | I | D | I | D | I | D | I | D |
| Mollusca | | | | | | | | | | | | |
| bivalve | | | | | | | | 0.2 | | | | |
| gastropods | 0.2 | | | 0.5 | 0.3 | 0.4 | 0.1 | | 0.3 | 0.4 | | |
| Polychaeta | 24 | 49 | | 8.0 | 27 | 5.4 | 3.7 | 5.2 | 186 | 10 | 35 | 5.5 |
| Crustacea | | | | | | | | | | | | |
| Copepoda | | | | | | | | | | | | |
| *Eurytemora affinis* | 21 | 21 | | 17 | 104 | 66 | 78 | 98 | 65 | 39 | 18 | 30 |
| *Acartia tonsa* | 10 | 14 | | 12 | 37 | 28 | 7.6 | 19 | 57 | 36 | 29 | 28 |
| *Pseudodiaptomus coronatus* | | | | | 0.3 | | | | 0.3 | | 0.6 | 1.1 |
| cyclopoids | | | | | 1.2 | 1.3 | | | | 0.9 | | |
| harpacticoids | | | | 0.5 | 4.7 | 1.7 | 0.3 | 0.6 | 1.1 | 0.5 | 0.6 | 0.5 |
| Amphipoda | | 0.6 | jar broken | 0.5 | 2.8 | 5.4 | 1.6 | 2.9 | 1.1 | 3.9 | 0.2 | 1.6 |
| Isopoda | | | | | | | 0.1 | 0.2 | | | | |
| Mysidacea | | | | | | | | | | | | |
| *Mysidopsis bigelowi* | | | | | 0.1 | | | | | | | |
| *Neomysis americana* | | | | | | 0.4 | 0.4 | 0.8 | 1.1 | 4.6 | 0.3 | 0.7 |
| Arachnida (Acari) | | | | | 0.3 | | 0.1 | | | 0.2 | | |
| Pisces | | | | | | | | | | | | |
| Fish larvae | | | | | | | | | | | | |
| *Micropogon undulatus* | | | | | 0.2 | | | | | 0.2 | | |
| Fish eggs | | | | | | | | 0.2 | | | | |

Table 17. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), January 14-15, 1976. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bongo sampler using 202 Nitex nets.

| | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | I | D | I | D | I | D | I | D | I | D | I | D |
| Annelida | | | | | | | | | | | | |
| polychaetes | 14 | 32 | 5.3 | 15 | 10 | 28 | 9.2 | 6.3 | 5.5 | 4.1 | 2.7 | 8.6 |
| Crustacea | | | | | | | | | | | | |
| Cladocera | | | | | | | | | | | | |
| *Bosmina longirostris* | 51 | 1.5 | 167 | 220 | 47 | 111 | 45 | 88 | 108 | 133 | 56 | 242 |
| *Daphnia* sp. | 1.3 | 7.4 | 2.7 | 3.1 | 1.3 | 9.8 | | | | 2.0 | | |
| *D. ambigua* | 1.3 | 5.9 | 4.7 | 9.2 | 2.7 | 7.0 | 5.3 | 3.6 | 2.2 | 6.1 | 6.7 | 13 |
| *D. parvula* | | 1.5 | 4.0 | 6.1 | 3.3 | 2.8 | 2.7 | 1.5 | 1.1 | 6.1 | 4.0 | 17 |
| *Chydorus sphaericus* | | | 2.7 | | 4.7 | 2.8 | | 1.0 | | | 2.7 | 4.3 |
| *Ceriodaphnia* | | 2.9 | 0.7 | | | | | | | | | |
| *Macrothrix laticornis* | 1.3 | | | 3.1 | | | | | | | | |
| *Simocephalus* sp. | | | 0.7 | | | | | | 1.1 | | | |
| *Leydigia quadrangularis* | | | | | 1.3 | | | | 1.1 | | | |
| *L. acanthocercoides* | | | | | | | | | | | 1.3 | |
| *Pleuroxus denticulatus* | | | | | 0.7 | | | 0.5 | | | | |
| *Alonella* sp. | | | | | | | | | | | 1.3 | |
| Copepoda | | | | | | | | | | | | |
| *Eurytemora affinis* | 441 | 560 | 928 | 1,105 | 725 | 2,126 | 496 | 498 | 4,442 | 3,233 | 731 | 1,436 |
| *Acartia tonsa* | 13 | 49 | 13 | 20 | 5.3 | 20 | 13 | 9.1 | 26 | 16 | 9.3 | 4.3 |
| *Diaptomus* sp. | 9.3 | 10 | 37 | 49 | 11 | 28 | 6.7 | 10 | 52 | 8.2 | 5.3 | 22 |
| cyclopoids | 21 | 28 | 75 | 49 | 56 | 95 | 8.0 | 18 | 44 | 41 | 48 | 61 |
| harpacticoids | | 2.9 | 2.7 | 3.1 | 8.0 | 2.8 | | | | 8.2 | | 2.2 |
| Amphipoda | | | | 0.8 | | 4.2 | | 0.8 | 1.1 | 0.8 | 0.3 | |
| Mysidacea | | | | 0.4 | 0.2 | | 0.3 | 0.5 | 0.1 | | 0.2 | |
| Pisces | | | | | | | | | | | | |
| *Anguilla rostrata* | | | | | | | 0.2 | | | | | |
| *Brevoortia tyrannus* | | | | | | | | 0.3 | | | | |

