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ZOOPLANKTON OF THE ST. JOHNS RIVER ESTUARY

BY

FREDERICK C. TONE
B.A., Rollins College, 1970

THESIS

Submitted in partial fulfillment of the requirements for the degree of Master of Science: Biological Science in the Graduate Studies program of the College of Natural Sciences of the University of Central Florida at Orlando, Florida

Fall Quarter 1979
Zooplankton populations in the St. Johns River Estuary ranged from 3,000/m$^3$ to 20,000/m$^3$ during monthly collections from September, 1973 to August, 1974. *Acartia tonsa* Dana was the dominant organism throughout the year, except for spring blooms of *Balanus* sp. nauplii in the lower estuary and summer occurrences of *Eubosmina tubins* in the upper estuary. With these two exceptions, species composition, and community structure were similar throughout the estuary, year round. A patchy distribution of the zooplankton caused high replicate sample variation which made it difficult to detect small population variations. Salinity appeared to have the greatest effect on the distribution and abundance of zooplankton within the estuary. Population numbers were sufficiently low to suggest that zooplankton were not the major component of secondary production.
ACKNOWLEDGEMENTS

Thanks go to the Jacksonville Electric Authority for funding the field and laboratory phases of this research through a contract between Reynolds Smith and Hills and Battelle Columbus Laboratories. I also thank my employer, Battelle Columbus Laboratories for providing me with the time and financial aid necessary to complete this research. I thank Dr. David H. Vickers and Dr. I. Jack Stout for their suggestions and review of the manuscript. Finally, I am indebted to Dr. John A. Osborne for his patience, guidance and critical review in preparing this manuscript.
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INTRODUCTION

Estuaries directly contribute to the production of marine populations by serving as the nursery grounds for numerous species of fish and shellfish (Odum, 1971). The estuarine environment is one of transition between marine and fresh water, where frequent and often rapid fluctuations in the physical environment occur. Estuarine species must therefore have broad physical tolerance limits to survive. This is particularly true for planktonic species (Jefferies, 1973).

Estuarine zooplankton can be categorized according to their life cycles as being meroplanktonic or holoplanktonic (Jefferies, 1973). Meroplankton spend part of their life in the plankton and consist largely of larval stages of mollusks, crustaceans and fish. Holoplankton are free-floating throughout their entire life and primarily consist of calanoid copepods. Since meroplankton generally appear in large numbers for short periods of time, it is the holoplankton that usually dominate estuarine zooplankton populations.

Populations of calanoid copepods are primarily regulated by salinity and temperature. The distribution of a species is often defined in terms of its tolerance of salinity and temperature (Gosner, 1971 and Jefferies, 1973). As stated by Jefferies (1973), each species reproduces in a limited salinity range with overlap in distribution along a salinity gradient. Often each range is composed of two congeneric associate species that coexist sympatrically. In
polluted estuaries, one species or species pair may dominate the estuary. Along much of the Atlantic Coast of North America two species of *Acartia* dominate copepod populations. This has been noted in New Haven Harbor, Conn. (Battelle Labs, 1972), Long Island Sound (Deevey, 1956), Delaware River (Cronin, 1962), St. Johns River (Tone, 1973) and Biscayne Bay (Reeve, 1970). In all cases, *Acartia tonsa* Dana and *Acartia clausi* Giesbrecht, either separately or together dominated.

In temperate climates *Acartia tonsa* and *A. clausi* appear to coexist. Competition with *A. clausi* limits *A. tonsa* to salinities below 25 ppt (Jefferies, 1973). In the absence of *A. clausi*, *A. tonsa* is found in salinities above 30 ppt (Bowman, 1971). Temperature greatly influences the range and seasonal distribution of both species. In Long Island Sound, Deevey (1956) found that *Acartia clausi* dominates during winter/spring and *A. tonsa* dominates during summer/fall. In the warmer climates of the Delaware River (Cronin, 1962) and Biscayne Bay (Reeve, 1970), *A. clausi* is absent and *A. tonsa* dominates all year.

