KEOLADEO NATIONAL PARK
ECOLOGY STUDY

ANNUAL REPORT
1986

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BOMBAY NATURAL HISTORY SOCIETY

KEOLADEO NATIONAL PARK
ECOLOGY STUDY

Annual Report

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PREFACE

This report summarises the various studies on the ecology of Keoladeo National Park conducted during 1986, which are largely continuation of the previous years work. While we have completed field work on many of the aspects, some are newly identified and launched. Field work is expected to be completed by the middle of 1989. Important findings of all the aspects studied are included in the report.

The research staff mainly were the same as in 1985, but we had two major 'erosions' from the research team namely Mr. B.K. Chakrapani, our chief limnologist, who resigned from the project in July 1986 in favour of a permanent assignment, and Mr. V.P. Prasad, our chief botanist, who resigned to join the Botanical Survey of India. In the latter part of the year we welcomed to our team Mr. S. Muralidharan who was with the bird hazard project of the BNHS.

We continued to encourage the post-graduate and doctoral research programmes of the staff. All but two are on these programmes, working on topics allotted to them earlier; topics which are essential parts of the ecosystem study. They are being supervised by experts from various universities such as Saurashtra, Rajasthan, Agra, Kanpur, Bombay, and Aligarh Muslim University.

Research topics handled by staff during 1986 were :

Mr. S. Muralidharan: Plankton biomass; planktonic primary productivity.

Mr. Deen Dayal Mittal : Physicochemical properties of water.

Dr. (Mrs.) Lalitha Vijayan: Aquatic macrophyte (since V.P. Prasad left), Land bird breeding, Land bird census, Siberian crane ecology.

Mr. John George: Aquatic macroinvertebrate; Bio-ecology of Cassida circumdata.

Mr. T. Sundaramoorthy: Land insects, Land bird community.

Mr. C.R. Ajith Kumar: Ichthyological studies.

Mr. C. Nanjappa: Terrestrial vegetation; phenology, grass biomass.

Mr. U. Sridharan: Ecology of resident waterfowl.

Mr. C. Sivasubramanian: Ecology of piscivorous birds.

Mr. N.K. Ramachandran: Ecology of jacanas.
Mr. S. Bhupathy: Ecology of migratory waterfowl, python and turtle.
Mr. Vibhu Prakash: Ecology of Raptors.
Mr. Md.Nayerul Haque: Mammal studies.

The team which studied the population of aquatic birds comprised Dr. (Mrs.) Lalitha Vijayan, M/s.U.Sridharan, Vibhu Prakash, C. Sivasubramanian, N.K. Ramachandran, T.Sundaramoorthy and S. Bhupathy.

We expect two botanists, two planktonologists, one biostatistician, one computer analyst and one lab analyst to join us.

Miss Marry Kutty Mathew, typist, and Mr. V.K. Sharma, accountant continued in service during 1986. We had nine local assistants to help us in the field.

Each aspect of the report is prepared by the respective scientist under the direction of the project scientist.

A list of reports, papers, short communications and theses which emanated from the project till March 1987 is appended.

V.S. Vijayan
(Project Scientist)

AN OVERVIEW

One of the unique features of the wetland ecosystem of Keoladeo National Park is its origin from a natural depression which was an evanescent rain-fed wetland. Construction of Ajan bund, a temporary reservoir half a km from the present park area, some 250 years ago and the subsequent flooding of the area marks the beginning of human involvement in the conversion of this natural depression into a permanent waterfowl reserve. Subsequenly several earthern bunds and sluice gates were constructed to contain and regulate the water level.

The water inside the Park, drawn through a canal from Ajan bund during monsoon, gradually recedes and the Park dries up during May - June, leaving only some pools in the deeper areas. These pools which teem with fish attract flocks of fish eating birds of different species. Despite this, a large number of fish die in the drying pools and scavengers have a feast. Still, many dead fish are left to decompose. Turtles become vulnerable to predation at this period although many aestivate and some take refuge in deeper pools like Manasarowar which never dries.

The monsoon strikes towards the end of June or the beginning of July. The seeds which were dormant through the summer germinates; the rizomes and tubers sprout. As water flows in from Ajan bund, millions of fish fry too are drawn in and the Park once again teems with life. Some of the adult fish which survive the summer in deeper pools begin to breed. Most of the heronry species also commence nesting and complete it by October. Resident ducks which begin nesting by the onset of monsoon bring out their downy chicks. The migratory waterfowl begin to arrive and the number reaches a peak by December - January. Return migration of the birds to their breeding grounds begins in February and by mid March all of them have left. Water recedes gradually and the cycle repeated.

As all the important ecological events of Keoladeo National Park

are centred on the availability of water, annual biological cycle in the Park has to be considered from one rainy season to the next, i.e. July to July. The first half of the year is influenced by the rainfall, and the amount of water let in during the monsoon of the previous year. Since the monsoon as well as the volume of water received in the Park was very high during 1985, the quantum of fish entry was also high. The more the waterspread area, the more the number of birds, migratory as well as resident. Such a condition prevailed through the first quarter of 1986 and, the spring-summer breeding of many aquatic birds such as the resident ducks, herons, sarus crane, was better than in any other year of our study. Water remained through summer in the major blocks. Even the terrestrial areas were humid in summer because of the extensive flooding in the previous autumn aided by the moderate rainfall in May, resulting in a high growth of grass, abundance of flowers and fruits, increase in the population of insects and breeding land birds. Biomass of aquatic plants and number of macroinvertebrates had their peaks in June. In 1986 monsoon failed. Consequently supply of water and fish into the park was much less which adversely affected the whole system - fewer migratory birds, poor breeding of heronry and other aquatic birds. The Siberian cranes though they came earlier had to remain in a small portion of the Park where water was present. Tube wells were bored and the major habitats were kept alive. Water hyacinth was removed manually to get rid of the weed as well as to reduce the evapotranspiration. The dry grasses, mainly in the terrestrial area, attracted fire which the management authorities fought successfully.

Variations in the major physical and biological features of 1986 are summarised below.

Mean annual rainfall was 364 mm and the quantum of water received from Ajan bund was 0.017 million m^3. Average water depth in the park was 24 to 108 cm. About 70% of the aquatic area was dry. Air temperature varied from 0.5C° to 46.5C° inside the park.

The average value of pH of the waters remained around 7.5 throughout the year; slightly more than that of 1985. Dissolved oxygen level continued to be almost the same as in 1985. The value was zero in many points. Free carbon dioxide decreased slightly; from 10.53 to 81 mg/l of 1985 to 6.36 to 43.2 mg/l in 1986. Values of alkalinity varied from 133.93 to 361.195 mg/l.

Phytoplanktonic surface net primary productivity varied from zero to 0.1723 mg $c/m^2/h$.

Thirty additions were made to the plant list of the park, making a total of 312 species. Among them, one species, Neptunia oleracea, is new to Rajasthan.

Biomass of the aquatic plants showed an increasing trend; the maximum was 1022 gm/m^2 as against 905 g/m^2 of 1985. Paspalum distichum continued to dominate in the biomass.

Number of macroinvertebrates of column water showed almost 50% reduction from 1985 and, the macrobenthos also had a declining trend.

The total quantity of fish fry entering the park was 10 million, whereas it was 65 million in 1985. The source of fry in 1986 was only river Gambir, as no water was supplied from the Banganga to Ajan bund this year. The number of air-breathing fishes increased slightly, whereas the population of gill breathers declined. Breeding of fishes in July - August was poor. Species diversity of fishes was 1.776, slightly higher than that of 1985.

Altogether, 145 pythons and seven species of turtles were recorded, adding two new records to the Rajasthan fauna.

Species diversity of aquatic birds also increased slightly; from 3.149 of 1985 to 3.534 of 1986. The 1986-'87 winter population of aquatic birds

was very low compared to that of 1985-86. The density during December 1986 was five times less than that of December 1985.

Breeding of the heronry species was very poor; only 610 nests were built and 78 young produced as against the 6407 nests and 6690 young of 1985. Failure of monsoon and, inadequate supply of water and fish fry were the main reasons.

Post-monsoon breeding of resident ducks was poor. Altogether, eight nests of spotbills, five nests of whistling teals and two nests of cotton teals were recorded.

Bronzewinged jacana was more common than the pheasant-tailed in the park. Only the bronzewinged bred inside the park. Breeding season was from May to September. Altogether, 38 chicks were recruited into the population. Wintering population of Siberian crane during 1985-'87 was 38 with 6 juveniles, whereas it was 37 with 6 juveniles during 1985-86. The Cranes remained in block E during 1986 as there was no water in their conventional feeding areas. Substantial difference in the food and feeding habit was noticed. Feeding time increased by 10% from 1985.

The population of raptors was higher in 1985-86 than in 1986-87. The breeding of Pallas's fishing eagle was successful with two chicks in 1986-87 but failed in 1985-86. The lesser spotted and greater spotted eagle bred in the Park for the first time.

The peak periods of the species of plants in flower and fruit were in September, and April-May, while the flower and fruit abundance was more in April and May respectively.

