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Mesozooplankton Distribution and Abundance in the Pagan River: a Nutrient Enriched Subestuary of the James River, Virginia

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ABSTRACT

The mesozooplankton in the Pagan River was dominated by calanoid copepods, with abundance peaks occurring during late winter-early spring and from late summer into early fall. This included spring, summer, and fall abundance maxima. The total mean abundance of the mesozooplankton was $3,008/m^3$.

INTRODUCTION

The Pagan River is a tributary of the James River and bisects the town of Smithfield in southeastern Virginia. During this period of study the river had been identified as a nutrient enriched river due to nutrient entry from point and non-point sources (VSWCB, 1990; LJRA, 1988; Seaborn, 1997). Early water quality studies within the Pagan River are reviewed by Davis (1994), with additional relationships to phytoplankton and autotrophic picoplankton given by Seaborn (1997) and Davis et al. (1997). Point sources have included waste water from meat packing plants in Smithfield, with non-point nutrient sources coming from agricultural, urban, and open woodland runoff (LJRA,1988, VSWCB, 1990). The discharge of enriched waters has been linked to increased biochemical oxygen demand (BOD), decreased dissolved oxygen (DO), pH changes, and increased suspended solids (TSS) in the receiving waters (Alden *et al.*, 1992).

The objective of this study was to identify the seasonal composition and abundance of the mesozooplankton community in the Pagan River. This study compliments other recent work within the Pagan River describing picoplankton and phytoplankton dynamics by Davis et al. (1997) and Seaborn (1997).

METHODS

Monthly mesozooplankton collections were made from October 1992 through September 1994 at four stations (PGN series) within the Pagan River (Figure 1). Two 0.5 m diameter bongo frames, fitted with 202-micron mesh nets, each 4 m long, were used for collecting two replicate samples. Both nets were equipped with flow meters (General Oceanics Model No. B10964) centrally attached within the net to estimate the volume of water during each tow. Nets were towed in an oblique pattern from the surface to approximately 2 m, and back to the surface for four minutes. The faunal collection from the cod-end canisters were transferred to 1 liter collection bottles and preserved with 7% formaldehyde. When gelatinous zooplankters became excessive, they were removed from the samples by sieving and an estimation was made of the major gelatinous groups (e.g. ctenophores, scyphozoas) with their percent compositions determined and recorded.

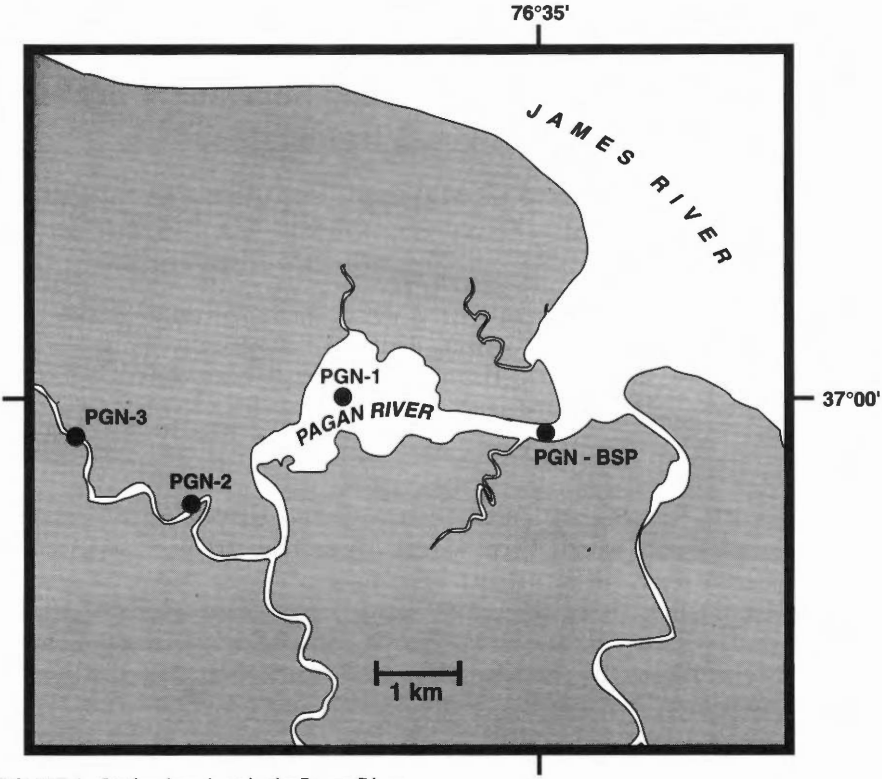

FIGURE 1. Station locations in the Pagan River.

