SUMMARY AND CONCLUSIONS

The Pennar estuary lying along the east coast of South India is a tropical oligomictic estuary characterized by flood discharges usually during October and December and drought discharges at other months. The chemistry of the bottom-waters is primarily dependent on the entry of sea water into the estuary during high tides, withdrawal of estuarine waters into the sea during low tides, and discharge by the River Pennar especially during monsoon. The temperature, which ranges from about 23 to 34°C, shows a seasonal cycle closely related to the air temperature with very little variation in the vertical direction. The salinity can be better determined from chloride rather than from specific conductance, density, and refractive index. The salinity shows a high seasonal variation from 3.5 g/l during monsoon to as high as 34.9 g/l during summer at the mouth and gets gradually decreased to as low as 0.2 g/l along the upstream direction. The hardness shows a high seasonal variation from 650 mg/l as CaCO₃ during monsoon, moderate in concentration during summer, and as high as 6,000 mg/l during winter at the mouth and gets gradually decreased to as low as 15 mg/l along the upstream direction. The hydrogen-ion concentration and oxidation potential indicate an alkaline, oxidizing environment transitional between that in contact with the atmosphere and that
isolated from the atmosphere. The organic matter, silica, phosphate, alkalinity, and dissolved oxygen show a gradual increase from the mouth along an upstream direction, indicating that the estuary gets them in a greater concentration from the river than from the sea.

The substrate of the estuary is essentially composed of unconsolidated sediments of brownish yellow to brownish gray color, containing sand, silt, and clay in varying proportions. There appears to be extensive reworking of the sediments on account of meandering of the river, reversal in the direction of flow during low and high tides, winnowing of the silt and clay particles by wind, washing of silt and clay particles into the sea by wave action and floods, settling of silt and clay particles in topographical depressions, and changes brought out by the fishermen who carve the substrate at places to effectively carry out fishing. The depth of the estuary is very shallow from 0.3 to 3.4 m and is generally more at the mouth than in the upper estuary, more in high tides than in low tides, and more in monsoon than in summer. In the nomenclature of Shepherd (1954), 87.8 percent of the sediment samples are represented by sand, 5.0 percent by silty sand, 2.8 percent by clayey sand, 2.2 percent by sandy clay, 1.7 percent by sandy silt, and 0.5 percent by sand-silt-clay. The phi mean size of the sediments ranges from 0.2 to 7.0, phi standard
deviation from 0.4 to 3.7, skewness from -0.76 to +0.81, and kurtosis from 0.52 to 5.65. Significant variations in the size distribution of sediments collected at each station at different intervals is attributed to changes in the kinetic energy of the depositing agent responsible for rapid sedimentation. The phi mean size and phi standard deviation are maximum at the mouth and get gradually decreased in the upstream direction. The high mean size and high degree of sorting of the sediments in the upper estuary may be because of high energy conditions of the depositional environment. The low mean size and low degree of sorting of the sediments at the mouth may be because of changes in the energy conditions of different types of parameters such as tidal action and river flow that influence deposition. If phi skewness is considered, about 87 percent of the samples show positive skewness and the rest show negative skewness. The positive skewness of most of the sediments suggests that the estuary is sheltered, with winnowing action limited to a few places for part of the time. The hydrogen-ion concentration and oxidation potential indicate an alkaline, oxidizing environment like that of the bottom waters.

The soil pH decreases slightly from mouth to estuary during September to November, 1970 and June to August, 1971 and increases slightly from mouth to estuary during December 1970 to May 1971. The oxidation potentials are comparable with those of bottom waters and decrease slightly from
mouth to estuary. The fine-grained fraction of sediments contains organic carbon ranging from 0.25 to 0.92 ppm with an average of 0.54 ppm, while organic nitrogen ranges from 0.021 to 0.090 ppm with an average of 0.045 ppm. Although a positive correlation exists between these two constituents, the C/N ratio ranges from 6.2 to 26.7 with an average of 13.2. Both these constituents generally increase from mouth towards the estuary. A rough inverse relationship is noted between organic carbon or organic nitrogen and weight percentage of fine fraction of sediments.

