*Asian Fisheries Science* 5(1992): 1-13.
Asian Fisheries Society, Manila, Philippines

https://doi.org/10.33997/j.afs.1992.5.1.001

# Cage Fish Culture in the Lakes of Pokhara Valley, Nepal, and Its Impact on Local Fishers

D.B. SWAR and B.R. PRADHAN

*Fisheries Development Section*
*Harihar Bhawan, Pulchowk*
*Kathmandu, Nepal*

## Abstract

Cage culture of fish in Nepal began in Lake Phewa in 1972. At present, three lakes in Pokhara Valley are being used for this purpose, Lakes Phewa, Begnas and Rupa. The major species are planktivorous fishes, *Aristichthys nobilis* and *Hypophthalmicthys molitrix*, which are raised in floating cages, usually of nylon or polyethylene, without supplemental feeding.

Fish stocking density varies with the trophic state of the lake; in Lake Phewa, 6 fish·m$^{-3}$ and in Lakes Begnas and Rupa, 10 fish·m$^{-3}$. Annual production rates per m$^3$ are 3.4 kg in Lake Phewa, 4.7 kg in Lake Begnas and 5.0 kg in Lake Rupa. Mortality during the production period is about 5%.

A five-cage system has proven to be sufficient additional work for one fisher family and can add Nepali Rupees 9,000-14,000 to their annual income. Cage culture faces several constraints, especially the shortage of fingerlings. A hatchery facility and technical support are needed to expand and intensify cage fish culture in the Pokhara Valley.

## Introduction

Fish production in Nepal can be expanded through the wise use of inland waters involving aquaculture development (Sharma 1979; Swar 1980). Natural lakes and rivers in the country are estimated to offer about 400,000 ha of water for aquaculture development and additional water bodies are being made available

for fisheries with the construction of new irrigation dams and hydroelectric power stations. Village ponds in the southern belt of the country are widely used for fish culture but little has been done to develop aquaculture in natural waters. Currently only three lakes in the Pokhara Valley are being used for cage culture. The general practices of cage fish culture and its impact on local fishers of the Pokhara Valley are described in this paper.

Pokhara Valley, in the western part of Nepal at 28°13'N and 84°00E, is part of the Nepalese midlands, a relatively flat area with subtropical climate at an altitude of 827 m. The valley is characterized by soil with poor water retention and limited ground water. There are seven lakes, with a total surface area of about 10 $km^2$ but more than 80% are contained in three lakes, Phewa, Begnas and Rupa. The four small lakes are mostly filled with silt. Lake Phewa is mesotrophic, while Lakes Begnas and Rupa are moderately eutrophic. The hydrographic and limnological characteristics of these lakes are shown in Table 1.

### *History of Cage Culture in Nepal*

Fish culture in cages in Nepal started in 1972 at Lake Phewa, Pokhara Valley (Swar et al. 1983) as a facility for holding common carp *(Cyprinus carpio)* broodstock in the lake when the fishpond of the Government Fisheries Centre near Lake Phewa suffered a water shortage. The cages were used for several years to rear fish but remained a demonstration/study unit.

The larger lakes were studied under the framework of the Integrated Fishery and Fish Culture Development Project, assisted by the Food and Agriculture Organization/United Nations Development Programme (FAO/UNDP) (Ferro and Swar 1978; Swar and Fernando 1979, 1980; Swar 1980). These studies reported that Lakes Phewa, Begnas and Rupa were productive and could support an annual fish harvest of 51 t with proper management (Ferro 1980/81). Early government cage trials with planktivorous species, bighead *(Aristichthys nobilis)* and silver carp *(Hypophthalmichthys molitrix)* were successful [B.R. Pradhan, unpubl. report] and attracted the interest of local fishers. Eight fishers initially received financial assistance from the Agriculture Development Bank of Nepal and set their cages in Lake Phewa in 1978. Fishers of Lakes Begnas and Rupa also showed interest and set a few cages in those

Table 1. Hydrographic and limnological characteristics of Lakes Phewa, Begnas and Rupa (after Swar 1980).