Replicate samples from each tow were analyzed separately and the results averaged. Zooplankton processing and analysis were done using the coefficient of variation stabilizing (CVS) method of Alden *et al.* (1982). The CVS method involves sample fractionization into five size classes, namely those retained by sieves of 2000, 850, 600, 300 and 200 μm mesh size. Size classes in which the organisms were too numerous to count were split with a Folsom splitter until an appropriate sample size for statistical validity of the dominant species was reached (Davis, 1994). The chosen level of a sampling error of 30% requires that each species of interest be available within a range of 30 to 56 individuals in a sample.

Water quality information on total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and silicon were obtained from the Virginia Department of Environmental Quality and represent average values between February 1988 and September 1994. Salinity, temperature, and dissolved oxygen readings were determined at each station during collection using a Hydrolab Surveyor II unit, in addition to determining secchi depths.

Data Analysis

Stations and collection times were classified into spatial groups using log-transformed abundance data. The variance between sites was obtained by calculating the Euclidean distance between sites (over all species) after these were centered to their

TABLE 1. Mean water quality measurements for stations in the Pagan River.

Parameter	BGN-BSP	PGN- 1	PGN- 2	PGN- 3
TP (mg/L)	0.2	0.30	0.85	0.90
TN (mg/L)	0.70	0.08	1.80	2.25
Oxygen (mg/L)	9.23	9.54	9.16	9.29
TSS (mg/L)	12,000	12,100	8,100	5,000
Salinity (ppt)	10.4	9.9	6.0	4.4
Silicon (mg/L)	4.8	5.1	5.2	5.0
Secchi (m)	0.5	0.5	0.5	0.4

respective means. The variance estimates were then used as a measure of dissimilarity for cluster analysis to determine the spatial groups (Williams and Stephenson, 1973). A flexible sorting strategy was used with a cluster intensity coefficient of -0.25 (Boesch, 1977). The mean variance between sites (over all times) was determined by calculating the variance attributable to the species over all inter-site comparisons, and then finding the mean of these values. The means were examined to determine the relative importance the sites had on the variation in the data (Williams and Stephenson, 1973).

Multivariate analysis of variance (MANOVA) was used to identify significant differences in centroids between spatial groups. Discriminant analysis was used to determine which species were most responsible for any separation between site groups. Plots of site groups of the major discriminant functions were used to display separation. Those species with high loadings and significant ANOVA were used as axis labels for the discriminant functions.

A second discriminant analysis was conducted using water quality variables. Plots of site groups and the environmental variables in discriminant space were compared to determine if separation between site groups was influenced by the environmental parameters (Green, 1979).

RESULTS

There was considerable range of salinity at these stations (0.0 to19.55 *ppt),* with mean station values between 4.4 ppt and 10.4 ppt (Table 1.). Lowest mean salinity values were associated with the upriver stations (PGN-2, PGN-3). Water temperatures at the four stations were generally similar, ranging from February lows (3.3°C) to highest readings in July (29.6°C). The mean concentrations for total nitrogen and total phosphorus decreased downstream with lowest values at PGN-BSP. Total suspended solids increased downstream and silicon values were relatively constant at all stations. No extensive periods of low oxygen were noted from this upper section of the water column, however, there were summer collection dates at PGN 2 and PGN-3 when values below 4.0 mg^{-1} were noted (i.e. 2.42 mg^{-1} July 1994 at PGN- 2). Mean Secchi depths were low (0.4-0.5 m) throughout the river, ranging from 0.2 to 0.8 meters.

