Indian J. Fish., 46(3) : 251-264, Jul.-Sep., 1999

Limnology and status of the fishery of Nelligudda Reservoir (Bangalore: India)

D.S. KRISHNA RAO*, KATRE SHAKUNTALA, E.G. JAYARAJ AND S.R. REDDY

Department of Zoology, Bangalore University, Bangalore - 560 056, India

ABSTRACT

Nelligudda Reservoir (area: 80 ha, mean depth: 3.0 m) is a warm dimictic lake with stable thermal stratification for two extended periods (September-October and February-May) and with an intermittent period characterised by irregular circulation. Continuous mixing occurs during June-August. The water is well buffered, hard (mean alkalinity : 142.7 mg/1), moderately rich in electrolytes (mean conductivity : 373.4 uS/cm) and low in transparency (mean secchi depth : 51.3 cm). Clinograde distribution of oxygen, high sestonic carbon (mean : 5.0mg/l) and chlorophyll 'a' values (mean : 98.5 (ig/1) and high primary production rates (2.4 mg $C/m^2/d$) suggest that the reservoir is productive . Despite low dissolved nutrient concentration (soluble reactive phosphorus <10 ug/1), high algal biomass implies internal cycling of nutrients. The reservoir harbours around 20 autochthonous fish species of which the exotic *Oreochromis mossambicus* contributes more than 80% to the commercial fishery. Growth overfishing has resulted in the decline of mean landing size of *O. mossambicus* to around 10cm. The importance of maintaining a minimum landing size of 20cm is discussed. The catch per unit effort showed two peaks with a major one in July and a minor one in March.

Introduction

In India, reservoirs constitute an important inland fishery source. As opposed to large multipurpose reservoirs, small reservoirs like the Nelligudda reservoir impounded by damming small intermittent water sources serve as storage of the surface run-off for irrigational needs. These ecosystems, numbering around 19,000 with a total surface area of 1.48 million ha (Sugunan, 1995), are becoming increasingly important not only from the point of view of fish production but also from a social context as a means of providing employment to a sizeable section of the rural population. To formulate sound scientific management measures for augmenting fish production in reservoirs, basic research on reservoir productivity is a must. This would provide clues to the production potential of the ecosystem and would help in setting targets of fish production from such water bodies. Though studies have been made on the ecology and fish yield from small reservoirs (Anon, 1989; Selvaraj *et al*, 1994; Khan *et al*, 1996), due to the wide degree of variations in their morphometry, nature and degree of watershed, climatic factors and human inteference, the problems related to fishery management and their solutions are location specific. This paper

*Present address : *22, Dr. Rajkumar Road, 4th Block, Rajajinagar, Bangalore • 560 010.*

comprises a part of the detailed studies conducted on the limnology and fisheries of the Nelligudda reservoir during 1993 -1995.

Study site

Nelligudda reservoir, hereafter referred to as NR, was impounded in 1940 below the confluence of two seasonal streams (12° 50' N, 77° 22' E, 740m msl). The principal physical features are: maximum depth, 10m; mean depth, 3m; area, 80ha at FRL; shoreline development 2.3; watershed, 7,469 ha (Table 1). The lake is sheltered to some extent due to its location in the Ramanagaram hill ranges. Direct human impact on the nutrient budget is still trivial. Allochthonous influences on the nutrient budget appear to be significant due to large unintercepted watershed. NR region, considered a dry zone, is characterised by low rainfall (annual ranges from 679 to 889mm). The region receives both southwest and northeast showers with more than 50% being received between August and October. The variation in total annual inflow being wide, a year of high water level followed by one or two years of low level is characteristic of this region. The coldest month is January (mean daily minimum of 15°C) and the hottest is April (mean daily maximum of 34°C). The months of June and July are characterised by heavy southwest winds. The reservoir has not been brought under scientific fishery management in the recent past.

Materials and methods

Water samples were collected from August 1993 to August 1995 from different depths of the water column at a fixed station near the centre of the reservoir using Mac Vuit sampler (Litterick and Macvuti, 1985). Temperature and oxygen profiles were recorded (every week upto November 1994 and every fortnight thereafter) from surface to bottom at one metre interval. Temperature was measured, immediately after lifting the sampler, using a mercury thermometer graduated at 0.1°C interval. No significant difference was observed between the temperature measured this way and by using a sampler fitted with a reversing thermometer. Oxygen was estimated by the azide modification of the Winkler's method, total alkalinity using bromo-cresol green as indicator, soluble reactive phosphorus and total phosphorus (after persulphate digestion) by ascorbic method and ammonia by phenol hypochlorite method (Wetzel and Likens, 1991). pH was measured by a combined glass-calomel electrode (Toshniwal model CL 24) and conductivity by a conducti-vity bridge (Elico model). pH, alkalinity, conductivity,

TABLE 1. *Morphometric and edaphic characteristics of Nelligudda Reservoir*

Morphometry		Edaphic factors	Mean (± S.E.)
Year of construction	1940.0	Water temperature (°C)	25.6 (0.5)
Elevation (m msl)	740.0	Transparency (cm)	51.3 (34.6)
Maximum depth (m)	10.0	Alkalinity ($mg-^{1}$)	142.7 (28.3)
Area at FRL (ha)	80.0	Conductivity (u.S)	373.4 (74.3)
Mean depth (m)	3.0	Chlorophyll fug^{1})	98.5 (74.0)
Catchment area (ha)	7,469.0	Sestonic carbon (mg^{4})	5.0 (5.1)
Shore line devp.	2.3	Gross prod. (mgC nr^{2} d^{1})	2.4 (0.8)

phosphorous and ammonia were monitored fortnightly at 2m intervals from surface to bottom. A white Secchi disc (20cm) was used to measure transparency. Integrated sample of the top 2m of the water column, collected with the help of Lund's tubing, was used for the analyses of particulate organic carbon (POC) and chlorophyll 'a' (fortnightly from January 1994 to April 1995). POC was determined by the wet oxidation method (Wetzel and Likens, 1991). Aliquots of unfiltered samples ('whole') and that filtered through a 35 um nylobolt mesh ('<35 um faction') were filtered on to pre-ashed (500°C) GF/C filters. The filter papers with the residue were stored at 4°C prior to analysis. Chlorophyll 'a' data is presented elsewhere (Krishna Rao *et al.,* 1996 MSS).

