SUMMARY
In view of total lack of comprehensive and long term limnological studies on limited freshwater resources of the small state of Goa, and the prerequisite information indispensable for proactive management of these resources already buckling under demophobic pressures rather than "hands-off" protection, the present work was undertaken. Of the 3 water bodies chosen for the study, the Pilar Lake (PL) is the smallest natural multipurpose village tank with barely 3.34 ha of waterspread. The other 2 namely Carambolim Lake (CL) and the Santa Monica Lake (SML) are the manmade lakes. Of these CL is the largest semi-permanent minor irrigation tank with a central water spread of 40 ha, surrounded by a wetland of 40 ha which was in jeopardy due to a mega rail alignment supposed to pass through its center. SML is a lake of intermediate size with surface area of 8.85 ha within the industrial premise of a multinational firm, water of which is put to industrial utility. It also harboured the only communal mixed heronry of the region. The limnological work carried out in the course of present study concentrated around 5 principal areas - physicochemical characteristics of water, plankton and primary productivity, sediment and benthos, macrophytes and fishes, and waterfowl has been presented in 5 separate chapters.

Chapter-I

1) The chapter deals with the comparative profile of 3 water bodies- PL, CL and SML with respect to physicochemical characteristics of water such as temperature, pH, conductivity, turbidity, total solids, FCO$_2$, DO; chloride concentration, total alkalinity, hardness, nutrients such as organic carbon, ammonical nitrogen nitrates and phosphates. Seasonal variations in these characters and the influence of meteorological parameters such as atmospheric temperature, sunshine hours, wind speed and rainfall on them were assessed by appropriate statistical methods.
2) Except for few specific interseasonal/ interlake variations, most of the parameters showed peak values during summer/ early monsoon and least values during post-monsoon/ winter. Only DO and pH were the exceptions to this general pattern, wherein they were at their peak during monsoon and at their lowest values during summer/ winter. The reduction in the volume of water during summer due to excessive evapotranspiration, increase in its volume during monsoon due to inflow of water and the consequential events seemed to be the prime causes for these seasonal variations. Within the broad regulatory frame, interlake variations were principally due to the lake specific water regime.

3) Perceptibly high levels of chlorides at SML could be due to seepage of salt water in its basin because of its position within the estuarine backwater limits of the Banastari river. Likewise, peak values of phosphates at PL may be due to the surface runoff bringing in the residual matter from the nearby crematorium.

4) Going by the degree and the pattern of overall physicochemical parameters, especially the key factors such as BOD, TOC, FCO₂, DO and nutrients, considerably higher values at PL signified it to be hypereutrophic, moderately high values indicated CL to be eutrophic and relatively low values at SML categorised it to be a mesotrophic lake. Neither the level of peak values nor the seasonal pattern of any of the above parameters indicated any overt pollution of exogenous nature.

**Chapter-II**

1) The second chapter embodies the studies on phytoplankton and zooplankton of the 3 lakes- PL, CL and SML with regard to their species diversity, community composition, temporal variations in their densities, if any, interrelationships, correlation with environmental parameters and the planktonic primary productivity.
2) PL, the smallest of the lakes investigated, showed the maximum species diversity harbouring 28 out of 38 species of phytoplankters, and 35 out of 44 species of zooplanktons with reference to the overall species recorded in the course of study. The diverse ecological microhabitats provided by rich aquatic macrophytes and the totally enclosed ecosystem with least human interference seem to be the causal factors for the best diversity at PL. In terms of composition the Chlorophyceans and Copepods dominated phytoplankton and zooplankton respectively in all the lakes. As to the second and third place amongst the other major groups there were interlake variations.

3) Contrary to the picture emerging out of species diversity, maximum densities of phytoplankton and zooplankton were encountered at SML and CL respectively. PL which had the best diversity had the least density of both the types of planktons. The near total absence of true aquatic macrophytes, high levels of alkalinity and nitrates at SML seem to have favoured better phytoplankton density. On the other hand, higher macrophytic density at PL and lower PO$_4$ levels at CL appear to have checked the phytoplanktonic densities in these lakes. Therefore it may be concluded that PL is a N-limited lake while CL is a P-limited one.