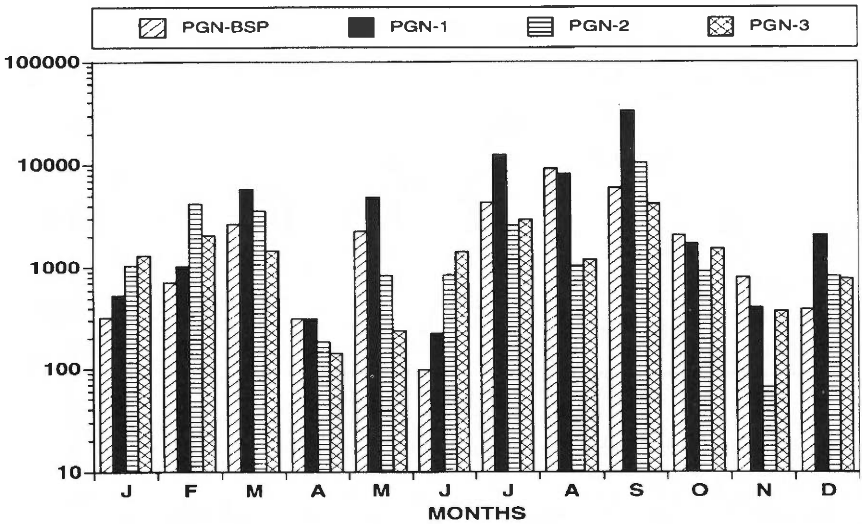

FIGURE 2. Mean monthly mesozooplankton concentrations (no. m^{-3}) at the four Pagan River stations October 1992 through September 1994.

There were 100 mesozooplankton taxons identified in the study and these included a variety of holoplanktonic and meroplanktonic components from invertebrate and fish larvae categories (Davis, 1994). The mesozooplankton abundance varied with season at the four stations, forming abundance peaks during late winter-early spring and from late summer into early fall (Figure 2).

However, there were different patterns noted both seasonally and yearly at different stations (Figures 3, 4). In general, there was a decrease in mesozooplankton abundance after the spring and fall pulse (April and November). Concentrations following the fall low gradually increased through winter into spring to form the spring pulse.

The total mean mesozooplankton abundance for the Pagan River stations was 3,008/m^3. Of this amount, 80% (2,411/m^3) were calanoid copepods (Figure 5). Among these calanoid copepods, 78% (1,882/m^3) were represented by *Acartia* spp., in addition to 17% *Eurytemora affinis*, 0.8% *Diaptomus* spp., and 0.9% *Pseudodiaptomus coronatus*. Also in this category, but in much smaller numbers were *Eurytemora americana, Labidocera aestiva* and several unidentified copepods. Calanoid copepods concentrations represented much of the seasonal pattern of total mesozooplantkon abundance and biomass. Their greatest numbers occurred in late winter and early spring (Feb-Mar), and late summer to fall (July-Sept). A similar dominance pattern by calanoid copepods is noted by Burrell (1972), Thayer *et al.* (1974), and Henle (1966).

The *Acartia* spp. (including *A. hudsonica, A. tonsa*) were most abundant in late spring, and from mid-summer to mid-fall, being mainly responsible for the summer-fall pulse (Figure 6). Their concentrations decreased into winter and spring, with lowest counts in April. *Eurytemora affinis* replaced *Acartia* spp. from December into May as the dominant species (Figure 7) This species was primarily responsible for the spring mesozooplankton increase in abundance. *Eurytemora affinis* was not common

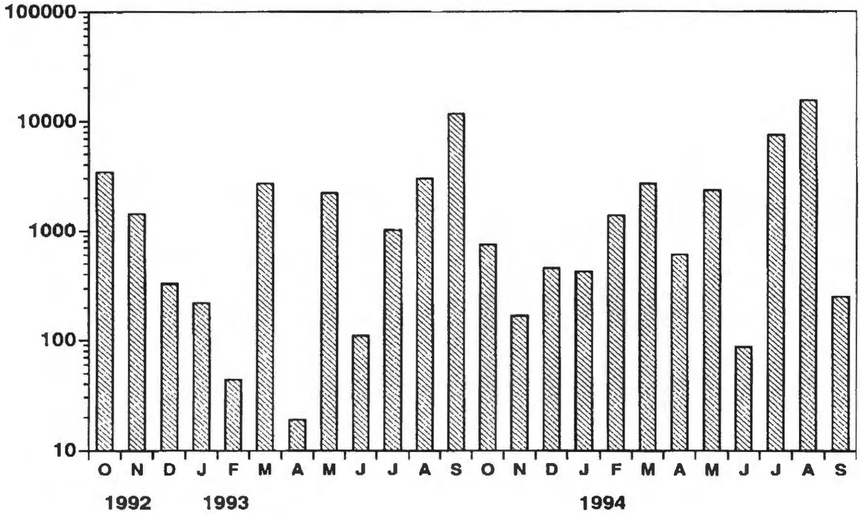

FIGURE 3. Monthly mesozooplankton concentrations (no. m^{-3}) at Station PGN-BSP.