Weekly catch and effort data on the fish resources of NR were collected from January 1994 through August 1995. As all the fish landings arrived at one point on the shore, it was possible to accurately record the day's total catch. The catch per unit effort (CPUE) is expressed as catch per craft-day The only craft used was *coracle.* Monofilament surface gill nets, ranging from around 25 to 50mm mesh bar was the principal gear used during all the seasons. Each *coracle* unit consisted of two fishermen and 5-7kg of nets (10-14 pieces). During the period of intense fishing, the nets were examined for fish, twice a day, once around 0600h and again around 1000h. The fish fauna was identified following Talwar and Jhingran (1991).

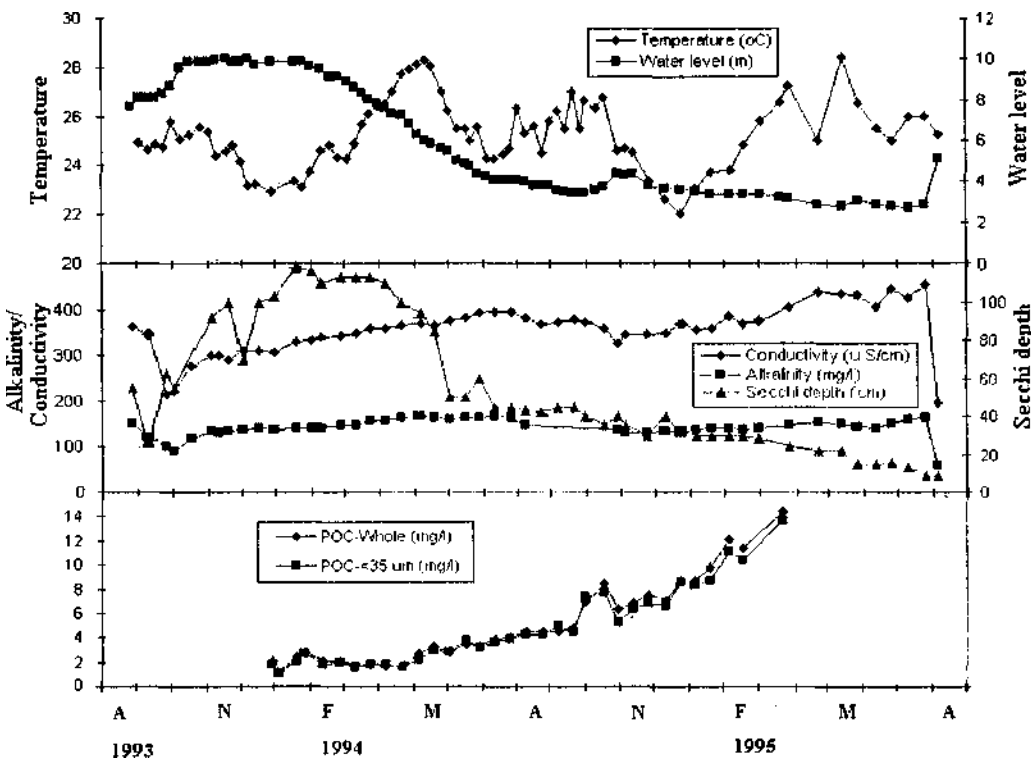

Fig. 1. Variations in water level and physico-chemical parameters (column averages of temperature, alkalinity and conductivity).

Results

Physical characteristics

The temporal variation in water level and physico-chemical parameters are given in Fig. 1 whereas the mean of the edaphic factors are presented in Table 1. The total rainfall received in 1993 and 1994 were 1,117mm and 736mm respectively. The reservoir became just full in 1993 due to sufficient inflow. The fluctuation in water level was negligible from mid October 1993 to January 1994, when thick growth of aquatic weeds {*Hydrilla, Vallisnaria* and *Potamogeton)* developed. Thereafter, the level rapidly decreased, due mainly to drawndown for irrigation, to reach the dead storage level by July 1994. Poor inflow in 1994 resulted in low water level in the second year.

Average temperature of the water column (1.0m below the surface to the bottom) varied sinusoidally from a winter low of around 22°C (December - January) to a summer high of around 28°C (May). A minor peak during September - October occurred when the weather was hot and wet (Fig.l). The depth-time distribution of temperature is presented in Fig. 2. In the first year, the reservoir exhibited

