Aquatic ecosystems (consisting of oceans, lakes, ponds, pools and lotic waters) play an important ecological role on a global scale, as the greater part of many natural microbial conversions occur in water. Heterotrophic bacteria in fresh waters are important in the processing of natural organic matter and in bio-purification of water, which receives organic pollution. There are many studies all of which have suggested that heterotrophic bacteria can also utilize a large fraction of the carbon that flows within the ecosystems, and serves as food for protozoan and also support the growth of microcrustaceans (Hessen., 1998; Travnik., 1998). The observation that the biological availability, quantity, quality and composition of DOC changes along rivers suggests that heterotrophic bacterial assemblages along a river continuum may change in a predictable manner (Leff and Meyer, 1991; Sabater et al., 1993; Sun et al., 1997). Recent evidences suggest that different bacterial species respond differently to changes in conditions along streams (Lemke et al., 1997). The abundance and ecological role of heterotrophic bacteria in marine and lentic waters is well documented, but research on lotic waters lag behind that of marine and lentic waters. The research studies on lotic waters are very few and far between. Hence, mainly to fill the gap of basic knowledge of lotic ecosystem in general and on Indian rivers particularly, this research work was taken up.

As far as this author knows, this is the first comprehensive studies of the micro-biota of the river Cauvery and its important tributaries like Lakshmanatheertha, Harangi, Hemavathy and Lokapavani in South Karnataka, India - using heterotrophic bacterial abundance, cell size of heterotrophic bacteria, SGR of heterotrophic bacteria and micro-plankton as microbial variables and some important environmental variables. The two year seasonal study revealed that, the mean abundance of Directly Counted Free Living Bacteria (DC-FLB), Directly Counted Particle Bound Bacteria (DC-PBB) and Directly Counted Total Bacteria (DC-TB) were significantly high in the river.
Lakshmanatheertha, when compared to the other four water courses studied. In general, the presence of more bacterial abundance in the river water indicates that the river is exposed to non-point pollution, particularly run-off from the agricultural land, sewage contamination and other anthropogenic activities (Adewoye, et.al., 2004) or due to low flow or reduced flow (Castillo, 2000), because the low flow favored high Chlorophyll-a concentration and high bacterial production, which in turn increased bacterial abundance (Castillo, et.al., 2004). In the present study both the bacterial abundance and Chlorophyll-a was more and also significantly different in the river Lakshmanatheertha only. This clearly supports the hypothesis that higher the Chlorophyll-a, higher will be the bacterial abundance. In the remaining four watercourses, low bacterial abundance was noticed which could be because of reduced autotrophic production and allochthonous DOC.

The abundance of Colony Forming Units (CFU's) were found more in the rivers Lakshmanatheertha and Lokapavani followed by the river Cauvery. However, CFUs were less and almost similar in Harangi and Hemavathy rivers, suggesting probably that the natural habitat in these rivers, is not favorable for normal growth of microbes. The proportion of Chromogenic Colony Forming Units (% of CCFUs) was assayed as a potential indicator of stress, since decrease in the proportion of pigmented colonies has been related to unfavorable acid conditions in the upland stream (Goulder, 1988; Simon and Jones, 1992; Yamakanamardi, 1995). However, in all the five water courses in this study the % of CCFUs behaved atypically in having similar mean values. CFU's as percentage of AODCs or % of culturable bacteria represent the ability of directly counted bacteria to cultivate on the artificial nutrient medium. As reported by Perry and Stanley (1997) in Oligotrophic and Mesotrophic aquatic habitats, only less then 1% of the total bacteria can grow on the best artificial nutrient agar media (Maki, et.al., 1986; McCoy and Olson 1986; Servais et.al., 1992). But, in the present investigation, higher percent of total bacteria could be grown on artificial nutrient media. For e.g., 2% in the river Harangi, 3% in the rivers Lakshmanatheertha, Hemavathy and Cauvery, while in the river Lokapavani 4% of the bacteria could be grown on the artificial nutrient agar media (Table 3.1).
Further, it was also observed that, the two bacterial communities i.e., FLB and PBB were both quantitatively and qualitatively different from each other. From the quantitative point of view, the abundance of TB was relatively high during the study period in all the five water courses studied. This increase in the abundance of TB was reflected mainly by the increased abundance of FLB, i.e., about 62.1% in the river Lakshmanatheertha, 57.9% in the river Harangi, 59.7% in the river Hemavathy, 58.5% in the river Lokapavani and 59.1% in the river Cauvery. This was in agreement with the similar findings of Mitsuru Yanda, et al., (2000) in Sub-arctic coastal water. However, from the qualitative point of view the two bacterial communities (FLB and PBB) are different, the difference being mainly due to the fact that, the two communities inhabit very different micro-habitat in these ecosystems. PBB are found attached to the surface of the particles, whereas, FLB were free floating in the water medium. A number of studies have shown that the bacteria attached to particles may be phylogenetically different from free living bacteria (Rath, et al., 1998; Crump, et al., 1999). This may be due to the different nature of the substrate to which they have access (Unanue, et al., 1992; Hollibaugh et al., 2000).