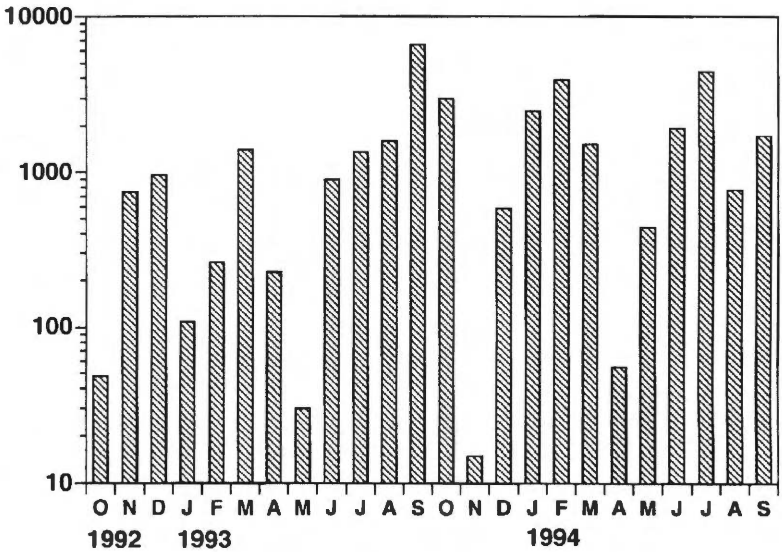

FIGURE 4. Monthly mesozooplankton concentrations (no. m^{-3}) at Station PGN-3.

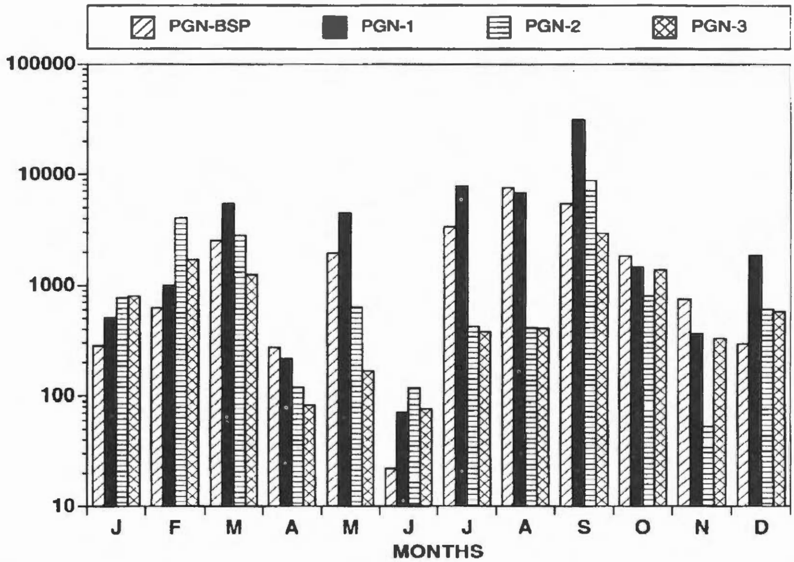

FIGURE 5. Monthly mesozooplankton concentrations (no. m^{-3}) of calanoid copepods at the four Pagan River stations. October 1992 through September 1994.