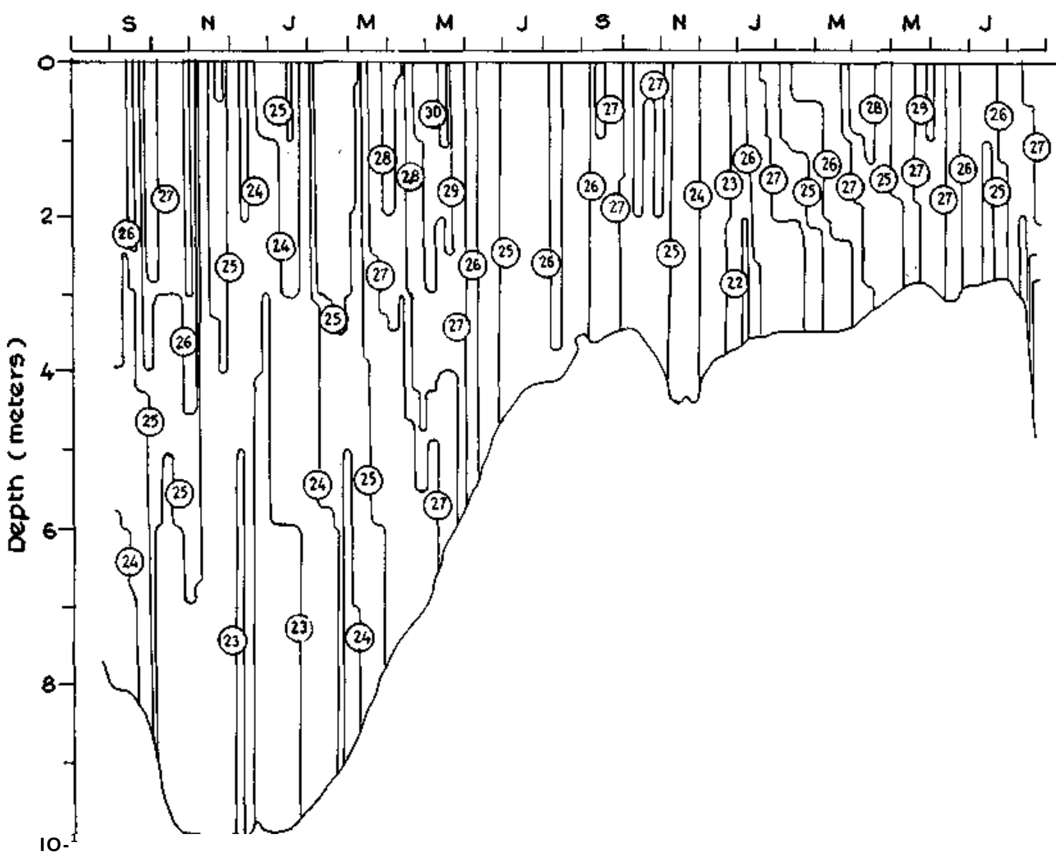

Fig. 2. Depth-time diagram for water temperature over the study period. Isopleths are drawn at intervals of 1°C.

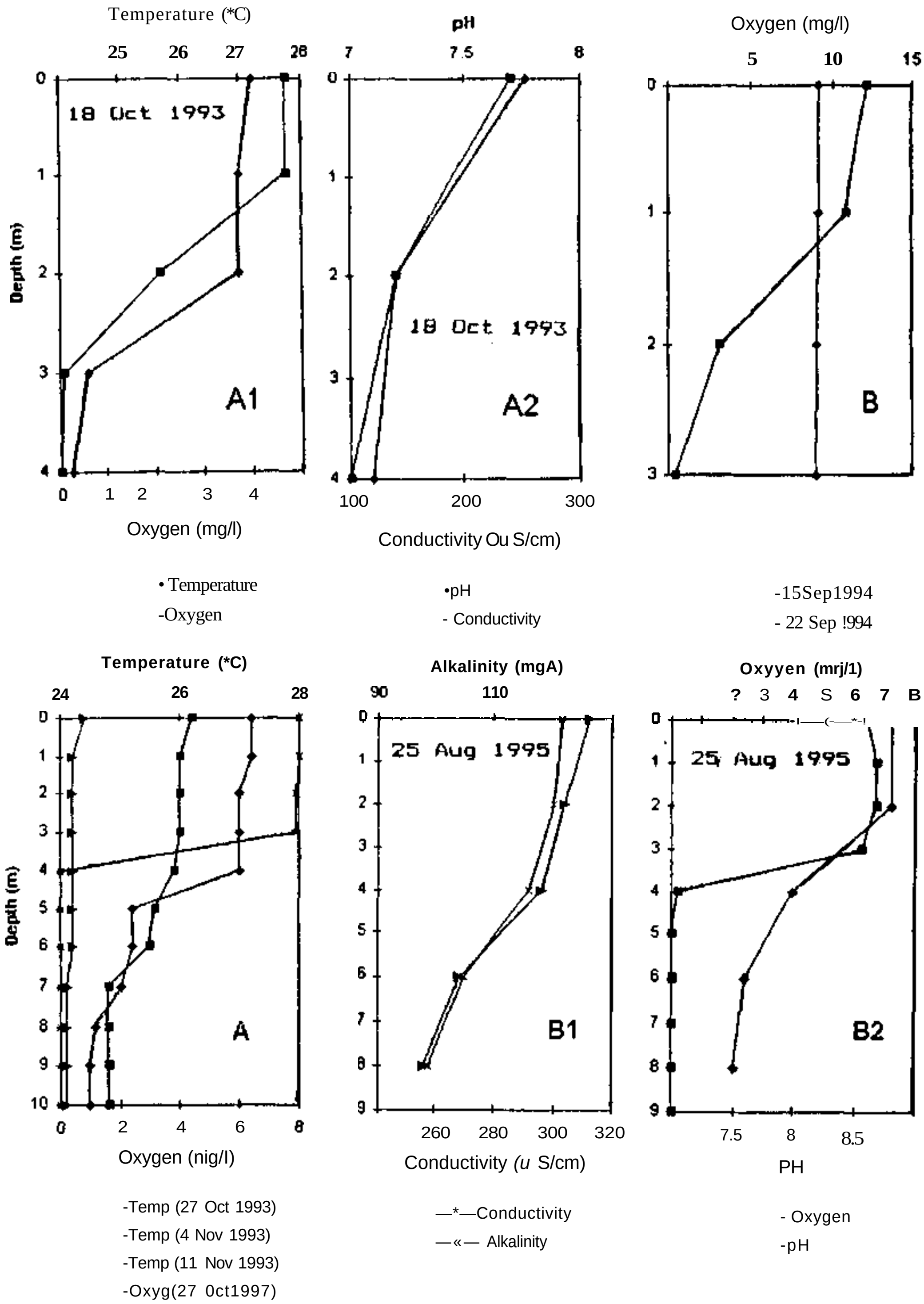

Fig. 3. Vertical profiles of temperature and chemical parameters on chosen dates.

stable thermal stratification for two extended periods namely late August to early November and again from February to mid May 1994. Complete circulation after the first stratification occurred during 4th - 11th November 1993 due to convective cooling (Fig. 3A). The period mid-November to January was characterised by frequent formation and breakdown of stratification. The reservior was in continuous circulation from June to August. In the second year, low water level prevented the establishment of a stable stratification. The thermocline depth during stable stratification was usually near 4.0 m. During the course of present studies, a maximum metalimnetic temperature gradient of 2.1°C was observed on 17 September 1993 when the thermocline was sharp.