Table 18. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), February 12-13, 1976. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bungo sampler using 202 Nitex nets.

| Taxon | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | D | I | DD | I | D | I | D | I | D | I | D |
| Cnidaria | | | | | | | | | | | | |
| medusae | 9.0 | | | | | | 2.8 | | | | | |
| hydroids | | | 4.8 | | | | | | | | | |
| Mollusca | | | | | | | | | | | | |
| Bivalvia | | | | | | | | 0.2 | | | | |
| Gastropoda | | | | | | | | 0.2 | | | | |
| Annelida | | | | | | | | | | | | |
| Polychaeta | 1.5 | 1.2 | 0.9 | 0.2 | 1.8 | 0.6 | 2.5 | 2.3 | 1.5 | 2.3 | 1.4 | 3.1 |
| Hirudinea | | | | | | | 0.3 | | | | | |
| Crustacea | | | | | | | | | | | | |
| Cirripedia | | | | | | | | | | | | 3.7 |
| Copepoda | | | | | | | | | | | | |
| *Eurytemora affinis* | 505 | 409 | 3926 | 1515 | 1478 | 1002 | 505 | 631 | 3674 | 1432 | 892 | 1116 |
| *Acartia tonsa* | 9.0 | 14 | 9.6 | 3.0 | 13 | 6.5 | 12.4 | 3.6 | 4.0 | 4.5 | 12 | 21 |
| *Pseudodiaptomus coronatus* | | 3.2 | | 3.0 | | | | | | | | |
| *Diaptomus* sp. | 18 | 32 | 19 | 6.1 | | 6.5 | 20 | 15 | 7.9 | 4.5 | 18 | 21 |
| cyclopoids | 18 | 9.6 | 67 | 33 | 58 | 45 | 20 | 29 | 134 | 45 | 92 | 105 |
| harpacticoids | | | | | 13 | | | | 7.9 | | 6.2 | 3.5 |
| Cladocera | | | | | | | | | | | | |
| *Daphnia ambigua* | 6.0 | 4.8 | | 4.6 | 13 | 6.5 | 5.0 | 6.4 | 7.9 | 9.1 | 18 | 26 |
| *Daphnia parvula* | 1.5 | | | 3.0 | 13 | | 0.6 | 0.9 | | | | 8.8 |
| *Daphnia* sp. | | | | 1.5 | | 3.2 | 2.5 | 0.9 | | | 25 | 1.8 |
| *Ceriodaphnia* sp. | | 1.6 | | | | | | | | | | |
| *Bosmina longirostris* | 165 | 172 | 96 | 80 | 410 | 71 | 111 | 154 | 284 | 195 | 166 | 207 |
| *Chydorus sphaericus* | 3.0 | 6.4 | | 4.6 | 6.4 | 3.2 | 1.9 | 1.8 | | 6.8 | 25 | |
| *Leydigia quadrangularis* | 0.8 | | | | | | | | | | | |
| *Leydigia acanthocercoides* | | | | | | | | | | 2.3 | | |
| *Alona* sp. | | | | | | | 0.6 | | | 4.5 | | |
| *Alonella* sp. | | | | 3.0 | 13 | 6.5 | | | | 2.3 | 6.2 | |