Among the land insects, lepidopterans and hymenoterans were fewer than in 1985, whereas coleopterans and orthopterans were more. They had two peaks of abundance, a major one in August-September and a minor in

March-April.

The peak period of breeding of land birds was April.

The land bird diversity increased for a short period following the fire in the grassland area. Sand-grouse and singing bush larks arrived after the fire.

Population of ungulates remained almost the same except for feral cattle (not buffaloes) whose number is on the increase.

Chapter I

PHYSICAL ENVIRONS AND LIMNOLOGY

Fig. 1 Keoladeo National Park with surrounding villages



PHYSICAL ENVIRONS

Rainfall: The mean annual rainfall was only 364 mm during 1986, whereas it was 520 mm in 1985. Maximum precipitation was in July, 199 mm, as in the previous year. Total number of rainy days varied from three to eleven in various months. Altogether, the year had rain on 38 days (Table 1).

Temperature : The mean minimum temperature was in December, 3.78 C°, whereas the mean maximum was in May, 39.41 C° (Table 1). The lowest and highest temperature recorded was - 0.5°C and 46.5°C, respectively (Table 1).

Relative humidity : The mean humidity varied from 44 to 74%, the lowest being in April and highest in November (Table 1).

Water : As the quantum of water received from Ajan bund was much less, 0.017 million m^3, and the precipitation was also poor, the water level was very low, ranging from 24 to 108 cm., the lowest was in December and highest in January (Fig.2). The higher water depth in January was due to the quantity supplied in 1985. The period of highest water level varied from August to October in the former years of study, but this year the level during this period was very low, only 40 to 62cm.It is to be mentioned that only about 30% of the total waterspread area had water during the latter part of the year.

PHYSICOCHEMICAL PROPERTIES OF WATER

Studies on the following physicochemical properties of water were continued in 1986, adopting the standard analytical methods as in the previous years : 1. water temperature, 2. pH, 3. dissolved oxygen, 4. carbon dioxide, 5. total alkalinity, 6. chloride, 7. inorganic phosphate, 8. magnesium, 9. calcium, 10. hardness, and 11. conductivity. Sampling sites were the same as in 1985.

Water temperature : Water temperature varied from 12.22 to 28.65°C during the year, the maximum in July and minimum in December (Fig.3).

Table 1

Mean temperature, humidity and rainfall of Keoladeo National Park during 1986.

Month	Minimum temperature in °C	Maximum temperature in °C	Mean relative humidity in %	Total rainfall in mm	Number of rainy days
January	9.75	21.13	71.75	nil	-
February	7.87	22.37	71	331	3
March	12	28.25	49.25	nil	-
April	20	39.16	43.6	25	one
May	22.16	39.41	45.14	140	one
June	25.83	38.25	56.63	444	4
July	24.88	31.85	65.85	1991	11
August	24.83	35.58	66.71	705	8
September	22.96	36.28	50.36	399	6
October	17.71	32.56	64.11	323	3
November	8.16	23.75	74.28	nil	-
December	3.78	21.58	71.45	14	one

Fig. 2 Monthly variation of water depth in the park.

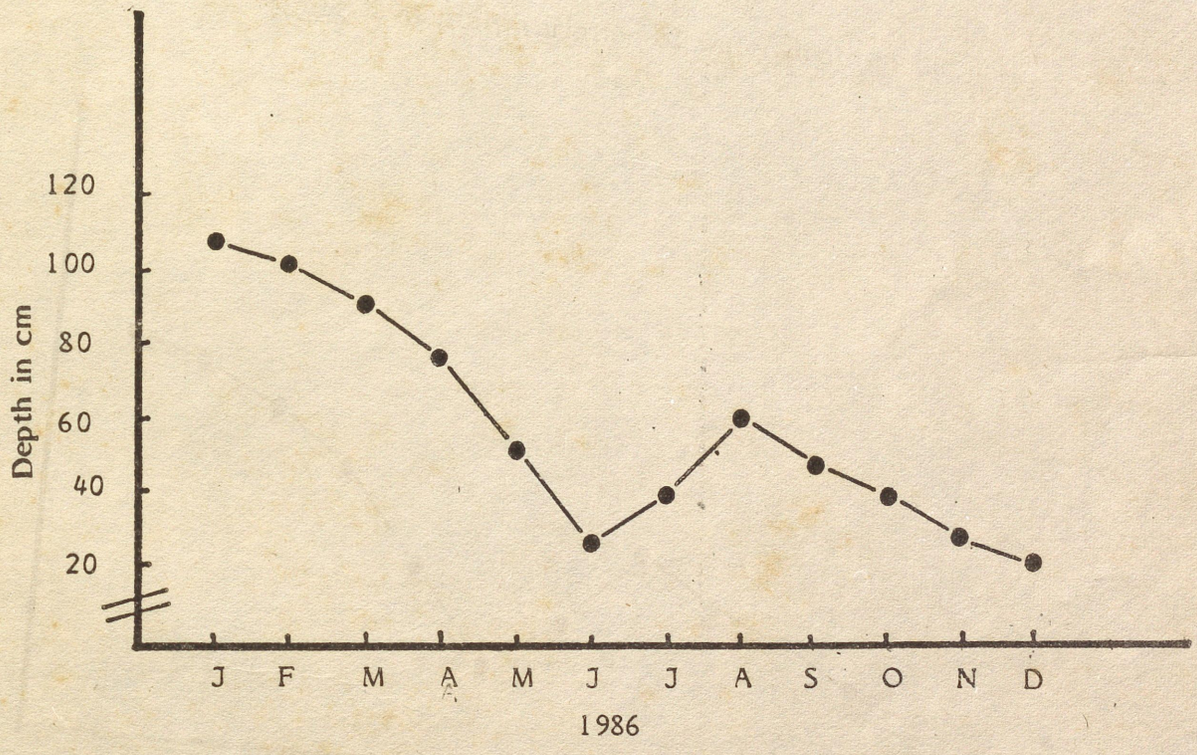
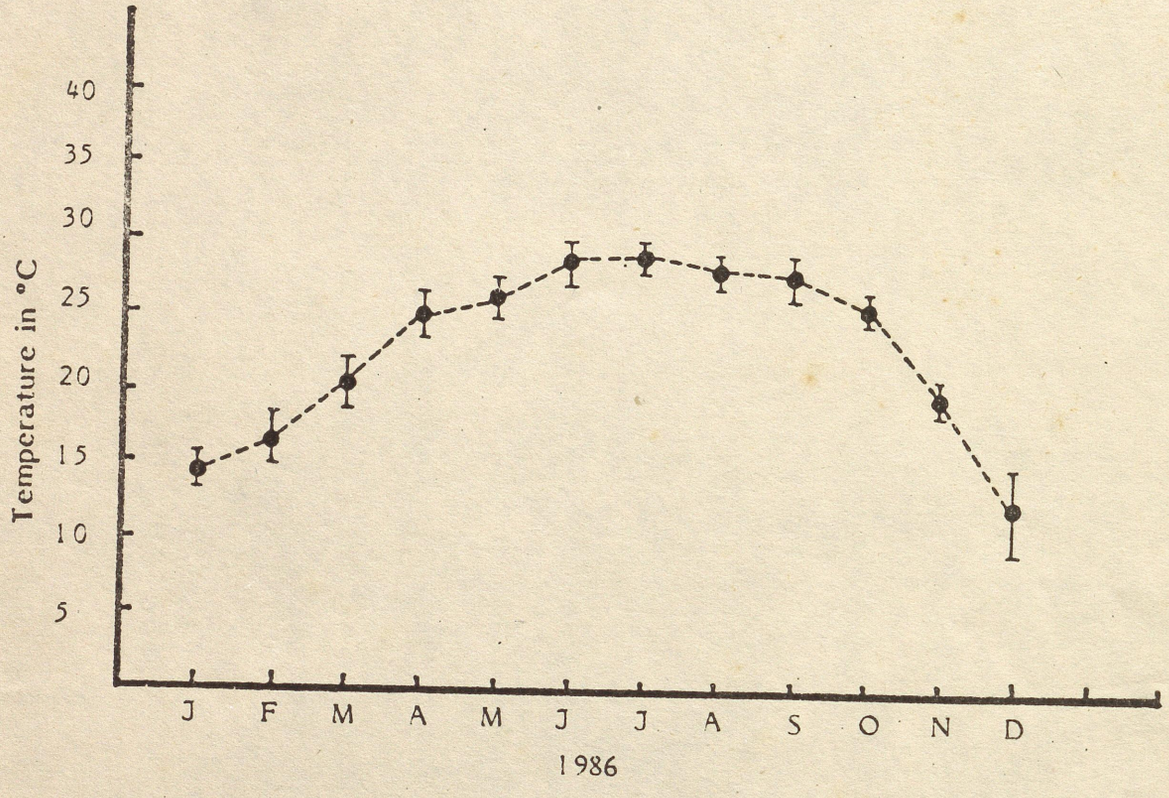


Fig. 3 Monthly fluctuation of water temperature



pH (Hydrogen ion concentration) : The pH remained around 7.5 throughout the year; the variation being 7.18 to 7.69 (Fig.4). The maximum was in November and minimum in October. The pH was around 7 in 1985, whereas it was below 7 in 1982.