The sub-tropical St. Johns River Estuary is of great importance to the commercial fishery of Florida and Georgia, and to the general marine productivity of the region. To date, biological investigations of the zooplankton community have been primarily inventories of organisms (Tone, 1972a, 1972b, and 1973, and Rehm, 1975).
The objectives of this study were: (1) to provide baseline information on the zooplankton populations and diversity in the St. Johns River Estuary, and (2) to determine the effects of salinity and temperature on the distribution of *Acartia tonsa* within the estuary.
DESCRIPTION OF THE STUDY AREA

The St. Johns is the largest river in Florida. From its headwaters near Melbourne, Florida it flows north to Jacksonville, Florida where it turns eastward to Mayport, Florida, flowing into the Atlantic Ocean. The east-west section of the river is the estuarine portion. The upper estuary passes through the heavily industrialized port city of Jacksonville where municipal wastes from sewage treatment facilities and industrial wastes from paper mills, power plants, ship yards, and sea port facilities flow into the river. In contrast, the lower estuary is dominated by a nearly 1,000 ha salt marsh consisting of Spartina alterniflora and Juncus roemerianus grasses (Rehm, 1975). This type of marsh serves as a nursery ground for juvenile fish and shellfish species by providing a protected habitat and supplying abundant food in the form of detritus. In estuaries such as this, salt marsh grasses are the major producer, creating a detritus based food chain in which dead plant matter is broken down by bacteria and fungi and consumed by specialized epibenthic detritovores which support higher trophic level fish species (Odum, 1971).

A productive commercial fishery in the river and near shore is supported by these nursery grounds. Commercial harvests consist of shrimp (Penaeus aztecus and P. setiferus), blue crabs (Callinectes sapidus), menhaden (Brevoortia tyrannus), and mullet (Mugil curema and M. cephalus, and to a lesser extent spot (Leiostomus xanthurus) and bluefish (Pomatomus saltatrix) (Florid Dept. of Natural Resources, 1974).
MATERIALS AND METHODS

The sampling area included a majority of the estuary extending from Blount Island (river mile 8) to the I-95 bridge in Jacksonville (river mile 26) (Figure 1). Two sampling designs were used; one in the lower estuary and one in the upper estuary. The lower estuary was sampled monthly from September, 1973 to August, 1974 at stations 9, 11, and 17 in the vicinity of Blount Island (Figure 2). Stations 9 and 17 were sampled for twelve months and station 11 was sampled for six months. The remaining twelve river miles in the upper estuary was sampled every third month (quarterly) at stations 41, 43, 44, 45, 46 and 47 (Figure 3). Monthly data were used to detect short term density and diversity fluctuations in zooplankton, while quarterly data were used in conjunction with the monthly data to detect seasonal salinity and temperature effects on diversity and density.

Zooplankton collections were made with a General Oceanics Bongo plankton net with an attached pair of 20 cm diameter PVC cylinders. A General Oceanics model 2030 digital flow meter was attached inside each cylinder. A 0.33 mm mesh and a 0.15 mm mesh net was attached to each cylinder pair. The bongo net was attached to a steel towing cable and was controlled by an on-board electric winch. Tows were made for ten minutes at a towing speed of 1 m/sec (2 knots). Samples were collected using a step oblique method. This consisted of towing for 3.3 min at 1 m off the bottom, 3.3 min at mid-depth, and 3.3 min just under the surface. Flow meter readings were recorded
Figure 1. Estuarine portion of the St. Johns River, illustrating region of monthly sampling (1) and region of sampling every third month (2).
One inch equals 2.75 miles or 4.4 kilometers.
Figure 2: Sampling stations for the monthly sampling program in the Blount Island Region.
Figure 3. Sampling station locations for the quarterly sampling program. Reddie Point Region from station 41-44, Southside Region from station 45-47.
to quantify volume filtered. Samples were transferred to 1 liter containers and preserved in 1.2 % gluteraldehyde.

Prior to each collection, in situ water quality was collected at surface, mid-depth and bottom with a Hydrolab DREL Surveyor System. Temperature, conductivity, salinity, pH, dissolved oxygen, and depth data were taken. Consecutive high and low tide zooplankton samples were collected at each station. Quarterly, three replicate collections were made at stations 9, 11, and 17.

The sampling area was subdivided into three regions of similar size. Three stations were sampled from each region. A mean value for each parameter per region was determined for each collection period. The three regions were: Blount Island (Figure 2), Reddie Point and Southside (Figure 3).