| | Phewa | Begnas | Rupa |
|---|---|---|---|
| HYDROGRAPHIC FEATURES | | | |
| Elevation, (m) | 742 | 650 | 600 |
| Area, (ha) | 400 | 244 | 117 |
| Maximum depth, (m) | 19 | 7.5 | 4.5 |
| Mean depth, (m) | 7.6 | 4.6 | 2.3 |
| Volume of water, ($m^3$) | $30 \times 10^6$ | $10.2 \times 10^6$ | $2.7 \times 10^6$ |
| Watershed, ($km^2$) | 110.00 | 20.00 | 30.00 |
| LIMNOLOGICAL FEATURES | | | |
| Secchi disc transparency (m) | 1.5-4.1 | 1.5-3.5 | 1.5-2.5 |
| pH of surface water | 7.5-9.1 | 7.2-8.9 | 7.1-8.0 |
| Dissolved $O_2$ in epilimnion ($mg\ O_2\ l^{-1}$) | 7-11 | 5.5-11.0 | 7.5-15.0 |
| Oxygen saturation of surface water (%) | 88-122 | 69-129 | 90-217 |
| Average conductivity over the water column (µmho) | 33-47 | 27-50 | 27-51 |
| Surface water temperature (°C) | 15.2-28.2 | 15.1-30.3 | 15.2-30.2 |
| Near bottom water temperature (°C) | 15-21.2 | 14.9-25.8 | 15-27 |
| Total gross primary production ($kg\ O_2\ m^2\ year^{-1}$) | 2.2 | 2.67 | 3.45 |

lakes in the following years. This program was further assisted by FAO from 1980. Under another project, 100 fishers were trained and cages and nylon twine were made available. The money paid by the fishers for the cost of the cages and other materials is being kept as a revolving fund to develop further the cage culture program. Cage culture has subsequently expanded among local fishers because it is a good source of income and employment. At present, the total number of cages in these lakes is 345 (16,740 $m^3$) and the estimated total production is about 66 t. The distribution of cages in the three lakes is shown in Table 2.

### *Fish Species*

The fish species raised in cages in Nepalese lakes are mainly carps. The natural fish food in the lakes varies, so fish species with

Table 2. Status of cage culture in the private sector, Nepal, 1986-1987.

| Lake | Total no. of cages | Total volume of cages ($m^3$) | Production cages | | Nursery cages | |
|---|---|---|---|---|---|---|
| | | | Number | Volume ($m^3$) | Number | Volume ($m^3$) |
| Phewa | 79 | 3,512 | 75 | 3,406 | 4 | 106 |
| Begnas | 112 | 6,239 | 86 | 5,987 | 26 | 252 |
| Rupa | 154 | 6,988 | 122 | 6,563 | 32 | 425 |
| Grand total | 345 | 16,739 | 283 | 15,956 | 62 | 783 |

different feeding habits are selected to utilize available resources. The following carps are used: bighead carp, silver carp, grass carp *(Ctenopharyngodon idella)*, common carp and rohu *(Labeo rohita)*. Bighead carp, which continue to feed down to 14°C, so far have the best potential for cage culture. Silver carp are intolerant of stress; sudden environmental changes can cause heavy mortality. Grass carp, which can be fed grass in cages, are suitable when water bodies are poor in plankton. They are cultivated in Lake Phewa but only in a few cages. Common carp, being a bottom feeder, need additional feeding in the floating cages; this practice is still in the experimental stage in Nepal. Rohu, a bottom and water column feeder which eats plant matter including decaying vegetation, also does poorly without artificial food. When stocked in cages at low densities (2-4% of total fingerlings) however, growth has been good. Rohu also help clean the cages by feeding on algae and other organisms growing on the mesh.

### *Construction and Design of Cages*

Although the first cage used in lake Phewa was made of nylon net, several cages constructed from local materials were tried in 1976-78. A few of them are described here:

- *Bamboo cages.* These were constructed entirely of bamboo and were anchored with heavy stones. They usually lasted about two years, but did not function well because of fluctuating water levels and occasional heavy storms. Fish handling was difficult.