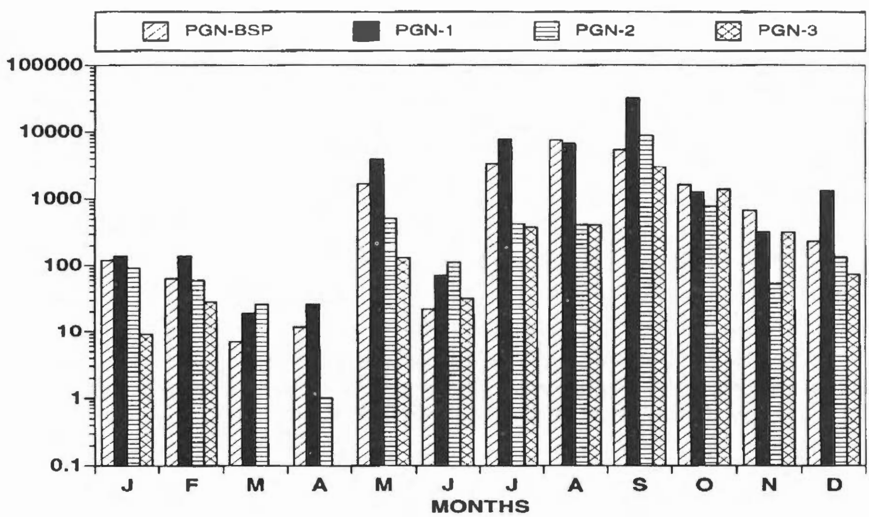

FIGURE 6. Monthly mesozooplankton concentrations (no. m^{-3}) of *Acartia* spp. at the four Pagan River stations, October 1992 through September 1994.

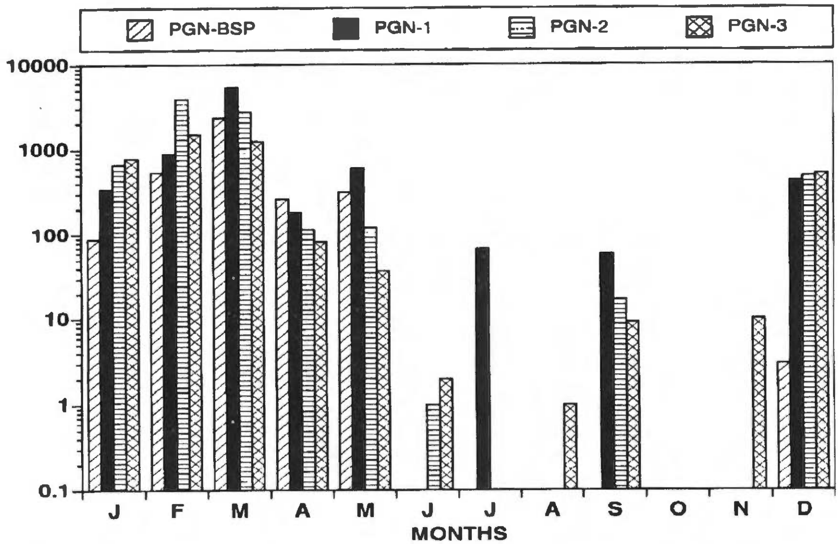

FIGURE 7. Monthly mesozooplankton concentrations (no. m^{-3}) of *Eurytemora affinis* at the four Pagan River stations, October 1992 through September 1994.

during the summer and fall months, but became the dominant copepod in December and remained dominant through winter and spring. This was also a period of lower salinities for the river, which Jeffries (1962 a, b, c) has indicated favors *Eurytemora affinis. Diaptomus* spp. were noted at this time,.being more abundant when the *Acartia spp.* were in decline. In contrast, *Pseudodiaptomus coronatus* was present from late summer into fall, but was rarely found January through May. Their numbers decreased with increased salinity upstream.

The composition of the remaining mesozooplankton consisted of 8% *Uca* zoea, 6% barnacle nauplii, 1% *Harpacticus gracilis,* 0.5% *Polydora ligni* (including trochophores), 0.5% ostracods, 0.3% cyclopoid copepods, 0.3% *Rhithropanopeus harrisii* zoea and 0.2% fish larvae. Barnacle nauplii were found in all 24 months of the study. They increased in abundance May to September and declined from October through February. In February, they were noted only at station PGN-1, but by May they were at all stations. The cypris stage was less common. Cyclopoid copepods were not abundant in the Pagan River, but were found upstream at station PGN-3 October through June, with greatest concentrations in March, and the least in August.