Identification and enumeration of zooplankton were made at 150X using a compound microscope. Each one liter sample was uniformly mixed and three 1 ml aliquots were taken with a Henson-Stempel pipet. Aliquots were placed on a Sedgwick-Rafter counting cell and all organisms were enumerated. Organisms composing 10 % or more of a sample numerically were identified to species; all others were recorded to taxon.
RESULTS AND DISCUSSION

Community Structure

Twenty seven species of zooplankton representing seven classes were collected during the study (Table 1). A majority of the species collected were crustaceans. These included 14 species of copepods, 4 species of cladocerans, and numerous larval forms of barnacles, decopods, and isopods (Table 1).

Monthly samplings from September, 1973 to August, 1974, in the Blount Island region resulted in 22 species. The greatest number of species taken in any month was 16 (July), and the fewest number was 9 (October). Seventeen species were identified from Reddie Point and Southside regions from quarterly collections. In both of these up river regions, the greatest number of species collected in a single sampling period was 11 (April), and the fewest was 8 (September and January). The increase in the number of species collected at Blount Island with respect to the other two regions was assumed to be related to sampling frequency since sampling was monthly at Blount Island and Quarterly at Reddie Point and Southside. This turned out not to be the reason as evidenced by comparing quarterly data collected at the same time at all three locations. In all four samplings, more species were collected at Blount Island, indicating a real decline in species number up river. A probable cause for this was the close proximity of municipal and industrial discharge sources at up river stations.
Table 1. Species list and percent composition (average) of the zooplankton collected in the St. Johns River Estuary from September, 1973 to August, 1974.
Phylum: Cnidaria
Class: Hydrozoa (medusae and polyps)  
Phylum: Aschelminthes
Class: Nematoda  
Phylum: Chaetognatha  
Phylum: Mollusca
Class: Gastropoda (larvae)
Class: Bivalva (larvae)  
Phylum: Annelida
Class: Polychaeta (larvae)  
Phylum: Arthropoda
Class: Crustacea
Subclass: Branchiopoda
Order: Cladocera
Daphnia sp.  
Eubosmina tubins  
Diphanosoma brachyrum  
Ceriodaphnia sp.  
Subclass: Copepoda
Order: Calanoida
Paracalanus sp.  
Centropages typicus  
Diaptomus minutus  
Eurytemora affinis  
Eurytemora herdmani  
Labidocera sp.  
Acartia tonsa  
Tortanus discadatus  
Order: Cyclopoda
Oithona similis  
Cyclops bicuspidatus  
Mesocyclops edax  
Macrocyclops sp.  
Order: Harpacticoida
Harpacticus gracilis  
Subclass: Cirripedia
Order: Thoracica (nauplii and cyprids)
Balanus sp.  
Subclass: Malacostraca
Order: Isopoda
Probopyrus sp.  
Order: Decapoda (zoea)
Callinectes sp. (Zoea)  
Phylum: Chordata
Class: Thaliacea (larvae)
The Simpson Index (Simpson, 1949) and the Shannon Index (Shannon, 1963) were used to define community structure. The Simpson Index ranges from 0 to a minimum diversity value of 1, and the Shannon Index ranges from 0 to infinity, with a minimum diversity value of 0. As a result, the diversity curves for the two indexes are inversely related (Figure 4). Simpson diversity ranged from 0.3 to 0.7 and Shannon diversity ranged from 1.1 to 2.5. The Blount Island region had the highest species diversity for zooplankton in September and March and the lowest in August. Diversity was generally lower at the Reddie point and Southside regions except in July, when high abundance of *Acartia tonsa* apparently caused a reduction in the species diversity at Blount Island.