- *Wooden cages.* Although wooden cages were very durable, they were not popular because of their weight and bulk. They were also affected by water fluctuation and fish handling was again difficult.
- *Iron wire mesh cages.* Galvanized iron chicken mesh was used on a bamboo frame. This type of cage was not successful because the mesh rusted within six months.
- *Angle iron and netlon cages.* Angle iron of 13 or 19 mm was welded to form a frame of 4 x 4 x 2.5 m to which netlon plastic mesh of 10 or 15 mm was attached with nylon twine. Four 200-l oil drums were mounted on four welded frames to float the cage (Fig. 1). The cage was partitioned into two compartments by netlon which allowed different sized fish to be kept separate. These cages also had a cover. The oil drums rusted after two years, and the welded joints started to rust and crack after heavy storms. Fish handling was done with a large scoop net attached to two long handles.
- *Nylon or polyethylene net cages.* Several types of ready-made cages were initially imported, but later local fishers wove nylon or polyethylene "bags" locally. They mounted the bag-type cages on a bamboo frame which also served as a float. The shape of the cage was produced by using stones at the four corners. Net cages are easy to handle and maintain. This type of cage can be set separately on a bamboo frame (Fig. 2) or on a wooden or galvanized iron pipe flotation system (Fig. 3). Fish can be harvested partially or totally with the help of a bamboo log. Net cages are most popular among fish growers in Pokhara Valley.

Most private cages in Nepal are 50 $m^3$ (5 x 5 x 2 m), a convenient size for handling. They are managed by boat. When four or more cages are set together with walkways between them, the frame must be constructed either of wood or galvanized iron pipes (Fig. 3). Empty oil drums or styrofoam blocks are used to float such frames. The number of floats and their placement depends on the size and configuration of the cages. The frame is anchored by a concrete block at each corner. This type of frame is costly but durable and convenient. A few large cages of 98 and 150 $m^3$ are in operation in the government sector.

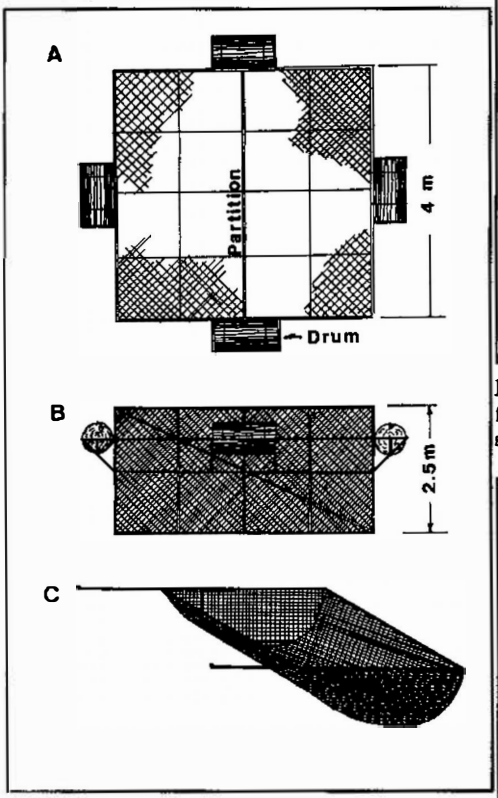


Fig. 1. Netlon cage with iron angle frame. A. top view; B. side view; and C. scoop net.

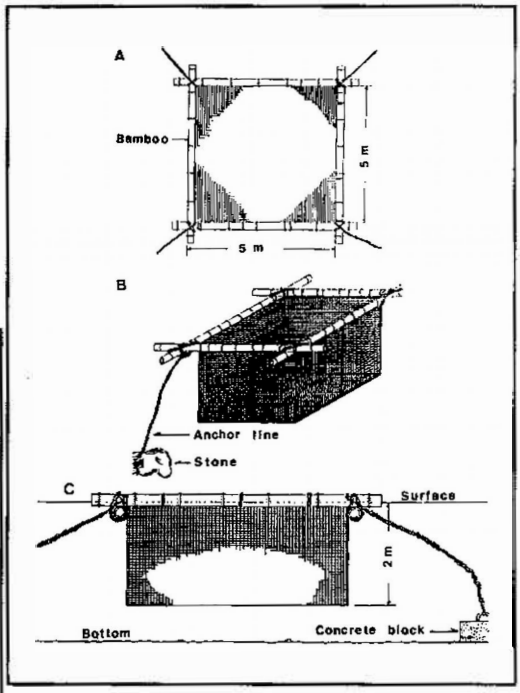


Fig. 2. Nylon or polyethylene net cage with bamboo frame and float. A. top view; B. isometric view; and C. side view.