Chemical characteristics

With few exceptions, the surface waters were well oxygenated down to 3.0 m (>3mg/l). The peaks and troughs in.surface oxygen coincided with winter and summer though no significant correlation was observed between

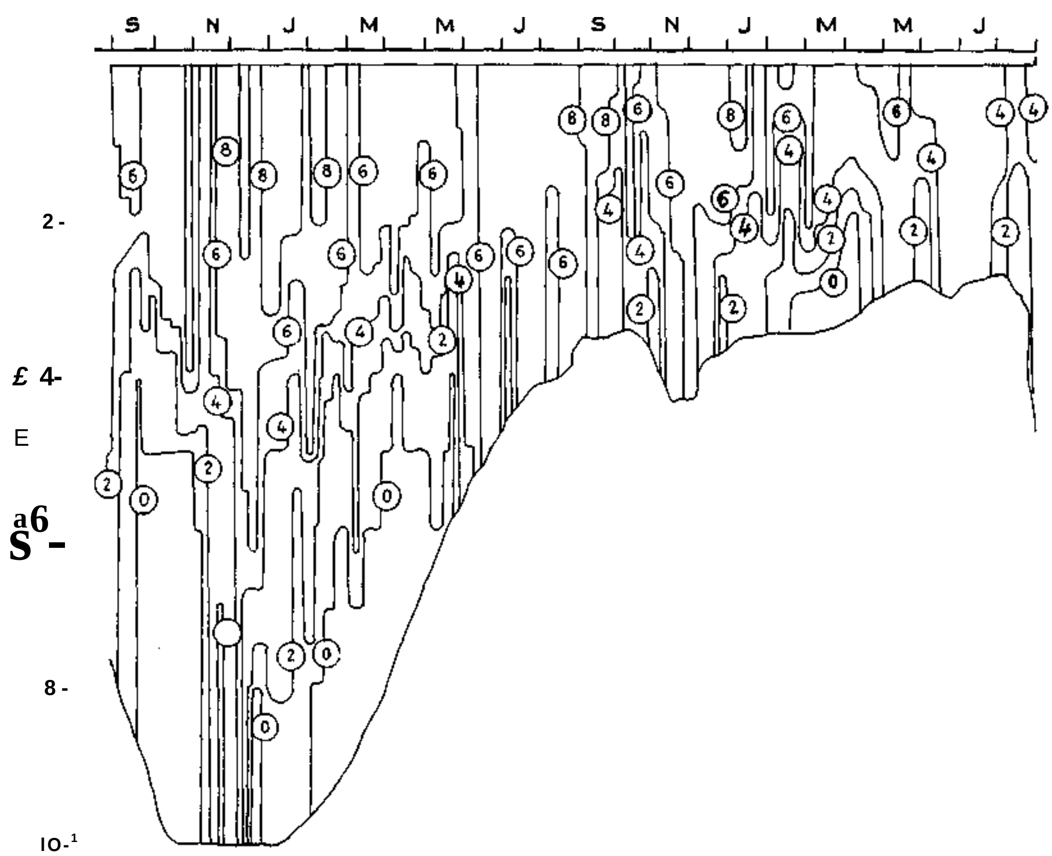

Fig. 4. Depth-time diagram for oxygen over the study period. Isopleths are drawn at intervals of 2 mg/1.

oxygen and temperature. The depth-time distribution of oxygen is presented in Fig. 4. During stable stratification, hypolimnion was anoxic for several weeks with the water emanating hydrogen sulphide smell. During other periods, calm weather lasting a few days was sufficient to totally deplete or reduce the oxygen to a very low level (e.g. 15-22 September 1994, Fig. 3B) indicating high decomposition activity. When the thermocline was sharp, a precipitous drop in oxygen was noticed (e.g. on 27 October 1993 oxygen at 4 and 5 m depths were 7.9 mg/1 and nil respectively; Fig 3A). Mixing followed by a calm weather raised the oxygen level in the surface layers due to greater photosynthesis (e.g. 15 - 22 September 1994; Fig. 3B).

Transparency showed clear seasonality during the first year with the minimum of 27 cm recorded in rainy season (inorganic turbidity) and the maximum of 118 cm in winter (high water level and low winds). In the second year, transparency remained low allthrough due to high algal standing crop (Fig. 1). The depth-time distribution of pH is presented in Fig. 5. pH of the surface waters registered narrow fluctuations during both the years (mostly between 8.5 and 8.9). Overall,