Dissolved oxygen : Dissolved oxygen level was almost the same as in 1985. The mean maximum was in January, 5.08 mg/l, and minimum in July, 1.2 mg/l. Anerobic conditions existed in many parts as the oxygen level was zero (Fig.5). However, in some areas a slight increase was noticed. Pumping of water either from one block to the other or from tube-well and the resultant increased movement of water may be responsible for the slight increase.

Free carbon dioxide : On the whole there is a slight decrease in the carbon dioxide level from 1985. The maximum was in July and minimum in November, 41.9 and 6.43 mg/l, respectively (Fig.6).

Total alkalinity : Total alkalinity was the highest in June and lowest in August, 372.501 and 129.737 mg/l respectively. Its level was high during July also (Fig.7). High values of alkalinity during spring and summer, as in the previous years, may be due to the decreasing water depth and the increasing population of plankton coupled with high transparancy of water.

Chloride : The chloride level fluctuated from 39.76 to 81.29 mg/l, the maximum was in June as in the previous years. The regular fluctuation of chloride level, a rise in summer and a sharp decline with the rain and inundation of the area, noticed in the previous years did not occur during 1986. Instead after the summer rise it showed only a decreasing trend, may be because of the low water depth resulted from failure of monsoon and inadequate supply of water (Fig.8).

Inorganic phosphate : The phosphate showed a steady increase from April to December; may be due to the decreasing quantity of water. The maximum was in December, 0.277 mg/l, and minimum in February, 0.161 mg/l. (Fig.9).