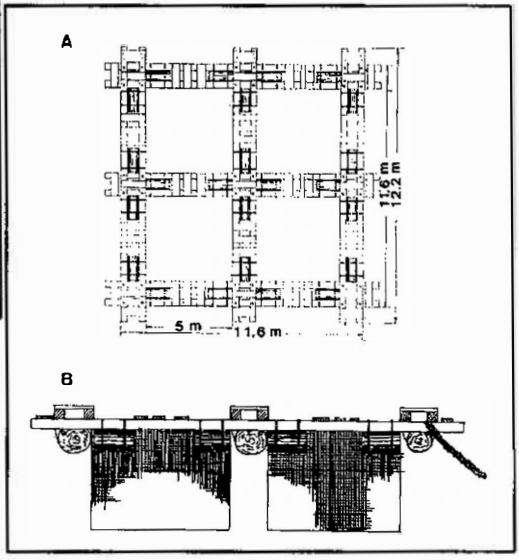


Fig. 3. Wooden frame with empty oil drum floats. A. top view; and B. side view.

In each lake, 20% of the cages were randomly selected to measure fish growth. Twenty per cent of Chinese carps (bighead and silver carp) were taken from each cage and bulk weighed monthly from October 1984 to October 1985. The total population of rohu was measured due to their limited number in the cages. The average weight of an individual was calculated by dividing the measured biomass by the number of fish weighed. Mortality was observed by directly counting the live fish of each species at the end of the observation period. Species biomass was calculated by multiplying the average weight of the particular species by its number. Total fish production per cage was calculated by adding the biomass of each species and average fish biomass per cage was divided by cage volume to find out the fish production per cubic meter. Actual costs and returns were based on the expenditures involved in the private sector and their fish production. The bankers were also interviewed to confirm the information on initial investment and interest rate. The market price of fish and other materials was observed.

### *Management*

Bighead and silver carp are the main species reared in the floating cages. Rohu are stocked at a low density to act as biological cage cleaners. Grass carp are also cultured on a small scale in Lake Phewa. The cultivation of common carp with low-cost feed did not yield a good harvest (Pillai and Sollows 1980).

The optimum stocking density of fingerlings varies with the trophic state of the lake. In Lake Phewa, 6 $m^3$ are stocked (bighead carp 95% and rohu 5%). In the more fertile lakes, Begnas and Rupa, the stocking density is 10 $m^3$ (bighead carp 49%, silver carp 49%, rohu 2%). The optimum density of fingerlings for each lake was derived from previous research on cage fish culture conducted by the Pokhara Fishery Development Centre (Pokhara Fishery Development Centre, unpubl. report). The average weight of fingerlings stocked varies from 15 to 25 g. The fry are raised in nursery ponds up to 5 g, then moved to nursery cages and reared to 15-25 g. At this weight they are stocked in production cages. Fish seed for cage fish culture in the Pokhara Valley was supplied by other fish hatcheries at Hetauda, Bhairahawa and Kathmandu. Details of

rearing of fish fry in nursery pond cages will be reported by the authors in separate papers.

Average annual gross production and monthly growth of fish during 1984-85 in the floating cages of three lakes are presented in Fig. 4. Lake Phewa had the lowest annual production, 3.4 $kg \cdot m^{-3}$, while the annual production of Lake Rupa was highest at 5 $kg \cdot m^{-3}$. Annual production in Lake Begnas was 4.7 $kg \cdot m^{-3}$ (Pokhara FDC, unpubl. report). Mortality during the study period was 4-5%.