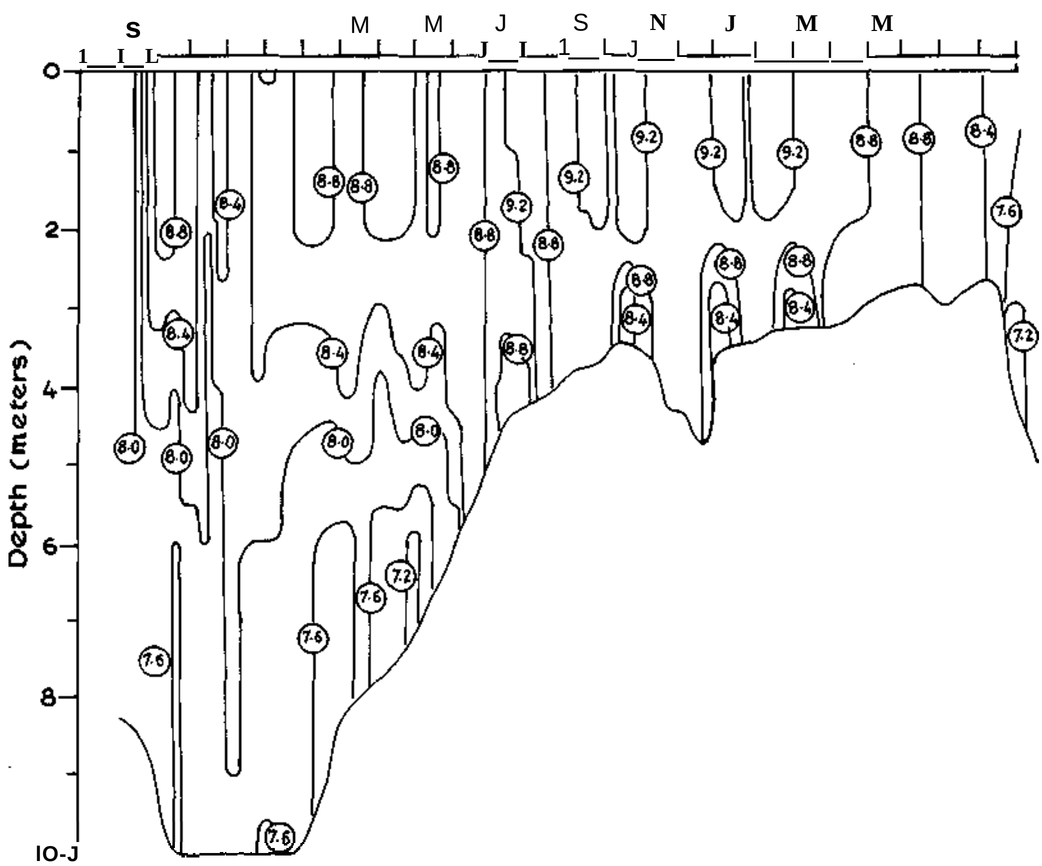

Fig. 5. Depth-time diagram for pH over the study period. Isopleths are drawn at intervals of 0.4.

pH in the second year was higher than the first year. During stratification, similar to oxygen, pH showed strong clinograde distribution (Fig. 3 A2 & B2). Both alkalinity and conductivity parameters showed more or less similar trend in seasonal variation with the peaks occurring in summer and the troughs in rainy season (Fig. 1). The maximum and minimum alkalinity values were 160 and 70mg/l and the conductivity values were 453 and 196 u S/cm (25°C) respectively.

Total phosphorus (TP) as well as soluble reactive phosphorus (SRP) were below our detection limit (<10 ug/1) during most part of the studies, except during September - December 1993 when concentration upto 110 (J^g/1 was recorded, the period coinciding with good inflow. Depth-wise analysis revealed a uniform distribution even during stratification. Ammonia-nitrogen was low (trace to 56.0 ug/1) near the surface on most occasions. However, high values (325 - 400 |ig/l) were recorded even near the surface during July - August 1995, the period coinciding with the collapse of algal bloom. Ammonia showed strong vertical heterogeneity during the stratification. In the bottom water, ammonia ranged from traces to 400 p.g/1.

'Total' as well as '<35 um faction' of POC showed near identical trend in fluctuations (Fig.l). After exhibiting low values (<3 mg/1) during summer stratification of 1994, the concentration gradually increased upto September 1994 coinciding with circulation and

TABLE 2. Fish fauna of Nelligudda reservoir

Family	Species
Cyprinidae	1. *Amblypharyngodon mola* (Hamilton-Buchanan)*
	2. *Cyprinus carpio* Linnaeus
	3. *Danio aequipinnatus* (McClelland)
	4. *Labeo boggut* (Sykes)*
	5. *Esomus danricus* (Hamilton-Buchanan)
	6. *Salmostoma belachi* Jayaraj *et al.**
	7. *Puntius dorsalis* (Jerdon)*
	8. *P. sarana* (Hamilton-Buchanan)*
	9. *P. sophore* (Hamilton-Buchanan)*
	10. *Parluciosoma daniconius* (Hamilton-Buchanan)*
	11. *Barilius bendalisis* (Hamilton-Buchanan)
	12. *Garra gotyla gotyla* (Gray)
Bagridae	13. *Mystus cavasium* (Hamilton-Buchanan)
	14. *M. vittatus* (Bloch)
Siluridae	15. *Ompok bimaculatus* (Bloch)
Cichlidae	16. *Oreochromis mossambicus* (Peters)*
Channidae	17. *Channa gachua* (Hamilton)
	18. *C. striatus* (Bloch)
Cobitidae	19. *Lepidocephalus thermalis* (valenciennes)
	20. *Nemachielus deninsoni* Day

•Common in commercial catches.

thereafter rapidly increased to reach a high of 13mg/l in April 1995. The '<35 urn faction' of POC constituted more than 90% of 'total' POC.

Correlation analyses

Transparency showed strong positive correlation with water level (r = 0.93) whereas pH, conductivity and POC showed strong negative correlation with water level (r = -0.62, r = -0.72, r = -0.74 respectively). Strong association of conductivity with transparency (r = -0.55) and alkalinity (r = -0.75), that of pH with transparency (r = -0.59) and POC (r = 0.77), that of POC with transparency (r = -0.80) were observed. Strong association also existed between chlorophyll 'a' and transparency (r = -0.87).

Fishery

The NR harbours a variety of fish species (Table 2) but the fishery was significantly dominated by *Oreochromis mossambicus,* contributing over 80% to the fish catches. The major carnivores (although present in sparse density) were *Channa gachua, C. striatus, Ompok bimaculatus, Mystus cavasius* and *M. vittatus.* In addition, some smaller species (eg. *Parluciosoma daniconius, Puntius sarana)* that are known to be important predators of fish fry especially that of *O. mossambicus* (in the

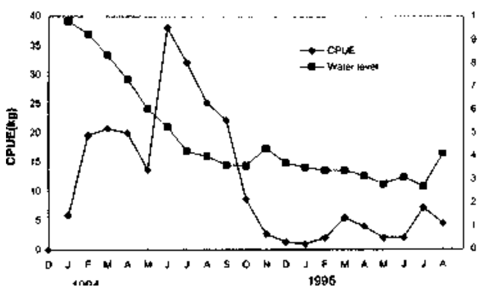

Fig. 6. Changes in the mean monthly catch per unit effort and water level.