Fig. 4 pH of water during 1986

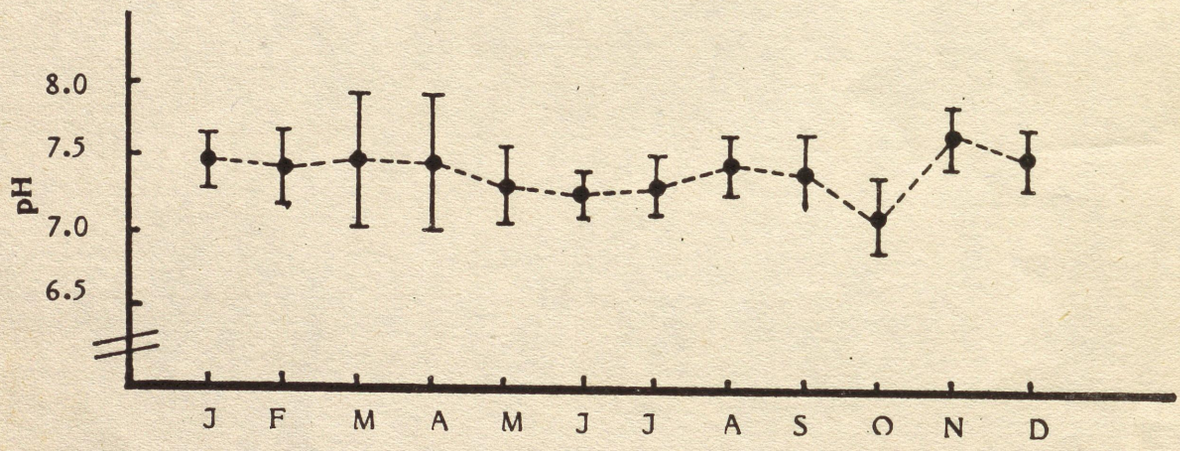


Fig. 5 Dissolved Oxygen concentration

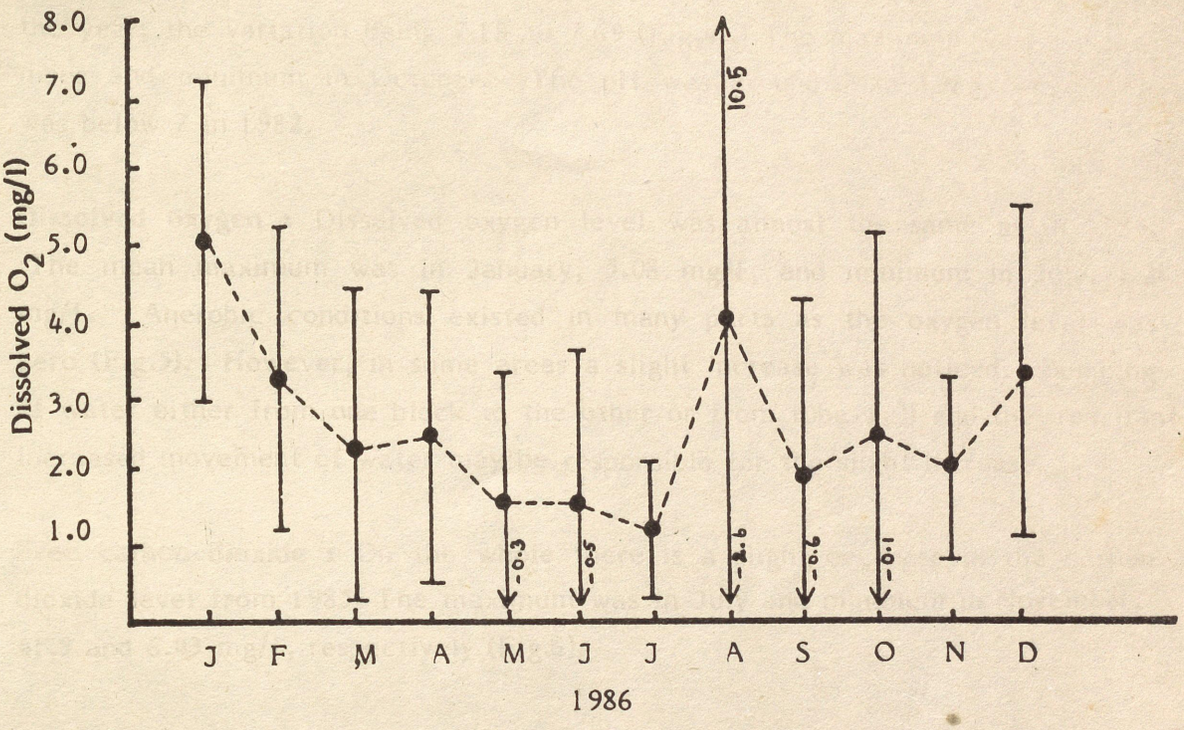


Fig. 6 Free Carbon dioxide concentration

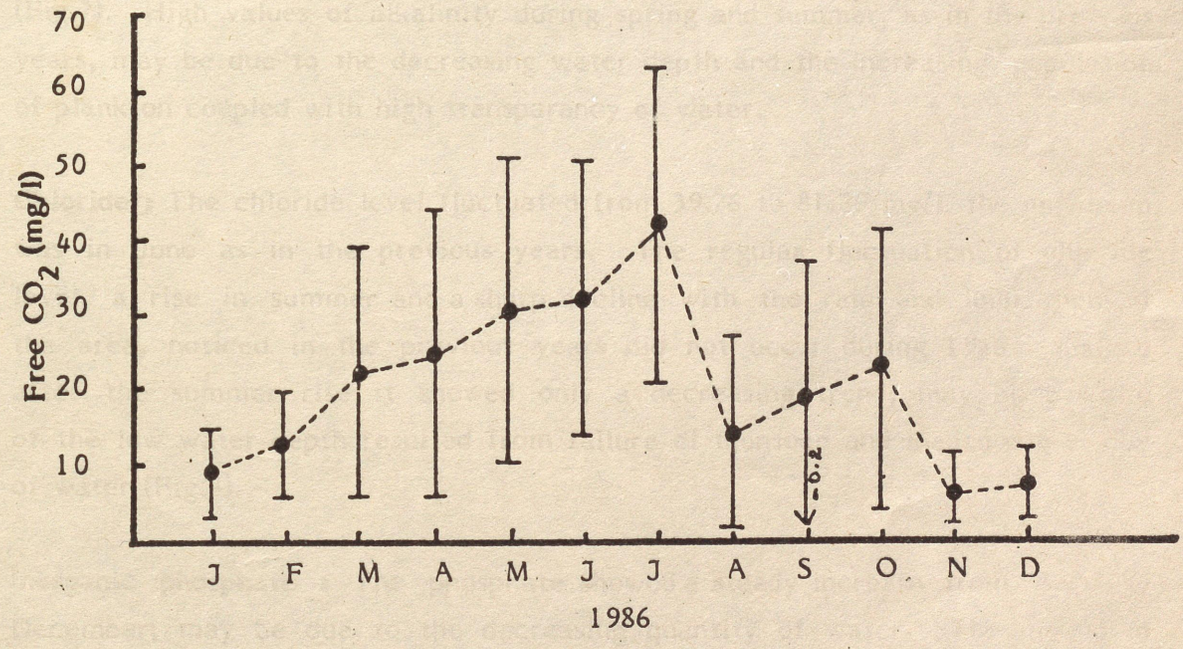


Fig. 7 Total alkalinity of water - 1986

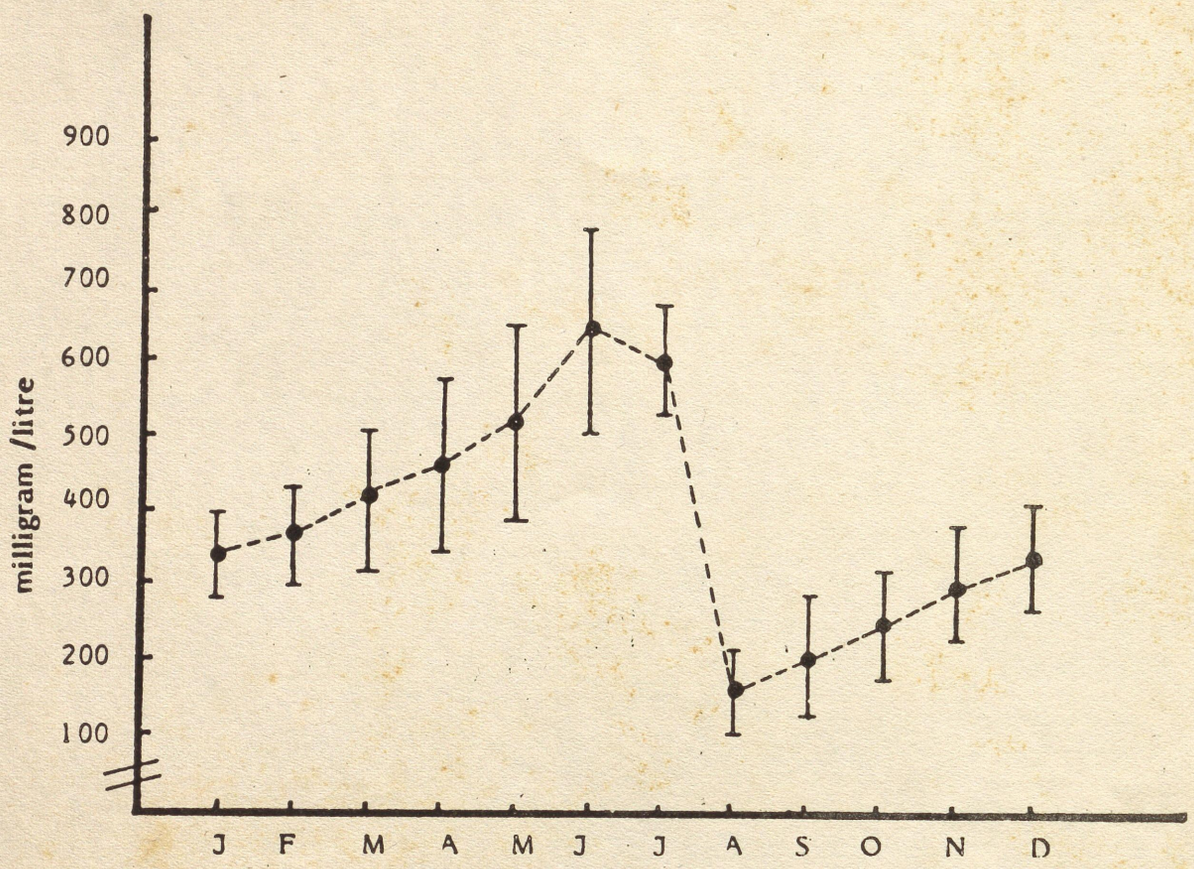


Fig. 9 Inorganic phosphate concentration in the water - 1986

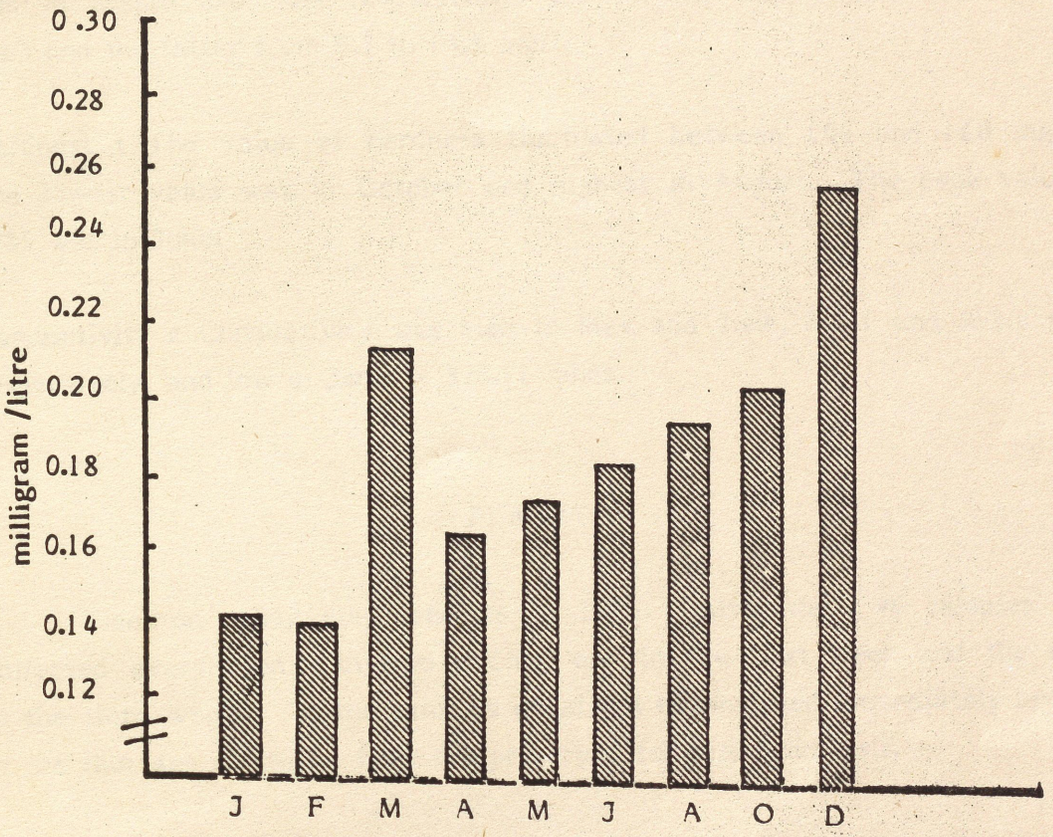
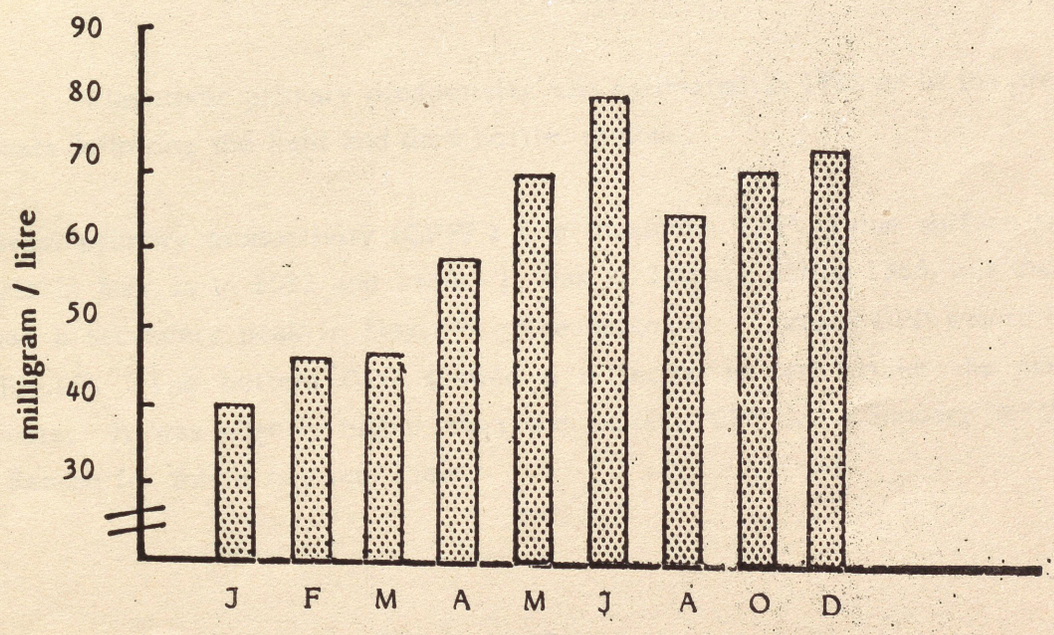


Fig. 8 Chloride content in the water - 1986



Calcium and magnesium : The maximum value of calcium and magnesium was in March and May respectively; the former varied from 23.5 to 35.6 mg/l and the latter from 9.5 to 14.9 mg/l.

Hardness : The value of hardness fluctuated between 104 and 160 mg/l. The lowest value was in October and highest in August. The peak value in 1985 was in June.

Conductivity : Conductivity was high in May and June, 808.1 and 913.4 mhos respectively, and low in January 326.11 mhos.

PLANKTON

Plankton study continued as in 1985. Altogether, 46 samples were collected every month in two cycles, one in the first week and the other in the third week. All the samples could not be analysed immediately because of the shortage of staff. They are preserved for future analysis.

PRIMARY PRODUCTIVITY

Planktonic primary productivity was estimated in 1986 as in the previous years following the light and dark bottle method.