The cage culture of planktivorous carps without artificial feeds has produced high yields in several tropical systems. In Selter Reservoir, Singapore, bighead carp production was 5.7 $kg \cdot m^{-3} \cdot year^{-1}$ (Chookajorn 1982). Khalil (1982) has documented bighead carp production as 5.9, 6.6 and 9.2 $kg \cdot m^{-3}$ (depending on the stocking density) in 8 months in the Durian Tunggal Reservoir, Malaysia. In comparison to the above, our fish production is low. Higher water temperatures and stocking densities are probably responsible for increased production in the reservoirs of Singapore and Malaysia. High production of silver carp and tilapia has been reported from the highly eutrophic systems in South Africa (Gaigher and Krause 1983). However, trophic levels of these aquatic systems are not comparable.

The cages are harvested either partially or totally. In partial harvests, harvested fish are, in general, the largest or least healthy individuals. Removal of the larger fish reduces competition for food, allowing small fish to reach market size faster. Harvesting unhealthy fish removes the sources of disease. A total harvest is advisable only if the overall production will be improved by replacing old stock with new fingerlings or if the cage will be restocked immediately after harvest.

### *Socioeconomics*

Cage culture is generally considered a lucrative practice in Nepal because there is no investment for feed; the cage can be used continuously for several years; and the survival rate of fish is high.

The actual costs and returns for a set of five 50-$m^3$ cages in three lakes are shown in Table 3. The initial cost for five cages and accessories was Nepali Rupees 21,000 (US$1 = NRs. 21.5). The cage

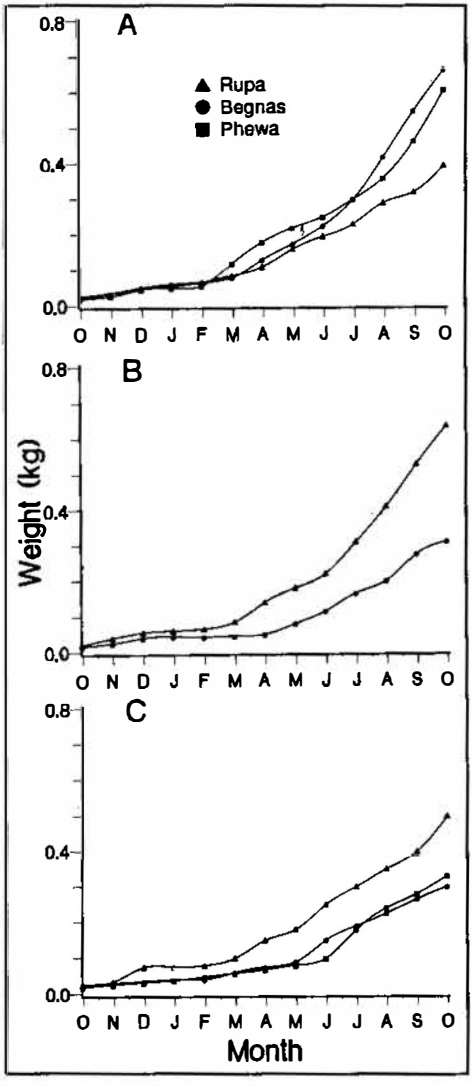


Fig. 4. Monthly average weight (kg) of A. bighead carp; B. silver carp; and C. rohu held in cages in lakes of the Pokhara Valley (1984-85).

can be used continuously for 8 years. The annual operating cost includes the yearly installment of the bank loan including interest, cost of fingerlings, labor charge, cost of bamboo poles and miscellaneous items. The total annual costs in the three lakes were similar - about 10,000-11,000 NRs. The return to the fish growers varied among the lakes due to different rates of annual production and the price of fish (Table 3). The net return on the annual cost ranged from 98% in Lake Phewa to 130% in Lake Rupa. Most fishers set up and operated their own cages in neighboring lakes.