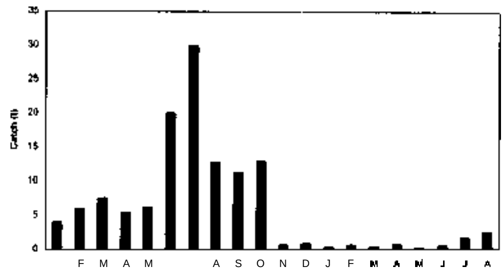

Fig. 7. Changes in the total catch.

littoral zone) may have a regulatory role on the population density of *O. mossambicus* (Schiemer and Duncan, 1987).

The temporal variation in CPUE is illustrated in Fig. 6. The CPUE showed near identical seasonal variations during both 1994 and 1995, with a primary peak around July and a secondary one around March. CPUE was at its lowest level in winter and could be due to dispersal of fish in the relatively high volume of water as well as poor activity patterns of fish. The CPUE remained high during major part of 1994 and the highest value of around 50 kg was recorded in June. After September 1994, a sharp decline occurred without further recovery. The CPUE was below 5 kg on most occasions in 1995 and the fishing intensity during this period was only around 0.25 craft/ha as compared to around one craft/ha during June - September 1994.

The monthly fish landings ranged from a low of around 200 kg/ha (May 1995) to a high of 30 t/ha (July 1994) Fig. 7). Consistently high catches were recorded during June - October 1994 (the period coinciding with receeding water level) followed by a sharp decline thereafter, the latter due to dwindling of stocks consequent to overexploitation in 1994, using small meshed gill nets. Estimation of annual fish production

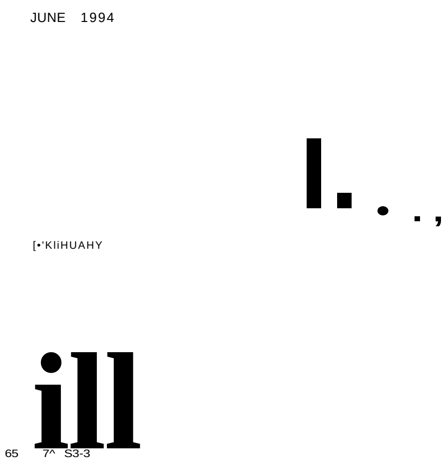

Fig. 8. Length-frequency distribution of *O. mossambicus* in the commercial catches (n : number of fish measured).

based on the absolute data on fish landings would be an overestimate due to severe overfishing. As the data pertains to a period of 20 months, the mean of the total landings for the first 12 months (January - December 1994, 114 t) and last 12 months (September 1994 - August 1995, 76 t) is taken as the estimate of the annual yield of 761. Considering this as the biomass (though an underestimate) and assuming that

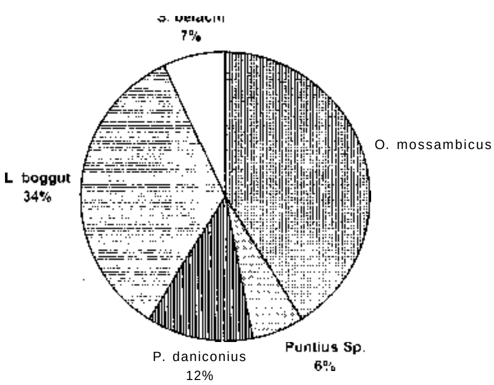

Fig. 9. Proportion of minor cyprinids in relation to *O. massambicus* in the experimental dragnetting.

sustainable yield is one third of biomass, the fish production would be a high of 460 kg/ha/a (average waterspread area : 55ha).

The landing size of *O. mossambicus* was small and around 40 - 100 g (7.5 -15 cm). The size which was around 10 - 15cm (mean : 12.7cm) during June - September 1994 to 7.5 - 12.5cm (mean : 10.4cm) after January 1995 (Fig. 8).

Based on observations made on experimental dragnetting (E.G. Jayaraj unpublished), minor cyprinids like *Labeo boggut, Parluciosoma daniconius, Salmostoma belachi* and *Puntius* spp. *(P. dorsalis, P. sarana* and *P. ticto)* appear to be abundant (Fig. 9).

Discussion

The productivity of a lake depends on nature and extent of the catchment area as well as the lake's morphometry. NR, with unintercepted large watershed and its proximity to the bourgeoning metropolis of Bangalore, has the advantage of receiving large quantity of organic rich allochthonous materia] and is corroborated by the anoxic hypolimnion during the period of inflow (September - October 1993 and August 1995). The morphological features of NR namely small surface area, sufficient depth and its sheltered location have strong effect on its physical structure. The lake thus exhibited stable thermal stratification for two extended periods i.e. September - October 1993 and again from February-May 1994, the former characterised by hot and wet weather and the latter by hot and dry weather (summer). The mixing during the intermittent period was due to convective cooling.

Continuous mixing during June-August was due to high winds and low water level. A number of workers have observed thermal stratification in tropical lakes with the fall in the metalimnetic temperature of less than 1°C (Lewis, 1973; Taylor and Gebre-Mariam, 1989). Despite rains and inflow, existence of stratification during September-October must be due to cool and dense inflow entering the lake along the bottom as a density current. This was corroborated by low values of conductivity and alkalinity in the bottom waters as compared to surface waters (Fig. 3 Bl & B2). Damas (1955) also observed Lake Mohasi in tropical Rawanda, only 13.8m deep, stratified during rainy season.

Though thermal stratification has been recorded in a number of Indian reservoirs - Tungabhadra (Rao and Govind, 1964), Rihand (Singh, 1985), Markonahalli (Krishna Rao unpublished) - there has been no mention of its stability as observations have been made at time intervals of about a month or more. Sreenivasan (1990) did not find stratification in a number of lowland Tamilnadu reservoirs. His speculation that 17°N latitude may be a dividing line for stratification is not true. In addition to geographical location (latitude), morphometry (surface area and depth) and vulnerability to wind stress have significant bearing on the thermocline stability (Lewis, 1973). NR is sufficiently deep to support thermocline that will be in equilibrium with strongest periods of the stratification period. Tropical lakes are divided according to frequency of circulation into polymictic, warm monomictic and oligomictic types (Hutchinson, 1957; Lewis, 1973). In a year of high water level, NR exemplifies a warm dimictic lake. There is no earlier record of a warm dimictic lake from India.