Gross primary productivity (GPP) : The maximum GPP of the surface waters was in May as in 1983 and 1984. It was in January during 1985, but the year had a secondary peak in May. The minimum surface GPP was in March (Fig.10). The bottom GPP showed a different pattern unlike the previous years. It was slightly higher than the surface GPP from January to March. Reason for this is not very clear.

Fig. 10 Gross primary productivity in the water - 1986

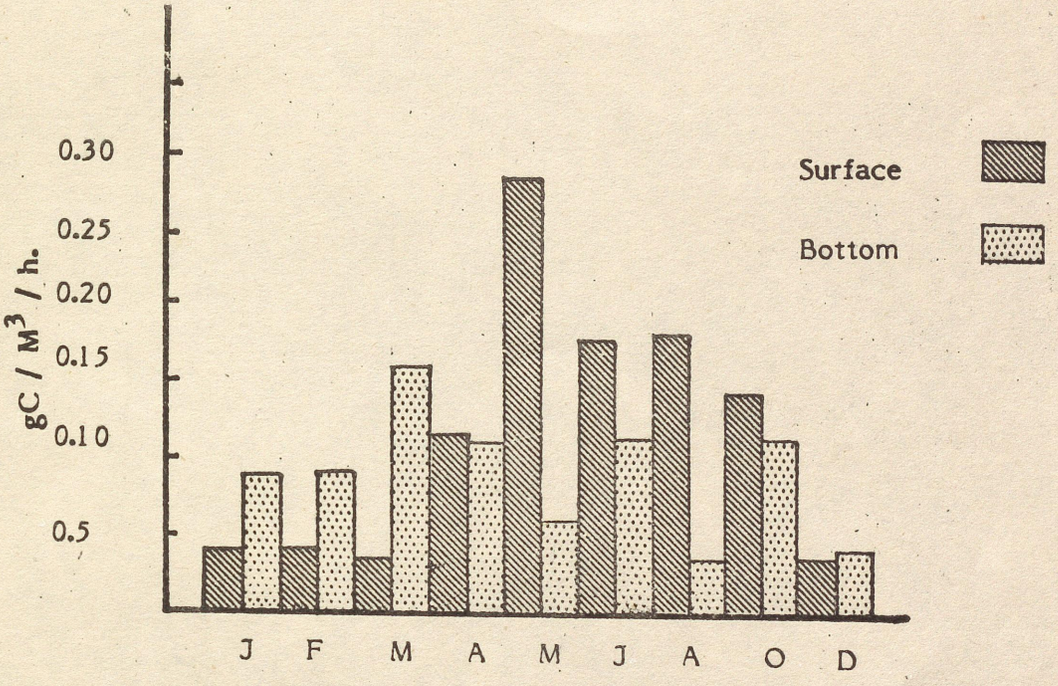


Fig. 11 Net primary productivity in the water - 1986



Net primary productivity (NPP) : The values of NPP followed those of the GPP. The surface NPP was nil during August and December (Fig.11). The value of bottom NPP followed the pattern of surface NPP; the bottom NPP was also slightly higher than surface NPP during January to March.

Compared to 1985, both GPP and NPP were very low.

Chapter II

VEGETATION

AQUATIC MACROPHYTES

The study on aquatic macrophytes was continued for monitoring the changes in the aquatic vegetation and macrophyte production. Samples were collected from 25 stations in alternate months following the same method as in 1985; a quadrat of 0.25 m^2 was used to sample the above ground biomass.

Species diversity

On an average nine to ten species occured in the sampling plots. The species diversity ($H = -\sum_{i=1}^{ST} Pi \ln Pi$) varied from 0.66 to one (Fig.12). Diversity was the highest in November because of the increase in number of species and decrease in the biomass of Paspalum distichum. Species diversity index varied from zero to 1.3 in the bulldozed areas; the maximum was in August and November and minimum in June (Fig.12). The increase from June was due to the reappearance of Paspalum distichum after bulldozing the area Only Ipomoea aquatica was present during June.

Succession of plant community in bulldozed areas

Observations were made mainly in blocks L and N, portions of which were bulldozed in May-June 1985. Ipomoea aquatica was the first weed to invade the area. When the water came in July, Nymphoides spp. started appearing along with Nymphaea spp., Hydrilla sp. and Najas sp. Their densities increased in October and it appeared as a suitable habitat for waterfowl. Paspalum distichum began appearing only from August 1986 (Table 2).

Biomass (Expressed in dry weight g/m^2)

Biomass of macrophytes maintained the increasing trend, reaching a maximum of 1022 g/m^2 in June 1986 (Fig.13). The maximum biomass in 1983 was 423.6 g/m^2 i.e. an average increase of 199 g/m^2 every year.

A large portion of the biomass was produced mainly by Paspalum distichum, Ipomoea aquatica, Pseudoraphis spinescens and Hydrilla verticillata (Table 3). Among these, Paspalum distichum was the dominant one. Out of the total biomass of 1022 g/m^2 in 1986, the biomass of P distichum alone

Fig. 12 Species diversity of aquatic macrophytes in the regular sampling stations and bulldozed areas.

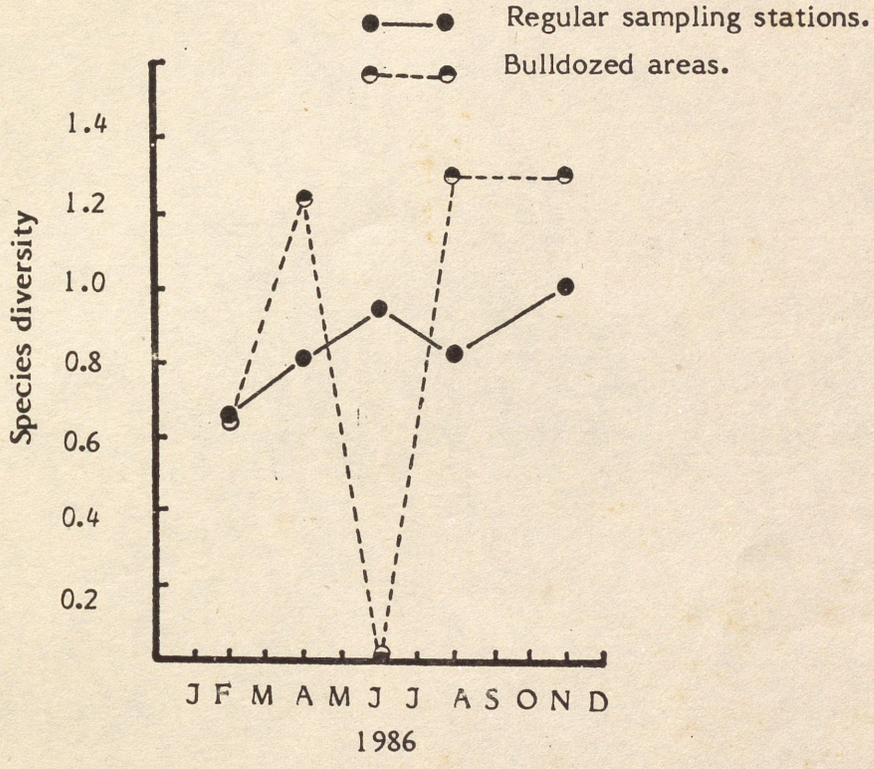


Table 2

Biomass of macrophytes in the bulldozed area

Species	1985				1986			
	July	Octob.	Dec.	Feb.	April	June	Aug	Nov.
Paspalum distichum	0	0	0		0	0	44.2	43.5
Ipomoea aquatica	0	0	0	16.0	0	76.0	24.9	29.1
Nymphoides cristatum	2.0	2.5	12.0	29.2	12.8	0	33.3	0
N. indicum	0	0	0	0	0	0	0	12.3
Nymphaea nouchali	0	25.1	0	0	0	0	0	0
Hydrilla verticillata	0	109.3	48.0	0	18.7	0	73.3	18.8
Najas sp.	0	12.5	10.0	0	2.3	0	0	0.4
Chara sp.	0	0	0	0	9.1	0	0	0
Potamageton pectinatus	0	0	0	0	0.3	0	0	0
TOTAL:	2.0	149.4	70.0	45.2	43.2	76.0	175.7	104.1

Table 3

Biomass of the four major and other aquatic macrophytes in 1986

	Feb	April	June	Aug.	Nov.
A	531.82	836.7	985.1	717.79	344.58
B	3.36	15.0	36.82	19.92	6.86

A= sum of the biomass of Paspalum distichum, Ipomoea aquatica, Pseudoraphis spinescens and Hydrilla verticillata

B= sum of the biomass of Other 15 species.

was 739.5 g/m^2. This was so in all the years studied, hence the increase in biomass of aquatic macrophyte was mainly due to this species. The maximum biomass of P. distichum was only 262.25 g/m^4 in 1983 while it was 739.5 g/m^2 in 1986, ie. an average annual increase of 159 g/m^2. The maximum and minimum biomass varied from year to year (table 4).