Table 18 (continued)

| Taxon | 1000 I | 1000 D | 1400 I | 1400 D | 1800 I | 1800 D | 2200 I | 2200 D | 0200 I | 0200 D | 0600 I | 0600 D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crustacea (continued) | | | | | | | | | | | | |
| Amphipoda | | 0,2 | 4,8 | 3,0 | 0,2 | 0,2 | | 0,5 | 0,1 | 0,3 | 0.2 | 0.4 |
| Mysidacea | | | 4,8 | | 0,2 | | | 0,5 | 0,1 | 0.6 | 0.2 | 0,7 |
| Aracnnida | | | | | | | | | | | | |
| Acarina | | | | | | 3,2 | | | | | | |
| Pisces | | | | | | | | | | | | |
| *Anguilla rostrata* | | | | | | | | | | | | |
| *Anchoa mitchilli* | | | | | | | | 0,2 | | | 0,2 | |
| *Micropogon undulatus* | | | | | | | 0,2 | | | | | |

Table 19. Identity and abundance of zooplankters at the Surry nuclear power plant (VEPCO), March 16-17, 1976. Numbers per cubic meter at the intake (I) and discharge (D) based on stepped oblique tows with an 8" bongo sampler using 202 Nitex nets.

| | 1000 | | 1400 | | 1800 | | 2200 | | 0200 | | 0600 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxon | I | D | I | D | I | D | I | D | I | D | I | D |
| Cnidaria | | | | | | | | | | | | |
| hydroids | | 0.2 | | | | | | | | | | |
| Mollusca | | | | | | | | | | | | |
| bivalves | | 0.6 | | 0.3 | | | | | | | | |
| gastropods | 0.8 | 4.8 | 0.4 | 6.1 | 0.2 | | 6.2 | | 0.3 | 2.8 | | 0.2 |
| Annelida | | | | | | | | | | | | |
| polychaetes | | 0.2 | 0.9 | 0.8 | 1.3 | | 32 | | 0.9 | 4.9 | 0.3 | 0.2 |
| Crustacea | | | | | | | | | | | | |
| Cirripedia | | | 0.2 | 0.3 | | | | | | | | 0.4 |
| Copepoda | | | | | | | | | | | | |
| *Eurytemora affinis* | 14 | 12 | 20 | 27 | 37 | | 60 | | 39 | 48 | 70 | 38 |
| *Acartia tonsa* | 0.8 | | 0.2 | 0.3 | 0.4 | | 1.4 | | 0.3 | 0.6 | | 0.2 |
| *Centropages typicus* | | | 0.2 | | | | | | | | | |
| *Diaptomus* sp. | | | | | 0.2 | | | | | 0.2 | | |
| cyclopoids | 2.7 | 0.8 | 2.8 | 0.8 | 10 | | 6.1 | | 8.5 | 3.7 | 15 | 11 |
| harpacticoids | 0.4 | 0.6 | 0.7 | 0.3 | 1.1 | | 16 | | 2.1 | 2.1 | 2.4 | 1.6 |
| Cladocera | | | | | | | | | | | | |
| *Chydorus sphaericus* | | | | | | | | | | | 0.3 | |
| *Leydigia quadrangularis* | | | | | | | | | 0.3 | | | |
| *Alona* sp. | | | 0.2 | | | | | | | | 0.3 | 0.2 |
| *Bosmina longirostris* | | | | | | | | | | | 0.3 | |
| Ostracoda | | | | 0.8 | | | | | 0.3 | | | 0.7 |
| Amphipoda | 0.2 | 3.5 | 3.3 | 2.5 | 5.2 | | 7.4 | | 3.9 | 6.7 | 4.8 | 4.0 |
| Mysidacea | | 0.2 | 0.2 | 0.8 | 0.9 | | 1.2 | | 0.9 | 0.6 | 0.3 | 0.2 |
| Arachnida | | | | | | | | | | | | |
| Acarina | 0.2 | | | 0.3 | | | | | | 0.3 | | |
| Insecta | | 0.2 | | | | | | | | | | |