Species number and diversity showed little seasonal variation but both appeared to decline up river. Both Simpson and Shannon indices were influenced by large numbers of *A. tonsa* (Figure 4). Percent composition of *A. tonsa* correlated directly with Simpson data ($r=0.875, p=0.15$) and inversely with Shannon data ($r=-0.820, p=0.20$). It is interesting to note the similarity between the coefficients since the Shannon index is more sensitive to rare species and the amount of evenness, while the Simpson Index is more sensitive to abundant species such as *A. tonsa* (Peet, 1974). The similarity in the correlation of *A. tonsa* populations with both indexes may be an indicator of how fundamentally this species affects zooplankton community structure in the
Figure 4. Species diversity indices compared with percent composition of Acartia tonsa at Blount Island, Reddie Point, and Southside regions of the St. Johns River Estuary from September, 1973 to August, 1974.
Population Dynamics

Mean zooplankton densities ranged from 3,000/m$^3$ to 36,000/m$^3$. (Figure 5). In the Blount Island region, densities were lowest in September (3,300/m$^3$) and highest in July (36,500/m$^3$). No regional differences were apparent except for the extremely high number of zooplankton at Reddie Point in July.

Seasonally, Blount Island populations were below 10,000/m$^3$ except in late winter and early spring (Figure 5). Up river regions were also below 10,000/m$^3$ except in summer. Increased numbers of A. tonsa at Blount Island and Eubosmina tubins up river were primarily responsible for these higher numbers.

Small seasonal variation and large replicate variation made analysis of population data difficult. As a result, only large scale changes in density were detected (Figure 5). This problem was identified early in the sampling period and increases in sample replication were made at stations 9,11, and 17 at quarterly intervals for the remaining nine months of sampling. Analysis of up to nine replications did not reduce sample variability. Further increases in sample replication were not possible because of time and cost constraints.
Figure 5. Mean monthly zooplankton densities ± one standard error of the mean at Blount Island, Reddie Point, and Southside regions of the St. Johns River from September, 1973 to August, 1974.
Three crustaceans composed a majority of the zooplankton community, *Acartia tonsa*, *Balanus* sp., and *Eubosmina tubins* (Figure 6). In the Blount Island region, *A. tonsa* generally dominated throughout the year except in spring when blooms of *Balanus* sp. nauplii dominated populations for approximately one month. In the Reddie Point and Southside regions, *A. tonsa* dominated during fall, winter and spring making up more than 50% of all individuals during those months (Figure 7). In summer, rainfall increased net river flow and carried large numbers of the fresh water cladoceran, *Eubosmina tubins*, into the estuary.

A comparison of seasonal *A. tonsa* densities among the three regions revealed that the Reddie Point region had densities generally above 4,000/m³, while the other two regions had densities generally below 4,000/m³ (Figure 7). Far greater numbers of barnacle nauplii were found at Blount Island than the other two regions, while *Eubosmina tubins* was much more abundant at Reddie Point and Southside regions.

**Hydrographic Effects**

Dissolved oxygen ranged from 5 to 9 ppm while pH ranged from 7 to 9 (Table 2). Since these parameters showed little variation during the study period, no attempts were made to relate them with population dynamics. Salinity and temperature were found to vary widely during the study. Variation in salinity was influenced by distance from
Figure 6. Mean monthly values for the major components of the zoo­plankton community in the Blount Island region from September, 1973 to August, 1974.
Total Zooplankton
Acartia tonsa-adult
Barnacle nauplii
Acartia tonsa-sub-adult
Figure 7. Mean seasonal values for the major components of the zooplankton community at three regions on the St. Johns River from Fall, 1973 to Summer, 1974.
Table 2. Average dissolved oxygen (D.O.) and median pH values at Blount Island, Reddie Point, and Southside regions of the St. Johns River Estuary from September, 1973 to August, 1974.
<table>
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<th>Blount Island</th>
<th>Reddie Point</th>
<th>Southside</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973-1974</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D.O. ppm</td>
<td>pH</td>
<td>D.O. ppm</td>
</tr>
<tr>
<td>September</td>
<td>6.0 ppm</td>
<td>8.2</td>
<td>--*</td>
</tr>
<tr>
<td>October</td>
<td>5.4</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>6.0</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>7.2</td>
<td>8.2</td>
<td>6.9</td>
</tr>
<tr>
<td>January</td>
<td>7.3</td>
<td>8.4</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>8.1</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>7.5</td>
<td>8.6</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>7.2</td>
<td>8.3</td>
<td>6.9</td>
</tr>
<tr>
<td>May</td>
<td>6.8</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>6.4</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>--*</td>
<td>7.9</td>
<td>6.7</td>
</tr>
<tr>
<td>August</td>
<td>6.0</td>
<td>7.9</td>
<td></td>
</tr>
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* No sample taken
the ocean, tidal stage, and net river flow. Salinities were recorded as low as 3 ppt in July at Southside, and as high as 34 ppt in May at Blount Island, however, most readings ranged from 8 to 32 ppt. At Blount Island, mean salinities ranged from 15-32 ppt with highest readings in November and May, and lowest readings in June and July (Figure 8). Reddie Point salinities ranged from 5-20 ppt, while Southside ranged from 3-11 ppt (Figure 9). These data reflect a general decrease in salinity in the up river direction.