Apart from this, several key environmental variables were potentially responsible for much of the bacterial variations, notable are PO4, Calcium, TASA, rainfall, COD, Conductivity, Chl-a, Chloride, Temperature, Turbidity, TSS, SWV, NO3, DO, LpH. Further, there are about 28 positive correlations were noticed between environmental variables and abundance of heterotrophic bacteria in the river Lakshmanatheertha, whereas, only 1-10 positive correlations were found to be affecting the heterotrophic bacterial variations in the other four rivers studied. Thus, the heterotrophic bacterial abundance in these five watercourses studied, were controlled largely by environmental variables. The strength of the relationship between bacterial variables and environmental variables in the river Lakshmanatheertha with as many as 41 correlations suggests that, environmental variables have retained a degree of bottom-up (nutrients) control of heterotrophic bacteria temporal variation. Whereas, in contrast, in river Harangi with 21 correlations, in river Hemavathy with 15 correlations, in river Lokapavani with 12 correlations and in river Cauvery with only 7 correlations, this may probably be due to ‘top-down’
Protozoan grazing) controlling mechanisms operating in these waters, along with lesser 'bottom up' controlling mechanisms. This was in agreement with the findings of Gude, 1989; Pace and Cole, 1994; Kirschner, et al., 1997.

The size of bacteria is an important trait in the predator-prey relationship of aquatic bacteria and bacteriovorous protests, because grazing by predators is size selective (Gonzalez, et al., 1990; Simek and Chrzanowski, 1992) and thus small and large bacteria may have a refuge from protozoan grazing. Filament formation or permanent filamentous growth is one highly effective, size dependent grazing defense mechanism of aquatic bacteria (Hahn, et al., 1999, 2000). The initial hypothesis that; the four upstream tributaries are similar to each other in the mean cell-length, but are markedly different from that of main river Cauvery was rejected, because the mean cell-length of heterotrophic bacteria in the river Lakshmanatheertha was different significantly than the remaining four water courses studied. In the present investigation, several key environmental variables were potentially responsible for much of the bacterial cell-size variations, notable are SO₄, DO, SWV, PO₄, TASA, BOD, COD, Conductivity, Chl-a, and Chloride. Thus, it could be concluded that the mean cell-length of planktonic bacteria in all these five watercourses were controlled largely by environmental variables, as reported similarly by Yamakanamardi, (1995), and Jugnia, et al., (2000). The strength of relationship between the overall mean cell-length of heterotrophic planktonic bacteria and environmental variables in the river Lakshmanatheertha with more correlations, when compared to other four water courses studied, suggests that, environmental variables have probably retained a degree of bottom-up (nutrients) control in the temporal variation of heterotrophic bacterial cell-size.