Table 19 (continued)

| Taxon | 1000 I | 1000 D | 1400 I | 1400 D | 1800 I | 1800 D | 2200 I | 2200 D | 0200 I | 0200 D | 0600 I | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pisces | | | | | | | | | | | | |
| *Anchoa mitchilli* | | 0.2 | | | 0.2 | | | | | | | |
| *Brevoortia tyrannus* | | | | | | | | | | | 0.3 | |
| *Leiostomus xanthurus* | | | | 0.3 | | | | | | 0.2 | | |
| fish eggs | | 1.2 | | 1.1 | | | | | | 3.7 | | 0 |

the period January - May.

Freshwater cladocerans, such as the Bosminidae and Chydoridae were especially numerous in winter and spring months, but were replaced by Diaphanosoma brachyurum in June and July. None were found in August and September or December and few in October and November. As many as eleven species occurred in January 1976, the most diverse appearance of freshwater cladocerans. Marine cladocerans occurred but rarely, in June 1975.

Amphipods were present year round and especially abundant during the warmer months. They were consistently and significantly more abundant in the discharge canal than at the intake. Populations must, therefore, be resident in either the intake canal or in the discharge canal itself.

Decapod larvae were restricted to the warmer months, with zoea of the mud crab, Rhithropanopeus harrisii, appearing most abundantly from May through September. Larvae of the glass shrimp, Palaemonetes sp. occurred frequently from June - September. Less abundant were zoeal stages of the fiddler crab, Uca sp; the sand shrimp, Crangon septemspinosa; and the shore crab, Sesarma sp. All of these meroplanktonic forms were absent from October through April.

The final crustacean group of any importance was the barnacle larvae, appearing rarely in spring months and increasing to abundance in July, August and September. These declined to trace levels in October and were absent from November through February.

Gastropods were abundant in July. They were very abundant at one August station and not found at others. This could be due to extreme patchiness, the sampler coming closer to the bottom at that station or to bias due to different persons sorting the samples. These gastropods are larvae that are small in size and adhere readily to detritus particles. Only a few gastropods were found at one station in September. Subsequently, they formed a small but consistent portion of the plankton.

Fish larvae, though never abundant in our catches with the small 8" bongos, occurred in every month of the year. Eggs and larvae of the bay anchovy, Anchoa mitchilli, appeared from June through October. Adults occurred in February and March collections, as well. The Atlantic menhaden, Brevoortia tyrannus, occurred irregularly in winter and spring collections of January, March and April. Larval gizzard shad, Dorosoma cepedianum, and some unknown freshwater fish larvae occurred in May 1975. Naked goby larvae, Gobiosoma bosci, occurred in summer months, June - September, paralleling the distribution of bay anchovy, another forage fish. The Atlantic croaker occurred rarely as early as August, but more frequently in fall and winter months, October - December, and February. Other fishes included elvers of the American eel, Anguilla rostrata, in January and February; the silverside, Menidia sp, in September; and the spot, Leiostomus xanthurus, in March.

Mysids occurring in entrained waters at the Surry plant were of two species, Neomysis americana and Mysidopsis bigelowi. The former occurred year-round, while the latter was restricted mostly to fall months.