4) In all the lakes, phytoplankton was abundant during summer, a season characterised by high temperature, long sunshine hours and water with higher alkalinity and nitrates. The phytoplankton density was lowest in all the water bodies during the post-monsoon, a season with relatively low temperatures, lesser sunshine, low alkalinity, lowest levels of nitrates and phosphates.

5) All the lakes showed a season based succession in predominance of major planktonic groups. Rotifer abundance coincided with Chlorophyceans in summer. Cyanophyceans and copepodes showed parallel peaks during monsoon, while
the rise of Bacillariophyceans and Cladocers were concomitant during postmonsoon/ winter.

6) The zooplankton density curves in all the lakes were higher than that of phytoplankton, which is a clear sign of their being far from the threat of phytoplanktonic blooms and possible dystrophication. Though in all the lakes phytoplankton was perfectly under the control of grazing pressure of zooplankton, the pressure was perceptibly higher at CL unlike at PL and SML.

7) In general primary production in these lakes was extremely poor in comparison with that recorded for the water bodies in the southern India. The maximum primary productivity at SML and minimum at PL was in accordance with the total phytoplanktonic density profile in these lakes. But the time frame of highest planktonic primary productivity varied amongst the lakes. It was at its best during summer, monsoon and post-monsoon at PL, SML and CL respectively. Taking into account higher phytoplankton densities in all the lakes during summer, seasonal productivity profile did not go well with it, at least at CL and SML. One obvious reason could be that, the numerical counts of phytoplankton adopted in the study might not have reflected the actual biomass, in view of the overall scantiness of the phytoplankton in these lakes.

8) Under the scheme of Nygaard's trophic state indices, taking into account the values of Chlorophycean as well as Cyanophycean indices, from a wholistic angle PL and CL fitted in hyper eutrophic and eutrophic category respectively, while SML was mesotrophic in nature.
Chapter-III

1) The chapter covers the studies carried out on the composition, diversity and seasonal variations of benthic macroinvertebrates at PL, CL and SML in relation to temporal profile of the substratum in the form of sediment texture and the principal nutrients - organic carbon, NH$_4$-N and PO$_4$-P.

2) The sediment at SML all through was of loamy-sand in nature, while it was of silty-sand type at PL and CL. The fine composition varied through seasons. In all the lakes, sand was on the rise during monsoon, while silt and clay were on the higher side during summer and post-monsoon/ winter respectively. The silt and TOC levels were maximum at CL and minimum at SML. The large scale death and decay of macrophytes and relatively low rate of clearance by less dense detritivore macrofauna seem to have contributed for the higher levels of silt and TOC at CL. Similarly poor macrophytic flora, and hence less autochthonous inputs coupled with increased clearance rate owing to strong detritivore chironomid component must have been the causative factors for the minimum levels of TOC at SML.

3) The species diversity of macroinvertebrates was at its best at PL while their density was highest at SML. Though 2-3 species dominated the benthos in all the lakes, one of them was most dominant, based on which the benthos of PL, CL and SML could be categorised as *Dytiscus*, polychaete and chironomid type respectively.

4) The predominance of restricted number of species as observed in the study, is generally considered as the tell tale sign of pollution. But, none of the water bodies under investigation had any indication of overt pollution of exogenous nature. Further the study also recorded that many other factors such as the grain size of sediment, macrophytic biomass, existence/ nonexistence of predatory
pressure might have had the overriding effect on the development of scenario. Therefore it is opined that, utmost caution need be exercised before applying indicator species concept and drawing conclusions as to the pollution status of any water body.

**Chapter-IV**

1) The aquatic/ wetland macrophytes, their diversity, composition, dominance, variation in standing biomass through seasons at all the 3 lakes on comparative basis is dealt in the chapter. In addition the chapter also looks in to the species diversity of teleost fishes, their relative dominance and fishery potential of these lakes.