The major lakes in the Pokhara Valley are surrounded by an estimated population of 300 traditional fishing families. The majority of these families are landless and live by fishing and doing occasional work as laborers in agriculture and general construction. Before 1960, these fishers used only local fishing methods including cast nets and hooks and line. Gill nets were introduced in the early 1960s. The fish catch in-creased for a few years, but this placed heavy pressure on the fish stocks of sahar *(Tor tor)* and katle *(Acrossocheilus hexagonolepis),* large, long-lived species (Ferro 1980). Gill netting shifted the species composition towards small and short-lived species such as *Puntius* and *Mystus* spp. and was accompanied by a great decline in the

overall fish catch which adversely affected the fishing community. Ferro (1980) estimated the 1977 income of a fishing family at about NRs. 1,236-3,800, depending on their locality and fishing effort, although the government reported their annual income to be around NRs. 4,000-5,000 in 1976 (B.R. Pradhan, unpubl. report). Regardless of which figure is used, the income was hardly enough for their subsistence.

With the introduction of the cage culture program, these families were encouraged to own cages and grow fish to earn additional income. The number of cages owned by an average family of five varied from one to five. However, a set of five cages (250 $m^3$) has proven sufficient and can add NRs. 9,000-14,000 to a family's annual income.

Fishers in the Pokhara Valley are grouped into two informal associations. The Khapaundi Fish Growers' Association is comprised of fishers living around Lake Phewa, while fishers of Lakes Begnas and Rupa formed the Deurali Fish Growers' Association. These associations assist the Government Fishery Development Centre in the overall management of the lake fishery and cage culture. They also take care of fish marketing. The technical aspects of cage culture, such as fingerling supply, training and technical supervision, are undertaken by the Fishery Development Centre, which also conducts research on cage culture.

### *Constraints and Recommendations*

The cage fish culture program in the Pokhara Valley has been beneficial and has attracted the attention of fishers and other members of the community. It has provided employment and additional income to local fishers, and increased the supply of fish protein for the people of Pokhara Valley. It has also helped to reduce pressure on native fish by diverting fishers from fishing to aquaculture. However, there are several constraints which limit the expansion of cage culture in these lakes. The principal constraint is a lack of suitable fingerlings to stock in the cages, which has also affected intensification. The supply of fingerlings is inadequate due to the lack of a fish hatchery in the valley and the tremendous increase in demand for fingerlings for pond culture throughout Nepal. Several measures are needed to expand and intensify cage

Table 3. Costs and returns for a five-cage system (250 $m^3$) in three lakes in the Pokhara Valley, Nepal, 1984-85.[a]

| | Lake Phewa | Lake Begnas | Lake Rupa |
|---|---|---|---|
| Initial costs: | | | |
| Five cages (at NRs. 4,000 each) | 20,000 | 20,000 | 20,000 |
| Ropes and anchors | 1,000 | 1,000 | 1,000 |
| Total initial costs | 21,000 | 21,000 | 21,000 |
| Annual costs: | | | |
| Annual installment on initial investment | 4,000 | 4,000 | 4,000 |
| Fingerlings[b] (at NRs. 0.66 for 20-g fish) | 990 | 1,650 | 1,650 |
| Bamboo poles | 500 | 500 | 500 |
| Labor 75 days (at NRs. 40 per day) | 3,000 | 3,000 | 3,000 |
| Interest on working capital (12%) | 659 | 659 | 659 |
| Miscellaneous | 1,000 | 1,000 | 1,000 |
| Total annual costs | 10,149 | 10,888 | 10,188 |
| Return to the grower[c] | 19,550 | 23,600 | 25,000 |
| Less cost of production | 10,149 | 10,888 | 10,888 |
| Net return to the fish grower (in NRs.)[d] | 9,401 | 12,712 | 14,112 |

[a]Based on field studies.
[b]Stocking density: Lake Phewa - 6 fish·$m^3$; Lake Begnas and Rupa - 10 fish·$m^3$.
[c]Annual production: Lake Phewa - 3.4 kg·$m^3$; Lake Begnas - 4.7 kg·$m^3$; Lake Rupa - 5 kg·$m^3$. Price of the fish: Phewa - NRs. 23/kg; Begnas and Rupa - NRs. 20/kg.
[d]NRs. - Nepali Rupees; US$1 = NRs. 21.50.

culture in the Pokhara Valley. A fish hatchery must be established in or near the Pokhara Valley to meet the increasing demand for fingerlings. Further development of cage culture will also depend on additional limnological information. As fish culture increases, the potential for disease increases. Therefore, the fish culture program must include the investigation and control of fish disease and parasites. Finally, the fishers' associations need to be strengthened in order to run the fish production program more effectively.