Other zooplankton groups of lesser importance included hydroids apparently swept from the bottom as well as medusoid stages of hydrozoans. Ctenophores did not occur in the plant's cooling waters, which were apparently fresher than the salinity tolerance range for this group. Bivalve larvae were rare, occurring sparsely in all months except April, August and January. Portions of adult polychaetes and numerous larvae of sabellid polychaetes occurred in the collections, most abundantly in December and January. Other forms uncluded leeches, ostracods, adult and larval insects (including Chaoborus sp.), and water mites.

## Estimated Survival of Zooplankton after Plant Passage

Preliminary estimates of survival after entrainment have been calculated by three methods: 1) differentiation of stained and unstained organisms, using the vital stain neutral red, 2) the technique of Marcy (1971) where the number of living organisms per cubic meter are determined, and those in the discharge are divided by those in the intake to give percent survival and 3) the method of Davies and Jensen (1974), also based on live counts, that corrects for dead organisms in the intake in calculating a corrected percent motility. Problems in staining stemming from interference by detritus and specific differences in uptake have been treated earlier in this report. Calculation of percent survival, following Marcy (1971), assumes that total dead plus live organisms in the intake and discharge are equal in density, theoretically not an unreasonable assumption, but in practice not one that we have been able to demonstrate. With estimates of abundance consistently higher in the intake, our calculations of percent survival are usually quite low, even though visual examination of discharge collections show few dead (intact) zooplankton. We, therefore, discontinued estimates by this method after preliminary trials. The final method (Davies and Jensen 1974) yields much higher percent survival estimates, but does so by ignoring absolute numbers per cubic meter, if these in fact are decreased through plant passage.

The various estimates are compared in Table 20. The correction applied by Davies and Jensen (1974) to their percent motility data to account for dead organisms at the intake has been utilized in our estimates for staining. The percent stained in discharge samples was divided by the percent stained in intake samples and multiplied by 100. Percentages less than 100 should indicate entrainment mortality; the lower the corrected percent stained, the greater the entrainment effect. Corrected percentages greater than 100 (which quite frequently occur) probably result from changes

Table 20. Estimates of zooplankton survival after plant passage at the Surry nuclear power plant, James River, Virginia, April 1975 - March 1976. Based on paired collections at the intake forebay and discharge canal.

| Month | Staining Corrected % Stained | | Marcy Method % Survival | Davies & Jensen Method Corrected by Motility |
|---|---|---|---|---|
| (1975-1976) | Total Zoopl. | Calanoid Copepods | Total Zoopl. | Total Zoopl. |
| April | 86.7 | 112.8 | No Estimates | No Estimates |
| | -stain failure- | | " | " |
| | 0 | 0 | " | " |
| | 216.5 | 140.8 | " | " |
| | 102.4 | 92.6 | " | " |
| May | 122.2 | 106.7 | 37.4 | 97.3 |
| | 122.7 | 94.1 | 79.6 | 94.8 |
| | 80.5 | 91.4 | 48.3 | 100.9 |
| | 142.0 | 127.1 | - | - |
| | 99.6 | 102.0 | - | - |
| | 140.0 | 98.2 | - | - |
| June | 95.1 | | 26.4 | 92.1 |
| | 20.3 | 19.6 | 17.1 | 93.2 |
| | 59.4 | 87.8 | 220.8 | 99.4 |
| | 76.6 | | - | - |
| | 69.8 | 76.3 | - | - |
| July | 55.3 | 77.9 | | 95.9 |
| | 4.4 | 7.4 | | 94.6 |
| | 1.0 | 1.9 | | 114.5 |
| | 68.9 | 102.7 | | - |
| | 90.8 | 97.8 | | - |
| | 97.8 | 94.7 | | - |
| August | 0 | 0 | (discontinued) | 91.7 |
| | -stain failure- | | | not preserved |
| | - " | " - | | 87.6 |
| | 90.9 | 84.2 | | - |
| | 471 | 12.4 | | - |
| | 98.2 | 97.1 | | - |
| September | 134.4 | 143.5 | | 88.9 |
| | 91.2 | 86.2 | | 98.6 |
| | 48.2 | 32.6 | | 98.1 |
| | 76.5 | 80.7 | | - |
| | 75.9 | 99.6 | | - |
| | 27.1 | 32.7 | | - |