Table 4

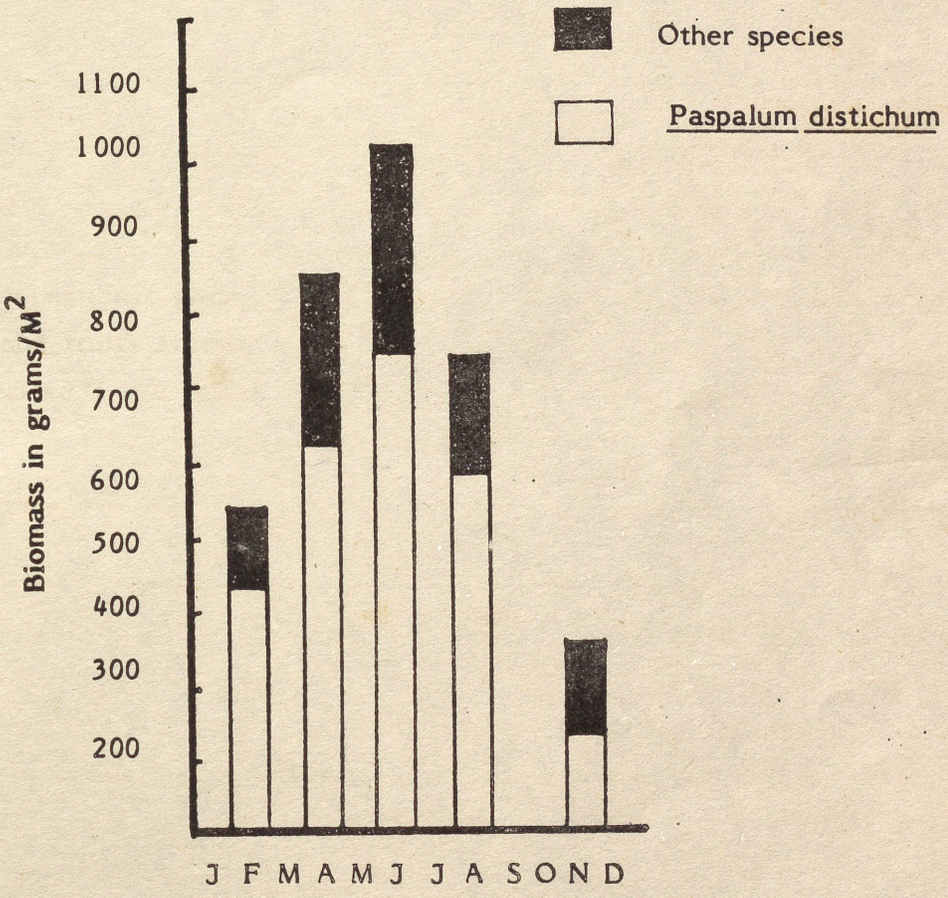
Variation in the maximum and minimum biomass of macrophytes in different years.

Year	Maximum		Minimum	
	Biomass g/m^2	Month	Biomass g/m^2	Month
1983	423.6	August	245.8	April
1984	836.3	December	355.3	January
1985	905.0	May	339.3	August
1986	1021.9	June	351.4	November

This variation appeared to be related to the pattern of rainfall and water level in each year. When water is less and the area starts drying faster during February-March spring growth appears, increasing the biomass. The spring growth is shifted to May-June when the water level is more even in summer and the growth is enhanced by the monsoon occurring moderately in May June.

Monthly variation of biomass is discernible (Fig. 13). The poor biomass production during November 1986 might mainly be due to the removal of tonnes (approximately 2000 tonnes) of green grass by the villagers during September-October and also the drought, leaving most of the areas dry.

Fig. 13 Biomass of aquatic macrophytes from the regular sampling stations - 1986



PHENOLOGY OF TERRESTRIAL PLANTS

Phenological events of the major plant species, were studied during 1986 as in 1985 with the following major objectives 1. to determine the flowering and fruiting season of the major species of plants. 2. to assess the peak periods of flowering and fruiting, and 3. to ascertain the correlation between the environmental factors and seasonality of plants.

Methodology

Altogether four sampling sites, 200 m^2 each, were marked in representative habitats in blocks B, J, I and O. The sampling site in each habitat was selected in such a manner that maximum number of species was obtained. Dominant and representative species of each habitat were selected for study. By visual observations, grades ranging from 0-10 were given separately for leaf, flower and fruits according to the abundance of each, on each individual of every species. Grades of individuals of each species were summed up and the average taken for each month to indicate the status of the production of leaf, fruit and flower of that species.

Results

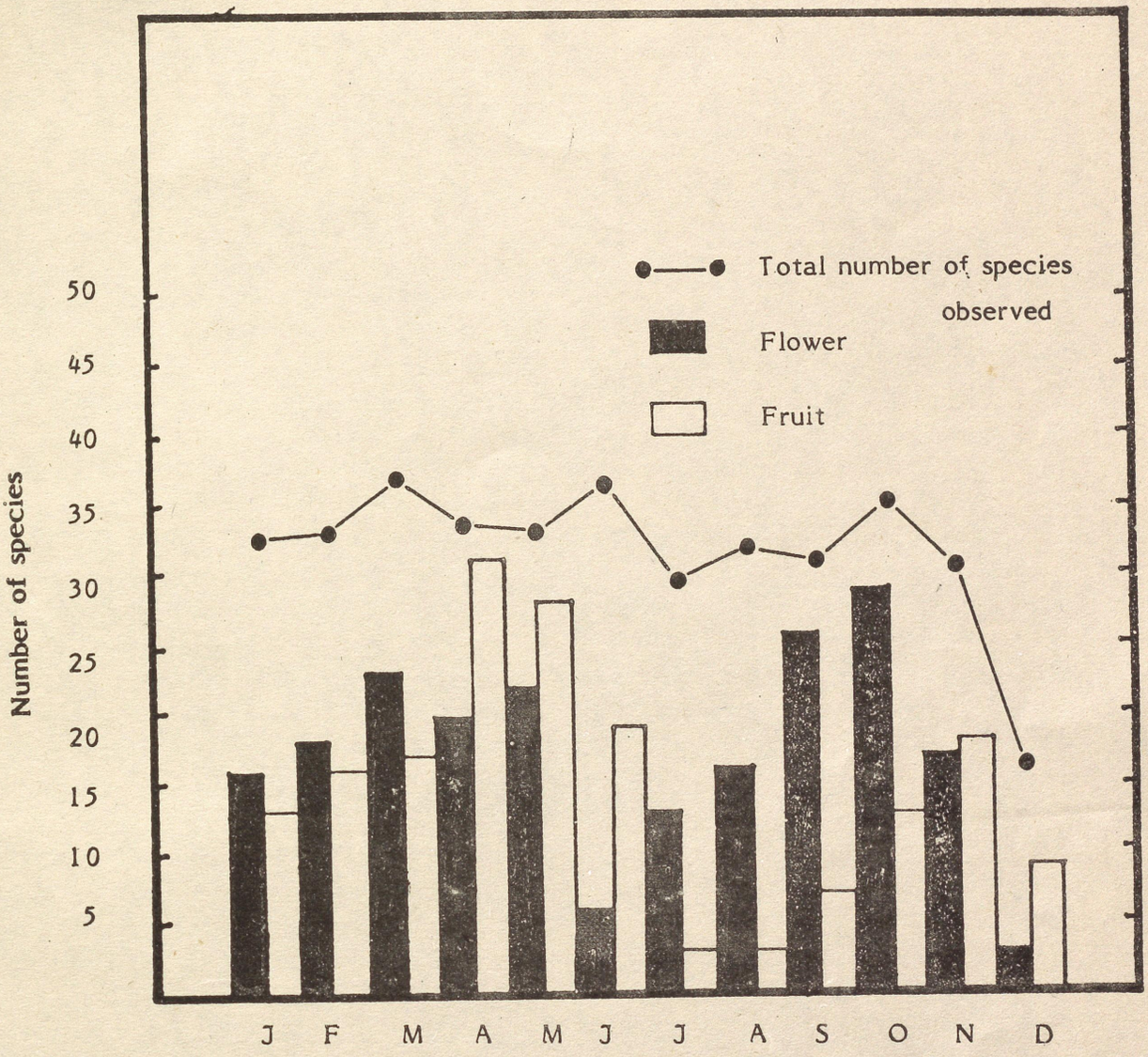
The flowering and fruiting season varied according to species.

Seasonality of number of species in flower and fruit

Considerable variation occurred in the total number of species in flower (Fig 14). The highest number was in September and lowest in December 29 and three respectively. The variation was not much during January to May (16 to 23), whereas it was very high from June to December (3 to 29).

The peak period when the number of species in fruit was April and May. The first half of the year had 13 to 31 species in fruit, while the second part had only 3 to 19 species (Fig 14). August to November had fewer number

Fig. 14 Number of terrestrial plant species in flower and fruit - 1986



of species compared to the same period in 1985, probably because of the lack of rainfall. Although there was more species in flower during September-October, many of them did not fruit and hence the number of species in fruit did not increase much. A gradual increase, however, was noticed from June, attaining a peak in November.