Regression analysis showed no correlation (p=0.10) between salinity and *A. tonsa* abundance in the St. Johns Estuary, using concurrent seasonal data from all three regions (Figure 9). Although lowest numbers of *A. tonsa* coincided with lowest salinities in all four samplings, population variation in higher salinities had no direct relationship. This indicates that *A. tonsa* is able to successfully compete in a broad salinity range with a lower limit that is below 6 ppt.

Temperature ranged from 16-30 C (Figure 8). Lowest temperatures occurred in February and highest temperatures occurred in July and August. Little temperature variation occurred between regions or through the water column during any one sampling period. From monthly data at Blount Island, it appeared that *A. tonsa* numbers varied inversely with temperature. Regression analysis indicated no significant correlation (p=0.10) however. It is apparent that *A. tonsa* populations
Figure 8. Average monthly salinity and temperature, and mean Acartia tonsa densities ± one standard error of the mean collected in the Blount Island region from September, 1973 to August, 1974.
Figure 9. Seasonal salinity versus *Acartia tonsa* densities at the Blount Island, Reddie Point, and Southside regions of the St. Johns River from Fall, 1973 to Summer, 1974.
at Blount Island undergo seasonal variation in abundance with numbers exceeding 6,000/m$^3$ in winter and ranging from 2,000/m$^3$ to 6,000/m$^3$ in spring, summer, and fall.

Although these data reflect the conditions of only one year, earlier zooplankton collections in the Blount Island region indicate that patterns in temperature, salinity, and copepod populations were similar to these (Tone 1972a, 1972b, and 1973).
SUMMARY

Zooplankton of the St. Johns River Estuary are similar to other Florida estuaries such as the Indian River (Young, 1975), Crystal River (Connell, Metcalf and Eddy, 1978), and St. Andrew Bay (Hopkins, 1966). At all locations, *Acartia tonsa* was the dominant organism composing greater than 50% of zooplankton numbers and total population densities ranged from 4,000/m³ to 50,000/m³. Species numbers and composition, however, varied at all locations. Differences in the number of species collected appeared to be a result of sampling intensity and the degree of taxonomic effort that was applied to identifications.

Salinity appeared to have the greatest effect on the distribution and abundance of zooplankton in the St. Johns Estuary. Spring blooms of barnacle larvae were confined to salinities above 20 ppt while the fresh water cladoceran *Eubosmina tubins* was found only in salinities below 10 ppt. *Acartia tonsa* appeared not to be effected by salinities between 6 and 34 ppt, but salinities below 5 ppt were limiting. This ability to exist in so broad a salinity range is consistent with Bowman's (1971) findings for *Acartia tonsa* in warmer climates.

Temperature effects were more difficult to determine. When temperatures ranged from 16-20 C, *A. tonsa* numbers nearly doubled reaching their highest densities of 10,000/m³. This temperature range was also found to be optimal for *A. tonsa* as far north as Long Island Sound (Conover, 1956).
Zooplankton densities in the St. Johns River Estuary and other similar subtropical marsh dominated estuaries are small compared with temperate estuaries where total numbers of zooplankton are one and sometimes even two orders of magnitude greater (Conover, 1956). It is not currently known whether this is the result of warmer temperatures, reduced phytoplankton production from high turbidity, or other factors. What is known is that in marsh dominated estuaries such as the St. John's, the food chain is primarily detritus based with marsh grass being the major producer, and epibenthic invertebrates being the major consumers. These factors suggest that even though zooplankton production in the St. Johns River Estuary cannot be dismissed as insignificant, it plays a secondary role in the general productivity and trophic structure.
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