Table 20 (continued)

| Month | Staining Corrected % Stained | | Marcy Method % Survival | Davies & Jensen Method Corrected by Motility |
|---|---|---|---|---|
| (1975-1976) | Total Zoopl. | Calanoid Copepods | Total Zoopl. | Total Zoopl. |
| October | 124.6 | 121.3 | | Samples choked |
| | 19.7 | 29.6 | | with detritus, |
| | 0 | 0 | (uptake by detritus?) | preventing counts |
| | 19.5 | 18.3 | | |
| | - | - | | - |
| | 115.2 | 107.1 | | - |
| November | 76.7 | 88.6 | DISCONTINUED | 102.4 |
| | 95.4 | 89.3 | | 130.1 |
| | 72.4 | 82.0 | | 99.8 |
| | 92.9 | 98.1 | | - |
| | 96.9 | 92.9 | | - |
| | 107.7 | 121.1 | | - |
| December | 93.4 | 88.0 | | 102.7 |
| | 91.4 | 92.3 | | Sample lost |
| | 59.7 | 65.3 | | 86.3 |
| | 84.4 | 84.9 | | - |
| | 83.4 | 79.4 | | - |
| | 82.1 | - | | - |
| January | 91.5 | 96.2 | | 94.9 |
| | 133.2 | 115.6 | | 98.6 |
| | 103.2 | 97.6 | | 99.8 |
| | 101.4 | 99.8 | | - |
| | 94.4 | 95.5 | | - |
| | 98.5 | 98.2 | | - |
| February | 96.6 | 99.3 | | 99.1 |
| | 88.8 | 89.4 | | 97.5 |
| | 99.8 | 100.6 | | 99.1 |
| | 108.5 | 100.1 | | - |
| | -stain failure- | | | - |
| | 111.0 | 102.3 | | - |
| March | 77.8 | 93.6 | | 104.3 |
| | 121.2 | 102.0 | | 93.1 |
| | No discharge samples (weather) | | | -no count- |
| | " " | " | " | - |
| | -stain failure- | | | - |
| | - " | " - | | - |

in composition and abundance between intake and discharge paired samples or occasionally from relative inefficiency of staining at the intake. Their occurrence seriously questions the reliability of the method.

Our method for staining organisms, i.e. one hour of exposure to a 1:100,000 concentration, cannot be followed during the summer months. During the hour of staining, mortality of the concentrated organisms being stained occurs rapidly. Many of these collections show evidence of decomposition within the hour. Reliance may have to be shifted to a rapid live count during warm weather. Both staining and live counts are hampered by the presence of large amounts of detritus as occurred during our October sampling.

Although our various estimates of survival were highly variable, an overview of Table 20 indicates that little mortality occurred through most of the year. The Davies and Jensen method applied to our data for total zooplankton suggests upwards of 12% mortality during summer months, and considerably less during cold months.

## CONCLUSIONS

1. The numerically dominant zooplankters in the intake waters of the Surry plant were the calanoid copepods throughout the year. The dominant species, *Eurytemora affinis* and *Acartia tonsa*, alternate seasonally, with *E. affinis* dominant in cooler

months and replaced by _A. tonsa_ in the summer.

2. The fauna at this location was characterized by a fresh-water complement of species, especially cladocerans, during the winter and spring months, when runoff reduced the salinity.

3. Diurnal differences in composition of the fauna were slight in both intake and discharge locations, probably a result of the shallowness of waters surrounding the intake forebay and turbulent conditions in the discharge canal.

4. An apparent reduction in the abundance of copepods from intake to discharge was evident during the first several months of sampling, but not in later sampling. Certain organisms, especially amphipods, were definitely more abundant in the discharge canal than in the intake forebay. Other intake-discharge differences beyond the variability attributable to sampling were difficult to detect.

5. Survival of entrained zooplankton, at least the most dominant forms, was apparently high throughout the year. Combined results from vital staining and live counts indicated a probable maximum of 12% mortality during summer months, and virtually none in winter months.

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