The mean specific growth rate of heterotrophic bacteria was significantly more in the river Lakshmanatheertha, when compared to other four water courses studied, suggesting that the river Lakshmanatheertha was more favorable to bacterial growth. This may be due to low level of water, reduced water flow, maximum anthropogenic activities, and other contaminations, which enrich the nutrient level, might be the reason, this was in agreement with the similar findings of Simek, et al., (2003; 2005), and Jezbera, et al., (2005). Further, in the present investigation, comparatively more negative values in
specific growth rates of heterotrophic bacteria were noticed in the river Lakshmanatetheertha. For example, out of 50 determination 15 in river Lakshmanatetheertha, 3 in river Lokapavani, 2 each in rivers Harangi and Cauvery, and 1 in river Hemavathy. The negative values were a result of decrease in observed bacterial cell counts after 48 h incubation. Similar observation by Coveney and Wetzel (1992) in Oligotrophic Lake, Yamakanamardi and Goulder (1999) in Holderness Drain, suggesting bacterial mortality and predators-prey interactions (Chrzanowski et al., 1995; Chrzanowski and Grover, 2001), or higher grazing-induced mortality (Jezbera, et al., 2005; Simek, et al., 2005), might have played dominant role in controlling bacterial growth rate (Carlsson and Caron, 2001). Regression analysis revealed that the SGR tended to respond strongly towards environmental variables like, Calcium, DO, CO2, Rainfall, Conductivity, TASA, and Chloride, which might have caused physiological stress which in turn regulated the growth rate of heterotrophic bacteria (Sinsabaugh, et al., 1997; Brett et al., 1999; Vrede et al., 1999). Further, this study suggested that the SGR is potentially useful in detection of inhibition of heterotrophic bacteria, and potential loss of biopurification capacity, brought about by adverse water quality which may be related to natural processes or to toxic pollution (Yamakanamardi and Goulder, 1999).

The micro plankton community is a heterogeneous group of microscopic organisms, adapted to suspension in the sea and freshwaters, and float in any aquatic body either fresh water or marine. The mean abundance of micro-plankton (micro-phytoplankton, zooplankton and total plankton) showed clear cut seasonal variation with less, moderate and high mean abundance. Further, significantly more mean abundance of micro-plankton was noticed in the river Lakshmanatetheertha only. This observation suggests that the river Lakshmanatetheertha was more favorable to abundance of micro plankton. Further, presence of more phytoplankton and diverse zooplankton abundance in water is due to eutrophication (Sharma, et al., 2000). In the present investigation more correlations were noticed between abundance of micro plankton and other environmental variables in the river Lakshmanatetheertha, as compared to other four water courses. The notable environmental variables were Chlorophyll-a, Conductivity, Temperature, pH, Surface Water Velocity,
DO, CO₂, BOD, Chloride, Calcium, Rainfall, Total Anions of Strong Acids, Nitrate and Sulphate, this was in agreement with the similar findings of Caljan, 1987; Sarojini, 1994; Kobayashi et al., 1998; Pandey, et al., 2000 and Rezai, et al., 2003. Over all investigation with special reference to the seasonal study revealed that the presence of phytoplankton species like, *Gomphonema*, *Navicula*, *Cyclorella*, *Melosira*, *Nitzschia*, *Synedra*, *Scenedesmus*, *Chlorella*, *Ankistrodesmus*, *Oocystis*, *Closterium*, *Actinastrum*, *Chlamydomonas*, *Gloeocystis*, *Crucigenia*, *Spirogyra*, and *Ulothrix*, and zooplankton species like *Paramecium*, *Strobilidium*, *Glaucoma*, *Colpodium*, *Coleps*, *Colpoda*, *Cyclops*, *Daphnia*, *Keratella*, *Lepadella*, *Brachionus* etc., in all the five water courses under study, supports the study of Palmer (1980) who reported that all these species as pollution indicators.