Seasonality of the abundance of flower and fruit

Fluctuation in the percentage of flower abundance was 29 to 50, the minimum in December and maximum in April. However, the flower abundance was rather steady from January to August and fluctuated more from September to December (Fig 15). Variation in the peak periods between the number of species in flower and total abundance of flower is discernible. This is because of the variation in the flower production by individual species.

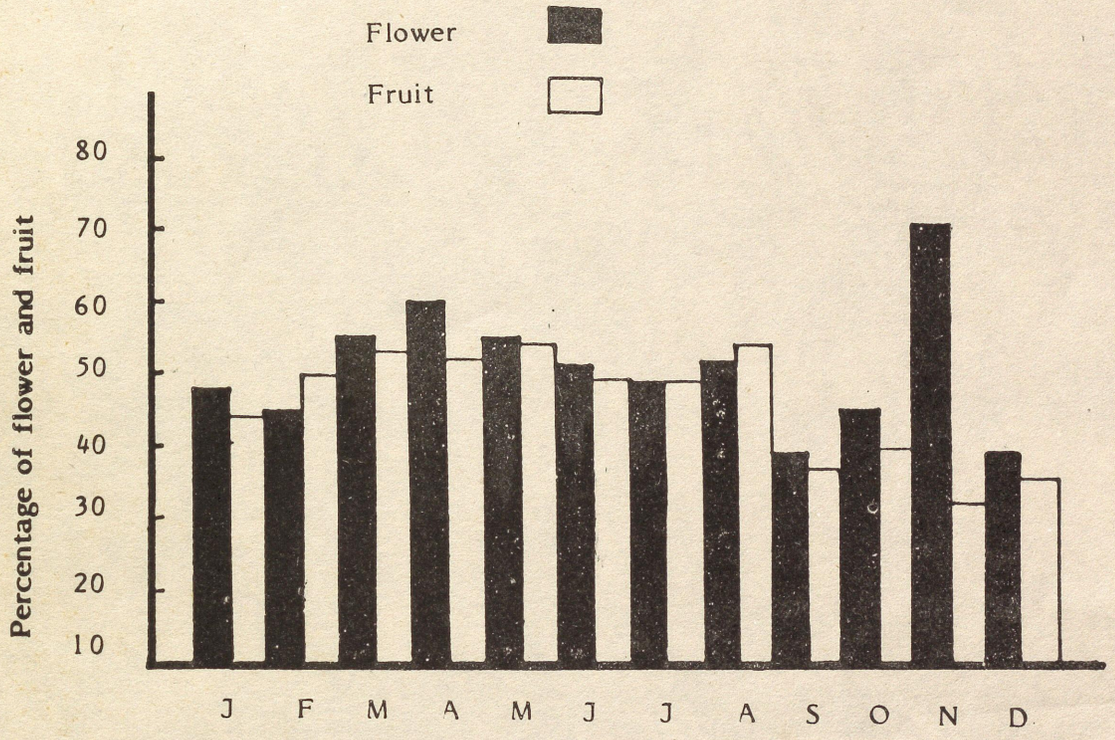
Fruit production showed an almost steady trend from February to August, 39 to 44%, but from September to December the production reduced varying from 23 to 30% (Fig 15). Here again, there is no correlation between the total number of species in fruit and the total percentage of fruit abundance, owing to the variation in the number of fruits produced by each species.

STANDING BIOMASS OF THE GRASSES OF TERRESTRIAL AREA

Keoladeo National Park has about 6 sq.km of grassland holding perennials such as Vetiveria zizanioides, Desmostachya bipinnata, Cynodon dactylon and annuals such as Dicanthium annulatum, Paspalidium punctatum, Sporobolus helvolus, Echinochloa colonum, Panicum antidotale, Paspalum scrobiculatum and Scirpus tuberosus, which appear mainly during monsoon. This area also gets inundated for 2 to 3 months during monsoon and attracts sizable number of waterfowl. Moreover, wild ungulates depend mainly on this habitat and hence a detailed study of grassland was taken up.

Objectives : 1. To estimate the above ground biomass and growth of grass. 2. To determine the species diversity of grasses and its seasonal fluctuation. 3. To find out the seasonal fluctuation in the biomass of each grass. 4. To record the phenology of grasses.

Fig. 15 Abundance of flower and fruit - 1986



Materials and method

Koladehar area which has the largest expanse of grassland in the Park has been selected for intensive study. An exclosure made of iron mesh, 1800 sq.m. in size, was erected to find out the effect of grazing by herbivores on the grassland. Above ground biomass was sampled from 30 sites, 15 from the exclosure and the rest from outside. Each sample was collected from 0.25 sq.m. area by placing a quadrat. It was then sorted out into species and wet weight taken. Dry weight was taken after oven drying it at 110°C for 24 hours. Height of individual grass was also measured before the collection.

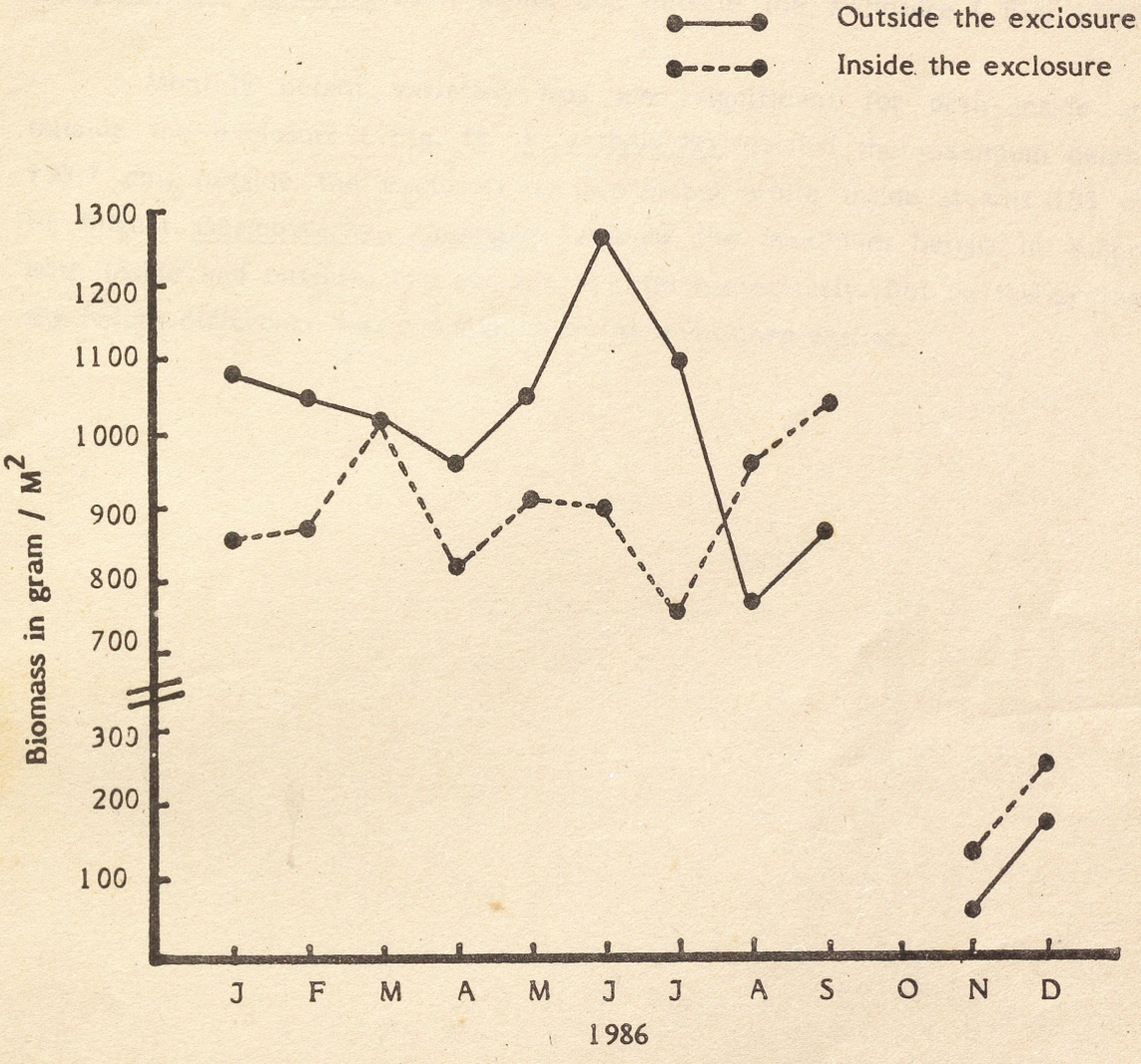
Results

Species diversity was more inside the exclosure than outside. Monthly fluctuation in the species diversity was noticed both outside and inside the exclosure. The fluctuation appears to be related to rainfall.

There was a significant difference between the biomass of inside and outside the exclosure from January to September (Wilcoxon test $t = 4$; $n = 9$ $p < 0.05$) Biomass was much higher outside the exclosure. Usually a higher biomass is expected inside the exclosure as there will be grazing pressure on outside biomass. In this case the grazing was so moderate that it might have stimulated the growth of grasses to compensate the biomass lost by grazing (Detailed paper in preparation). However, it is interesting to note that average height of grasses did not show such difference from inside and outside the exclosure (Wilcoxon test. $t = 20$, $n = 9$). This might be because of the non-preference of ungulates to the dry tips of grasses.