Thermal stratification produced the expected classical changes in the chemical structure of the NR such as oxygen depletion, pH reduction, increase in ammonia and accumulation of hydrogen sulphide in the hypolimnion (Golterman, 1975) and reflects the productivity of the reservoir. Similar to NR, clinograde distribution of oxygen has also been observed in some of the Indian reservoirs (Singh, 1985). Higher pH in the second year was due to higher photosynthetic activity (Krishna Rao, MSS), resulting in removal of more carbon dioxide (Huchinson, 1957). Narrow fluctuation in pH indicates the good buffering capacity of the water. Strong vertical heterogeneity in ammonia during stratification may be due to its release from decomposition of detritus and anaerobic denitrification of nitrate (Keeney 1973). The alkalinity and conductivity values suggest that NR is a hard water lake with the water moderately rich in electrolytes. Despite low SRP concentration, high primary production rates (2.4g Cm^2/d) recorded from the lake (Krishan Rao, 1996) is an indication of efficient P cycle mechanism. Excretion by zooplankton, rich in cyclopoids (Krishna Rao, 1996), may contribute significantly to the soluble P and N pools as in the case of Lake George (Ganf and Blazka, 1974). The orthograde distribution of phosphate during stratification has also been observed by Taylor and Gebre-Mariam (1989). The concentration of POC (also referred to as sestonic carbon) which includes the phytoplankton as well as detritus in suspension, gives a rough estimate of particulate food available to zooplankters. Rotifers prefer food less than 35 urn (Morgan, 1980). The POC values for NR *vis-a-vis* published information suggest that the lake is productive (Duncan and Gulati, 1980 ; Hart, 1987). The relation of water level with transparency, pH, conductivity and POC agrees with the published information (Patil and Gouder, 1985; Desai and Soni, 1994). Evaporation, with the progression of summer, leads to concentration of nutrients and increase in algal biomass and POC. Strong association between transparency and chlorophyll 'a' indicate that turbidity was mainly due to alga.

High yield recorded in NR, as compared to 100 - 300 kg/ha obtained in scientifically managed reservoirs (Jhingran, 1992; Selvaraj *et al.,* 1994) is primarily due to the shallowness of the habitat, high trophic status and overwhelming dominance of herbivore-detritivore, *O. mossambicus* (Fernando and Holick, 1982). Predicted fish yield of 137 kg/ha based on morphoedaphic index (MEI) (Joews and Griffith, 1979) is low. Attempts to apply the MEI to predict the fish yield for Asian reservoirs have not been successsful as these reservoirs do not confirm to the requirements on which the original MEI concept was based (De Silva, 1992). According to McConnell *et al.* (1977), gross photosynthesis (Pg) provides a fairly dependable guide to fish productivity. Assuming a transfer efficiency of 1% between gross production and fish production, the fish yield would be around 840 kg/ha and this may be more reasonable than our calculation. The small size of *O. mossambicus* was due to growth overfishing as recruitment overfishing is unlikely for *O. mossambicus* in a shallow reservoir like NR, as the cichlids are said to maintain their reproductive capacity at original level by changing their growth rate and maturity size, even at high mortality levels (lies, 1973). The decline in mean landing size from June-September 1994 (12.7cm) to January 1995 (10.4cm) further confirms the overexploitation, which was aided by the low water level (water level - June 1993 : 8.5m, June 1994 : 5.5m and June 1995 : 3m) (Fig.l). For optimum utilisation of O. *mossambicus,* the minimum landing size need to be maintained at or above 20cm through restriction of mesh size to around 100 mm (Amarsinghe, 1987). The strategies for their exploitation without causing any damage to the fishery of *O. mossambicus* have to be worked out (De Silva and Sirisena, 1987; Sirisena and De Silva, 1988). Despite riverine origin, the contribution of Indian major carps in augmenting fish production in Indian reservoirs is well documented (Selvaraj *et al,* 1994; Anon., 1998). Further, major carps fetch three times the price of *O. mossambicus.* Hence, is it worthwhile to continue with *O. mossambicus* or to take steps to stock major carps is a moot point.

Summarising, NR can be categorised as a warm dimictic lake in a year of high water level, when the lake shows stable thermal stratification for two extended periods (September-October and February-May) with the intermittent period characterised by irregular circulation. Continuous mixing occurs during June-August. The water is well buffered, hard, moderately rich in electrolytes and low in transparency. Clinograde distribution of oxygen, high POC and chlorophyll 'a' values and high primary production rates suggest that NR is productive. Despite low dissolved nutrient concentrations, high algal biomass implies internal cycling of nutrients. The fishery is monospecific, gill net fishery with predominant contribution by the exotic *O. mossambicus.* The mean landing size of *O. mossambicus* indicates overexploitation.

Acknowledgments

Thanks are due to Dr. M. Sinha, the Director, Central Inland Capture Fisheries Research Institute, Barrackpore - 743 101 for encouragement and to Dr. K.V. Devaraj for valuable guidance during the course of the study.

References

Amarasinghe, U.S. 1987. Status of the fishery of Pimburettewa Wewa, a man-made lake in Sri Lanka. *Aquacult. Fish. Manage,,* 18: 375-385.

Anon. 1989. Limnology and production biology of two man-made lakes in Rajasthan (India) with management strategies for their yield utilisation. Final report of IDA assisted pilot project on reservoir management in Rajasthan. CIFRI, Barrackpore.

Anon. 1998. Ecology and Fisheries of Marconahalli Reservoir. *Bulletin* No. 78, Central Inland Fisheries Research Institute, Barrackpore, India.

Damas, H. 1955. Recherches limnologiques dans quelques lacs du Rawanda. *Verh. Int. Ver. Limnol,* 12 : 335 - 341.