## Acknowledgements

We thank our colleagues, Messrs. B.C. Shrestha, T.B. Gurung and R.C.L. Das, Fisheries Development Centre, Pokhara, for their assistance in collecting the information presented in this paper. We also express our sincere appreciation to Dr. M. Nakanishi, Otsu Hydrobiological Station, Kyoto University, Japan, for his constant encouragement and cooperation throughout the study. Dr. J.F. Craig, Freshwater Institute, Winnipeg, Canada, provided useful suggestions. Part of the study was completed during the tenure of the Japan Society for the Promotion of Science Fellowship awarded to D.B. Swar.

## References

Chookajorn, T. 1982. Cage culture in reservoirs in Singapore. Thai Fish. Gaz. 35(6): 661-665.

Ferro, W. 1980. Data on the fishery in Pokhara Valley (Nepal) and their implication for the fishery management. Inst. Sci. Tribhuvan Univ., Kathmandu.

Ferro, W. 1980/81. Limnology of Pokhara Valley lakes (Himalayan region, Nepal) and its implication for fishery and fish culture. J. Nepal Res. Cent. 5/6: 27-52.

Ferro, W. and D.B. Swar. 1978. Bathymatric maps from three lakes in Pokhara Valley (Nepal). J. Inst. Sci. 1: 177-188.

Gaigher, I.G. and J.B. Krause. 1983. Growth rates of Mozambique tilapia *(Oreochromis mossambicus)* and silver carp *(Hypophthalmichthys molitrix)* without artificial feeding in floating cages in plankton rich waste water. Aquaculture 31: 361-367.

Khalil, R. 1982. Cage culture in freshwater in Malaysia with emphasis on the program of the freshwater fish culture research station (MARDI), Batu Berendam, Malacca, Malaysia, p. 177-185. *In* Report of the training course on small scale pen and cage culture for finfish. Los Baños, Laguna, Philippines, 26-31 October 1981 and Aberdeen, Hong Kong, 1-13 November 1981.

Pillai, T.G. and J.D. Sollows. 1980. Cage culture in Nepal. A report prepared for the Integrated Fisheries and Fish Culture Development Project. FI: DP/NEP/73/025, Field Doc. 8, 28 p. FAO, Rome.

Sharma, R.N. 1979. Cage fish culture in Nepal, p. 93-96. *In* Proceedings of the International Workshop on Pen and Cage Culture of Fish, 11-12 February 1979, Tigbauan, Iloilo, Philippines. Southeast Asian Fisheries Development Center, Aquaculture Department, Iloilo, Philippines.

Swar, D.B. 1980. Present status of limnological studies and research in Nepal, p. 43-47. *In* S. Mori and I. Ikushima (eds.) Proceedings of the First Workshop for Promotion of Limnology in Developing Countries. Organizing Committee XXI Congress, Societas Internationalis Limnologiae, Kyoto, Japan.

Swar, D.B. and C.H. Fernando. 1979. Seasonality and fecundity of *Dalphnia lumholtzi* Sars in Lake Phewa, Nepal. Hydrobiologia 64: 261-268.

Swar, D.B. and C.H. Fernando. 1980. Some studies on the ecology of limnetic crustacean zooplankton in Lakes Begnas and Rupa, Pokhara Valley, Nepal. Hydrobiologia 70: 235-245.

Swar, D.B., B.C. Shrestha and P.L. Joshi. 1983. Observation on the growth rate of two fishes *Aristicthys nobilis* and *Hypophthalmichthys molitrix* in the cages of Begnas Lake, Pokhara Valley, p. 258-260. *In* Proceedings of the National Science and Technology Congress, National Centre for Science and Technology, Kathmandu, Nepal.

*Manuscript received 21 February 1989; revised ms received 27 October 1989; accepted 2 February 1990; corrected galley received 12 December 1991.*