2) PL had diverse macrophytic flora representing 12 species belonging to 8 families, wherein the wetland plant *Portulaca oleracea*, submergents- *Hydrilla verticillata* and *Utricularia aurea* dominated the group in that order. CL had 13 species belonging to 9 families, of which rooted plant with floating leaves, *Nymphaea stellata*, emergent wild rice, *Oryza rufipogon* and submergent *H. verticillata* dominated the aquatic macroflora. On the other extreme SML was relatively poor in species diversity of aquatic plants with only 5 species belonging to 5 different families. The littoral *Polygonum glabrum* was the dominant plant and other species not contributing substantially to the biomass.

3) PL showed relatively stable biomass through the seasons except the marginal reduction during winter. Biomass of flora was pronounced during post-monsoon/ winter at CL, which decreased during monsoon and reached lowest limit during summer. The biomass of aquatic flora depicted a distinct seasonality at SML, wherein it was maximum during post-monsoon, which steadily decreased through winter and monsoon reaching the lowest range during summer.
4) In terms of species diversity of fishes, all the 3 lakes were extremely poor with only 3-4 species in every one of them. Planktivorous cyprinids dominated PL as well as SML, while benthophagus bagarids dominated CL. Fishery potential was very low at PL, possibly because of extreme clogging of the lake by submergents. Almost total lack of truly aquatic flora and resultant boost to the phytoplanktonic growth at SML must be responsible for the best fishery potential at SML.

5) The fairly balanced and diverse hydrophytic vegetation, reasonably good planktonic diversity owing to open water surface, adequate benthic macroinvertebrates, and resultant support of planktivorous and benthivorous fish must have been working in unison to sustain rich waterfowl population at CL in the form of primarily herbivorous ducks, insectivorous rails and piscivorous herons etc.

Chapter-V

1) The chapter deals with the information on the population dynamics of birds at PL, CL and SML with reference to their residential/ migratory status, arrival-departure schedules, food and feeding habits, habitat utility, breeding, inter/ intra species co-operation and conflicts.

2) The lake environs supported 60-69% of terrestrial bird species contributing up to only 10% of the population, while 90% of the population was that of waterfowl. Thickly vegetated waters of PL and CL supported a good number of herbivores, whereas clear waters of SML harboured large population of piscivores. From a utilitarian perspective, PL and CL were used to a great degree as foraging/ diurnal resting sites, while SML was utilised predominantly breeding/ nocturnal roosting site by the birds.
3) Communal breeding colony shared by Little cormorants, Little egrets, Cattle egrets, Purple herons, Darters and Night herons happens to be the only communal mixed heronry known to exist in the region, and reported for the first time by the author (Walia and Shanbhag, 1996 and Lainer, 1999). The breeding performance of egrets in the colony was hinged on the degree of confrontation they had with Little cormorants at the time of nesting. Night herons were not consistent in patronising the area. In view of limited/ restricted breeding of Lesser adjutant storks and Grey herons in the Indian subcontinent, their unsuccessful attempts to breed in the site are of interest. The foolproof security/protection the birds get in the area, in the form of industrial security could probably be one of the prime promoting factors for their communal breeding in the premise.

4) The Pintail ducks, Lesser whistling teals, Cotton Teals and Coots were the principal winter visitors of the lakes. Less of crowding and abundance of choice food reserves in the form of *Hydrilla* and *Utricularia* all along the wintering period could be responsible for the confinement of Cotton teals to PL. CL appears to be utilised by Pintails and Lesser whistling teals as diurnal resting and supplementary feeding site. Coots can be considered as opportunistic passage migrants at CL due to their brief stay for couple of months, making use of *Hydrilla* and benthic polychaetes abundant during the period.

5) Glaringly higher cumulative count for avifauna in general, waterfowl, and two of the three principal winter visitors—Pintail ducks and Lesser whistling teals during the year 1997 when compared to that during the previous year, amounts to indicate that the Konkan Railway track laying activities when at their peak did disturb the avifauna of the lake considerably. However, the impact was successfully recovered after the hectic building activities came to a halt. The routine running of train services does not seem to have the undue effect of any
kind, which may be because of precautionary measures adopted by the railway authorities in the form of declaring the area as the no hooting zone, and the establishment of the vegetation on the banks of the dike facing the lake to act as a buffer filtering the noise and visual disturbance.