De Silva, S.S. 1992. Recommendations. In : *Reservoir Fisheries of Asia* S.S. De Silva (Ed.), p. 13-17, International Development Research Centre, Ottawa, Canada.

De Silva, S.S. and H.K.G. Sirisena. 1987. New fish resources of reservoirs in Sri Lanka : feasibility of introduction of subsidiary gill net fishery for minor cyprinids. *Fish. Res.,* 6: 17-34.

Desai, V.R. and S.C. Soni 1994. Potential fish yield of Ravishankarsagar reservoir (Dist. Raipur, M.P.) through chemical parameters of water. *J. Inland Fish. Soc. India,* 26(2): 1-8.

Duncan, A. and R.D. Gulati 1980. Feeding trials with natural food particles on tropical species of planktonic rotifers. In : *Limnology of Parakrama Samudra, Sri Lanka : a case study of an ancient man-made lake in tropics.* F. Schiemer (Ed.). Dr. W. Junk, the Hague, p. 95-106.

Fernando, C.H. and J. Holik 1982. The nature of fish communities : A factor influencing the fishery potential and yield of tropical lakes and reservoirs. *Hydrobiologia,* 97 : 127-140.

Ganf, G.G. and P. Blazka 1974. Oxygen uptake, ammonia and phosphate excretion by zooplankton of a shallow equatorial lake (Lake George, Uganda). *Limnol. Oceanogr.,* 19: 313-325.

Golterman, H.L. 1975. *Physiological Limnology-An Approach to the Physiology of Lake Ecosystem.* Elsivier, Amsterdam.

Hart, R.C. 1987. Population dynamics and production of five crustacean zooplankters in a subtropical reservoir during years of contrasting turbidity. *Freshw. Biol,* 6: 183-198.

Hutchinson, G.E. 1957. *A Treatise on Limnology,* Vol. 1. Wiley.

lies, T.D. 1973. Dwarfing or stunting in the *genus Tilapia,* Cichlidae: a possibly unique recruitment mechanism. Rapports et Process-Verbaux des Reunions. *conseil International pour L'Exploration de la Men,* **164** : 247-254.

Joews D.A. and J.S. Griffith 1979. Emperical estimate of potential fish yields for the Lake bangewelu system, Zambia, Central Africa. *Trans. Am. Fish. Soc,* 108 : 241-252.

Jhingran, A.G. 1992. Recent advances in reservoir fisheries management in India. In: *Reservoir Fisheries of Asia.* S.S. De Silva (Ed.), p. 158-178. International Development Research Centre, Ottawa, Canada.

Keeney, D.R. 1973. The nitrogen cycle in sediment-water systems. *J. Environ.Qua.,* 2: 15-29.

Khan, M.A., H.P. Singh, R.K. Dwivedi, D.N. Singh and R.K. Tyagi 1996. Ecology and fish yield from Baghla reservoir- a small impoundment in Ganga basin. *J. Inland Fish. Soc. India,* 28(2): 91-100.

Krishan Rao, D.S. 1996. Zooplankton dynamics and production in a tropical man-made lake. *Ph.D. Thesis,* Bangalore University, Bangalore.

Lewis. W.M. 1973. Thermal regime of lake Lanao (Philippines) and its theoretical implications for tropical lakes. *Limnol. Oceanogr.,* 18: 200-217.

Litterick, M. and K.M. Macvuti 1985. The Mac Vuti sampler: a new and inexpensive volume sampler for plankton and water. *Freshw. Biol,* 15: 465-467.

McConnell, W.J., S. Lewis and J.E. Olson 1977. Gross phytcsynthesis as an estimator of potential fish production. *Tran. Am. Fish. Soc,* **106:** 417-423.

Morgan, N.C. 1980. Secondary production. In : *Functioning of Freshwater Ecosystem* E.D. Le Cren. and R.H. Lowe-McConnel (Ed), p. 247-340. Cambridge University Press.

Patil, C.S. and B.Y.M. Gouder 1985. Ecological study of freshwater zooplankton of subtropical pond (Karnataka State, India). *Int. Revue, ges. Hydrobiol.,* 70 : 259-267.

Rao, D.S. and B.V. Govind 1964. Hydrology of Tungabhadra reservoir. *Indian J. Fish.,* 11A: 321-344.

Schiemer, F. and A. Duncan 1988. The significance of the ecosystem approach for reservoir management. In : *Reservoir Fishery Management and Development in Asia.* S.S. De Silva (Ed.), p. 183-194, International Development Research Centre, Ottawa, Canada.

Selvaraj, C, V.K. Murugesan, V.K. Unnithan and S. Manoharan 1994. Fish production potentiality of small reservoirs in Tamilnadu. *J. Inland Fish. Soc. India.,* 26(2): 9-16.

Singh R.K. 1985. Limnological observations on Rihand reservoir (Uttar Pradesh) with reference to the physical and chemical parameters of its water. *Int. Revue ges. Hydrobiol,* 70: 857-875.

Sirisena, H.K.G. and S.S. De Silva 1988. Nonconventional fish resources in Sri Lankan reservoirs. In : *Reservoir Fishery Management and Development in Asia.* S.S. De Silva (Ed.), p. 113-120, International Development Research Centre, Ottawa, Canada. .

Sreenivasan, A. 1990. Limnology and fisheries of South Indian reservoirs. In : *Reservoir Fishery Management and Development in Asia.* S.S. De Silva (Ed.), p. 23-37, International Development Research Centre, Ottawa, Canada.

Sugunan, V.V. 1995. Reservoir fisheries of India. FAO, Rome, Italy. *Fisheries Technical Paper* 345.

Talwar, P.K. and A.G. Jhingran 1991. *Inland Fishes of India and Adjacent Countries.* Oxford and IBH Publishing Co., New Delhi, 2 Vols.

Taylor, W.D. and Z. Gebre-Mariam 1989. Size structure and productivity of plankton community of an Ethiopian Rift Valley Lake. *Fresh Biol.,* 21 : 353-363.

Wetzel, R.G. and G.E. Likens 1991. *Limnological Analyses.* Saunders, Philadelphia, USA.