The harpacticoid copepods were not numerous in the Pagan River. The most abundant species was *Harpacticus gracilis.* It occurred almost entirely during winter and spring, being most abundant upstream. Ostracods were in significant numbers ($15.0/m^3$) November through May, with their highest concentrations downstream in March

Decapod crustaceans zoea were noted from late spring through early fall (May-Sept). Zoea of the grass shrimp, *Palaemonetes* spp. were most abundant in June and July, before decreasing into winter. *Uca* zoea were present May through September

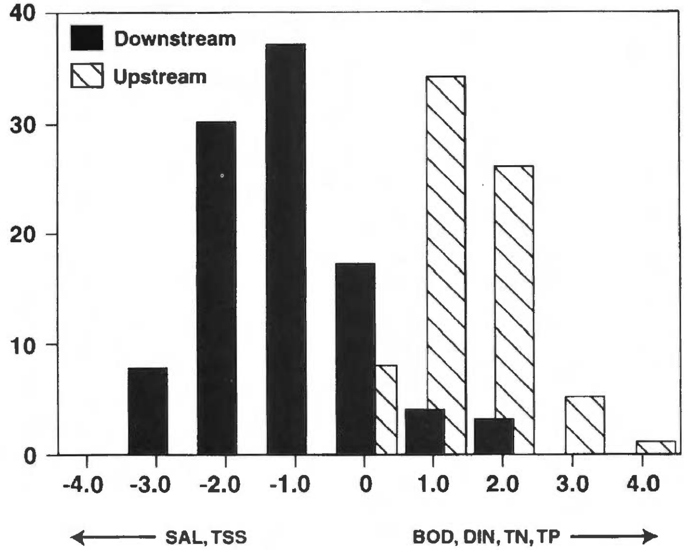

FIGURE 8. Frequency histogram of canonical discriminant scores for surface water quality variables at upstream (PGN-2, PGN-3) and downstream (PRN-1, PGN-BSP) stations. SAL=salinity, TSS=total suspended solids, BOD=biological oxygen demand, DIN=dissolved inorganic nitrogen, TN=total nitrogen, TP=total phosphorus.

and most abundant in July. *Rhithropanopeus harrisii* zoea were also found May through September, but were most abundant in May. Scyphozoa and ctenophores reached their peak abundance downstream in June and July 1993, and August 1994. *Gobiosoma bosci* larvae were the most numerous of 10 species of fish larvae observed in the samples. They were common May through September at all stations, reaching their highest concentrations downstream. *Anchoa mitchilli* larvae were abundant October through September, peaking downstream July through September. *Brevoortia tyrannus* larvae appeared from December through May with peak concentrations in March upstream. Lesser concentrations of the following fish larvae, and the months in which they were found were: *Anchoa hepsetus* (Jan.-Feb.), *Micropogonias undulatus* (Dec.-Mar.), *Menidia beryllina* (May-June, Aug.), *Menidia menidia* (May-Jun., Aug), *Leiostomus xanthurus* (Jan., May), *Trinectes maculatus* (Jul.), and *Elops spp.* (Jun.). Insect larvae, while never abundant, were often common. For instance, larvae of *Pentaneura monilis* and *Chaoborus punctipennis* occurred in winter and spring at all stations. The arachnids, *Hydracarina spp.* were noted in April, May, and June at stations PGN-2 and PGN-3. In April and May they represented 17% of the total mesozooplankton abundance at station PGN-3.

The results of the cluster analysis, based on the different water quality values and mesozooplankton composition, separated the four Pagan River stations, into two groups (Figures 8, 9). The two upstream stations formed one group and the two downstream stations the other. The section of the river containing the two downstream stations (PGN-BSP and PGN-1) was characterized by increased salinity, higher levels of