A total number of 45 foraminiferal species belonging to 28 genera, 18 subfamilies, 19 families, 9 superfamilies, and 3 suborders were recognized. Total populations range from 1 to 23,400 specimens per 100 grams sample and average 3,167 per sample for the whole estuary. They generally occur in large numbers in the middle estuary, moderate numbers at the mouth, and low numbers in the upper estuary. Populations are less during monsoon months and fairly high during summer months. The distribution of living populations generally parallels the total populations, with living/total ratios ranging from 10 to 100 percent with an average of 26 percent for the whole estuary. The high rate of fluctuation in the living/total ratio for sediments collected at the same station in different seasons indicates fluctuations in the rate of deposition.
Most of the foraminiferal species are benthonic and
calcareous with a few species being of planktonic and
arenaceous nature. In all the total and living populations,
Rotaliina is the dominant suborder with Miliolina in small
amounts and Textulariina in very small amounts. The plots
showing higher concentrations of Miliolina and Textulariina
represent invariably populations from the middle estuary.
The average diversity indices calculated by different methods
for both total and living populations are more at the mouth
and get decreased gradually in the upstream direction.

Size analysis of total and living populations of
Ammonia beccarii and Quinqueloculina seminulum indicated
a large variation in their sizes with lengths ranging from
about 0.10 to 0.45 mm. Presence of populations of mixed
age groups of Ammonia beccarii mostly during monsoon in-
dicates that its reproduction takes place at a greater
pace in monsoon than in other seasons. A similar study
for Quinqueloculina seminulum indicated that its repro-
duction takes place at a greater pace in summer than in
monsoon.

A comparative study on the total and living foramin-
ifers indicated that a study of the total foraminifers gives
a rough idea about the distributional pattern of the
living foraminifers. The only exception is the diversity
index which is much higher for the total populations.
than for living populations at the mouth. The higher diversity index obtained at the mouth for the total populations is interpreted as due to the entry of dead tests of stenohaline marine species from the Bay of Bengal into the estuary by tides and currents.

The species are broadly grouped as stenohaline marine, slightly euryhaline, moderately euryhaline, and truly euryhaline species. Twenty four species, which never occurred in living state in any part of the estuary, and Spiroleuolina orbita, whose living specimens occur in small numbers only at the mouth, are included in the stenohaline marine group. Eight species, whose living specimens occur sparingly in a few stations, are grouped under slightly euryhaline group, while seven species that occur in moderate amounts in a few more stations are included in the moderately euryhaline group. Five species which are most dominant in the estuary are included in the truly euryhaline group. The most widespread species of this group are Ammonia beccarii and Ammonia beccarii var. tepida.

The principal ecological factors that limit the distribution of foraminifera include the tropical climate of the estuary, extreme shallowness of the estuary, and high variations in the salinity. Although the number of foraminiferal species recorded were the highest under conditions
of highest salinity, the highest number of foraminiferal species were recorded only under conditions of salinity a little lower than the highest salinity. This is attributed to the presence of large number of specimens of truly euryhaline species having optimum development at salinities ranging from about 32 to 33 g/l among the foraminiferal populations. The occurrence of foraminifera even when salinity was as low as 0.2 g/l is explained by suggesting that the salinity of interstitial water of the substrate carrying the foraminifera is much more than that of the bottom waters. The occurrence of extremely low foraminiferal populations in November 1970 is attributed to the effects of high discharge of river water during the preceding month.

A positive correlation exists between the number of living specimens and the mean size or the percentage of finer fraction of sediments.

The other ecological factors like temperature, pH, alkalinity, oxidation potential, dissolved oxygen, and hardness are considered to be not so important in accounting for the distribution of foraminifera.

The presence of less number of foraminiferal population at the mouth compared to the middle estuary is attributed to the action of tides and currents at the mouth.
which reduce the foraminiferal abundance. The preference of *Asteroprotalus pulonella* and *Ammonia centata* to be at mouth rather than at other parts of the estuary is probably because of their general occurrence as beach fauna. The relatively high foraminiferal counts obtained in October 1970 and in certain months at station 13, in spite of adverse salinity conditions, are explained as due to the availability of nutrients in larger concentrations. The population maxima of July and August, 1971 probably reflects peaks of phytoplankton production, which provide abundant readily available food for the luxuriant growth of foraminifera.