Overall investigation (February 2000 to January 2002) of variation in the environmental and aquatic microbial variables revealed that the surface water of river Lakshmanatheertha is more polluted than the other four water courses studied. The evidence for these conclusions is that, except in river Lakshmanatheertha, the microbial (abundance of heterotrophic bacteria, cell-size, SGR of heterotrophic bacteria and abundance of micro-planktons) and most of the environmental variables studied were similar in the four water courses, but were significantly different in river Lakshmanatheertha (Tables 3.1 & 4.1). This was probably due to low level of water because of absence of annual rainfall in the catchments - less dilution which might have increased the entry of allochthonous bacteria from bottom sediments into the water column, maximum anthropogenic activities at the sampling spot, massive growth of surface algae and aquatic plants, and discharge of sewage, agricultural wastes and other effluents, etc., all of which might have accumulated microbial growth. Waste plastic covers, cups, bottles and old cloths, flowers, slippers and coconut husk, electrical bulbs and tubes were observed along with solid garbage at the sampling spot, all these might have caused the pollution and eutrophic nature of the river, leading to the variation in abundance, cell-size and SGR of heterotrophic bacteria and abundance of micro plankton in the river Lakshmanatheertha. This was in agreement with the similar findings of Adewoye, et al., (2004), Castillo, (2000), Castillo, et al., (2004), Sharma, et al., (2000), Pandey, et al., (2000), Rezai, et al., (2003), Simek, et al., (2003;
Surprisingly, even though this Lakshmanatheertha tributary join main river Cauvery, the water quality of river Cauvery has not been affected at all. This disproves the initial hypothesis that; the four upstream tributaries might have caused pollution and thus might be responsible for the deterioration of water-quality in the main river Cauvery. This is probably because of the construction of a dam at Kannambadi village, thus converting temporarily the lotic ecosystem into a lentic ecosystem. Further, due to long-distance of flowing water before and after joining the main river Cauvery, the self bio-purification processes might have rendered the main river Cauvery water being non-polluted.

Comprehensive spatial study along the full length of rivers Lakshmanatheertha and Lokapavani (till near confluence point with main river Cauvery) was carried out on five occasions, as explained in Part-II of this thesis. The study revealed that both environmental and microbial variable show abrupt pattern. This abrupt pattern may be due to different geographical condition or addition of waste water from different point and nonpoint sources. In general, most of the water quality and microbial variables measured during present investigation showed more significant variations in sites LT-4 and LT-5 in river Lakshmanatheertha, and in site LP-4 in river Lokapavani, as revealed by ANOVA. Further, the environmental parameters such as temperature, SWV, chloride, TASA, calcium, and Chlorophyll-a, and among the microbial variables such as micro phytoplankton and total plankton responded differently with respect to spatial variation in the sites LT-4 and LT-5. However, the site LT-5 was entirely different significantly with respect to conductivity, turbidity, CO₂ and abundance of FLB, TB, CFU's, % of CCFUs and SGR of heterotrophic bacteria, when compared to other four upstream sites on river Lakshmanatheertha (Tab 9.1 & 9.2). Whereas, in the site LP-4 in river Lokapavani, only few environmental parameters such as conductivity, SWV, Chloride, TASA and Calcium, and microbial variables like SGR of heterotrophic bacteria, micro phytoplankton and total micro plankton responded differently with respect to spatial variation when compared to remaining sites on river Lokapavani (Tab 10.1 & 10.2). The final conclusions of
spatial investigation revealed that the site LT-5 in river Lakshmanatheertha and site LP-4 in river Lokapavani were significantly different than the remaining sampling sites studied. Further, site LT-5 was more polluted than the site LP-4 also, because more number of significant variations in both environmental and microbial variables was noticed in site LT-5, when compared to site LP-4. Generally this may be due to low water level with reduced or no water flow, more anthropogenic activities, sewage and other effluent contamination, solid garbage, and algal bloom and other aquatic plants on the water surface, might be the reason, that more spatial variation in site LT-5, similar findings by Sharma and Pandey (1998), Mini et al., (2003), Gadhia, et al., (2000), Somashekar (1988) etc., Similarly, in the site LP-4 on river Lokapavani, more anthropogenic activities such as bathing, washing cloths, vehicles, cattle and bullock cart etc., and also contamination of agriculture runoff and other wastes water from the adjoining sugar cane crushing industries were observed during this investigation, but water was less polluted this is because of regular water flow in this site which probably prevented the accumulation of pollutants in the water course might be the reason that less number of significant variations in both environmental and microbial variables in site LP-4. Further, some of the water quality parameters such as, DO, BOD, Chloride, Carbon di-Oxide, Nitrate, Sulphate, Calcium were well within the permissible limits, where as the values of Conductivity, Turbidity, COD, Phosphate and Total Suspended Solids were above the permissible limits of drinking water standards as prescribed by WHO, ISI and USPH. Hence, in the present investigation the content of some of the parameters could be minimized and indiscriminate entry of domestic sewage, agricultural runoff and other effluents into these running water courses is to be prevented. Finally, the present study also warrants for strict vigilance and continuous monitoring for conservation and sustainable management of these natural ecosystems.