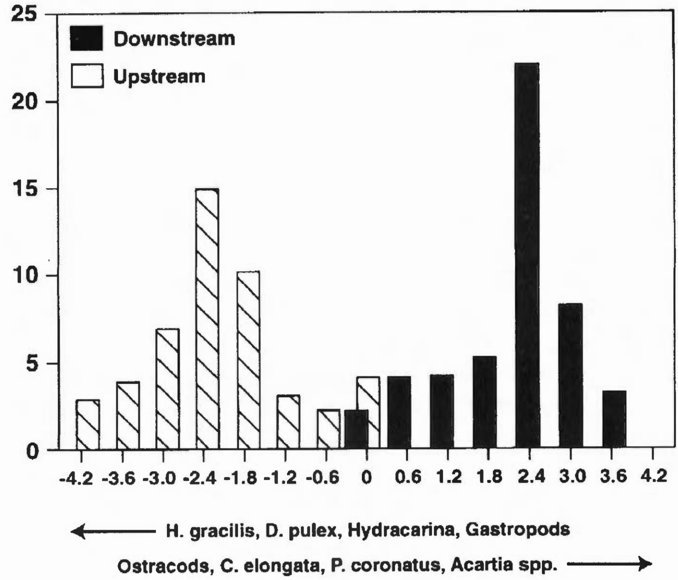

FIGURE 9. Frequency histogram of canonical discriminant scores for mesozooplankton at upstream (PGN-2, PGN-3) and downstream (PGN-1, PGN-BSP) stations.

total suspended solids (TSS), and reduced nutrient levels when compared with the upstream stations (PGN-2 and PGN-3). The upstream stations had higher mean levels of total nitrogen (TN), dissolved inorganic nitrogen (DIN), and total phosphorus (TP), plus a greater biological oxygen demand (BOD) when compared to the downstream stations (Figure 8). Certain fauna were also associated with these different sections of the river. Downstream, *Acartia* spp., *Canuella elongata, Pseudodiaptomus coronatus,* and the ostracods were associated with the water quality and habitat conditions of this river section. This section was more closely associated with the tidal influence of the James River, its higher salinities, and its source of fauna that may enter the Pagan River. In contrast, an abundant, but different assemblage characterized the upstream stations. These included *Harpacticus gracilis*, *Hydracarina* spp., *Daphnia pulex*, and gastropods (Figure 9).

SUMMARY

The mesozooplankton in the Pagan River had two seasonal periods of high abundance that occurred during late winter-early spring and from late summer into early fall. This period is more extensive than the spring and fall maxima reported by other investigators for sites between Virginia and Delaware Bay, where reduced summer concentrations are attributed to ctenophores predation (Burrell, 1972; Burrell and Van Engel, 1976; Mountford, 1980; Cronin et al., 1962). There were ctenophores common to the summer fauna of the Pagan River, but their predation impact was not evident in these monthly mesozooplankton concentrations. Calanoid copepods were the dominant mesozooplankton in the Pagan River, comprising 80% of the total community, and were responsible for the two faunal abundance maxima within the river. They were more abundant at the downstream stations, mainly due to the high percentage of *Acartia* spp. and their preference for higher salinity waters, with a higher percentage of *Eurytemora affinis* located in less saline waters upstream.

The total mean abundance of mesozooplankton for the Pagan River was 3,008/m^3. This amount was somewhat lower than those reported by other authors. Maurer *et al.* (1978) found 4,650/m^3 in Delaware Bay; Alden *et al.* (1992) reported 5,400/m^3 in the York River, 11,500/m^3 in the James River, and 10,000/m^3 in the Rappahannock River; Sage and Herman (1972) recorded 8,500/m^3 in Sandy Hook Bay; Lonsdale and Coull (1977) reported 9,257/m^3 in North Inlet; and Thayer *et al.* (1974) found 4000-8400/m^3 in Beaufort, NC. However, there were summer concentrations in the Pagan that were within several of these density records (Fig. 2).

Seasonal abundance differences occurred in the Pagan River, but appeared to be related to species preferences for different temperatures and/or salinity. For example upstream the spring abundance increase occurred in January and peaked in February while downstream the spring increase occurred in February and peaked in March. This difference was due to an earlier increase in *Eurytemora affinis* in the lower salinity waters of the upstream stations. *Eurytemora affinis* occurred in winter months in association with lower saline mesohaline waters. By January the increase in *E. affinis* had reached the downstream stations but in June, abundance decreased only downstream. This decrease coincided with an overall decrease in calanoid copepods, whereas *Uca* zoea increased in abundance upstream. *Uca* spp. also prefer less saline waters (Crane, 1975). These results infer any effects that may be associated with increased amounts of nutrients upstream are obscured by species preference for particular seasonal or salinity conditions.

In conclusion, there is a diverse and abundant mesozooplankton community in the nutrient rich Pagan River.. This fauna is dominated by a calanoid copepod assemblage that produces seasonal peaks of abundance that are of longer duration, but in the lower range of magnitude in comparison to the mesozooplankton from other regional estuarine habitats. The dominant fauna are also similar to those in other regional estuarine sites.

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