The maximum biomass outside the exclosure was in June, 1263 gm/m^2. and the minimum in August, 770 gm/m^2. Data for November and December are not considered, since the area was totally burnt in the middle of October. However, the pattern changes after the fire; the biomass was much higher inside than outside (Fig. 16) because of the heavy pressure of herbivores on the sprouting grasses.

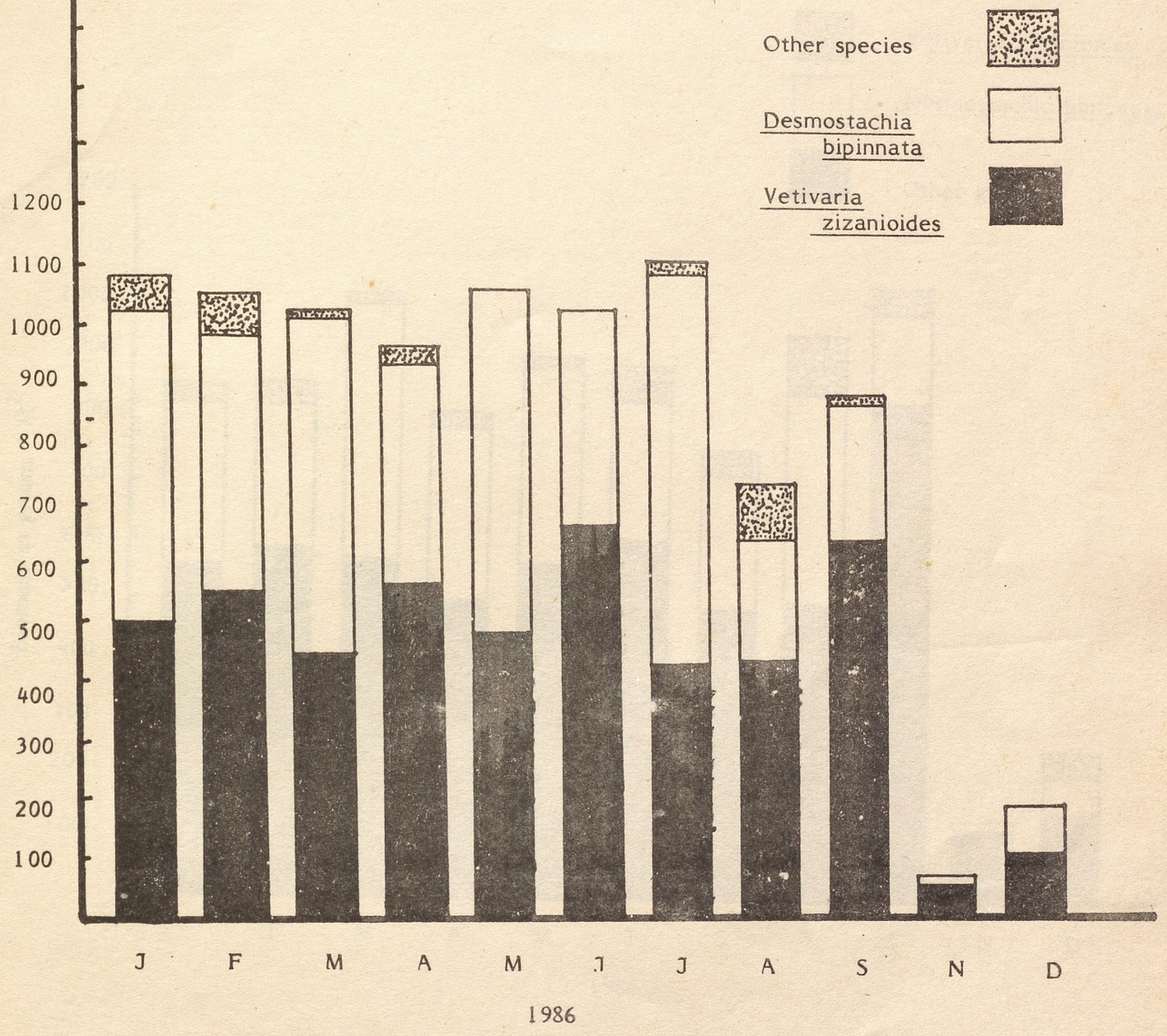
Fig. 16 Biomass of terrestrial grasses (inside and outside the exclosure)



There was a significant variation in the total monthly biomass both inside and outside the exclosure; the fluctuation was more outside (Fig. 16). The principal contributors to biomass was Vetiveria zizanioides and Desmostachya bipinnata both inside and outside the exclosure (Fig. 17,18).

Monthly height variation was also significant for both inside and outside the exclosure (Fig. 19 V. zizanioides reached the maximum height, 193.7 cm, outside the exclosure in September while inside it was 183 cm in August. Desmostachya bipinnata attained the maximum height in August both inside and outside, 110 cm and 112 cm respectively. But on the average the height difference was not significant as mentioned earlier.

Fig. 17 Standing biomass of terrestrial grasses (outside the exclosure)



Note : No data for October due to grassland fire.

Fig. 18 Standing biomass of terrestrial grasses (inside the exclosure)

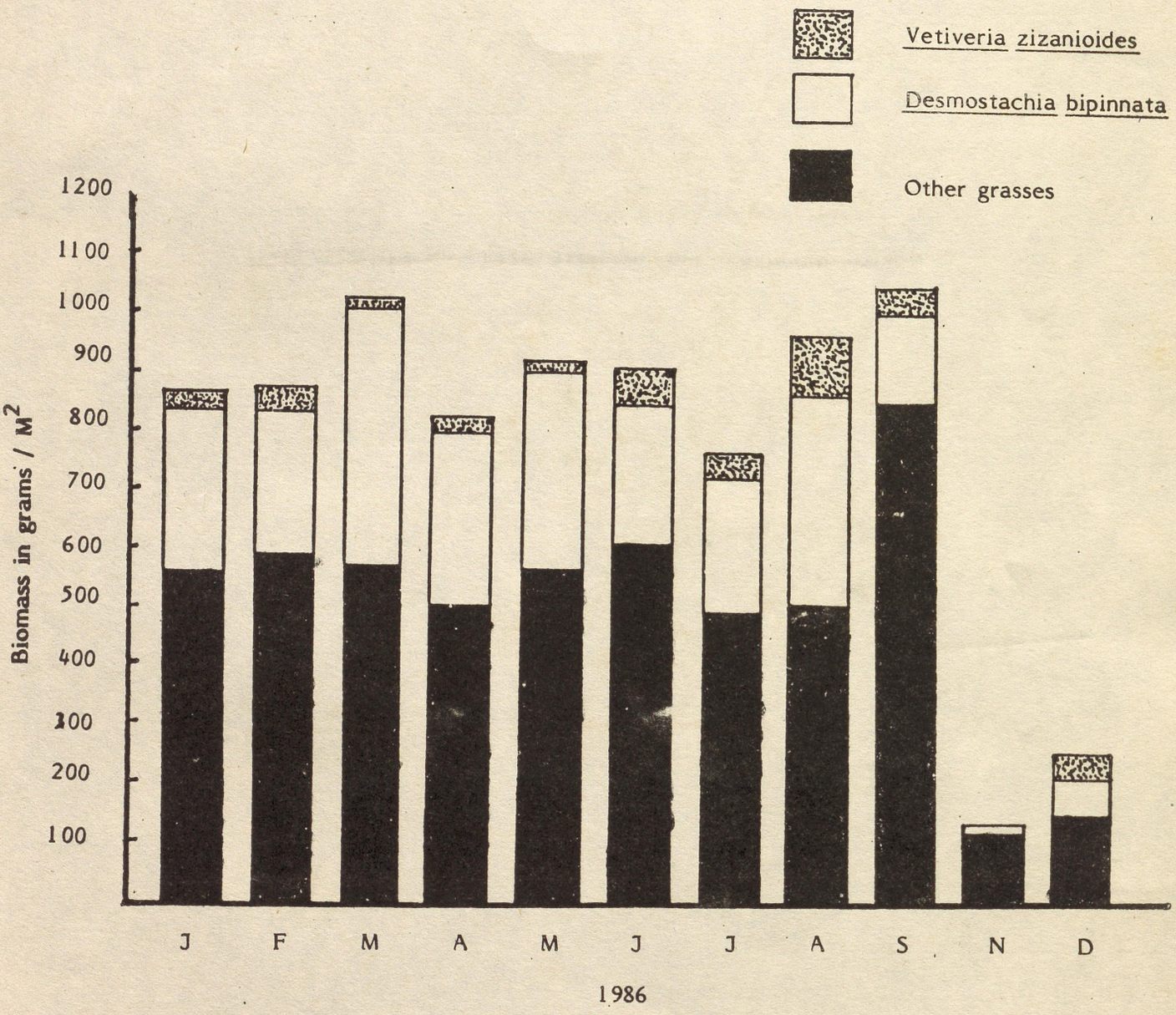
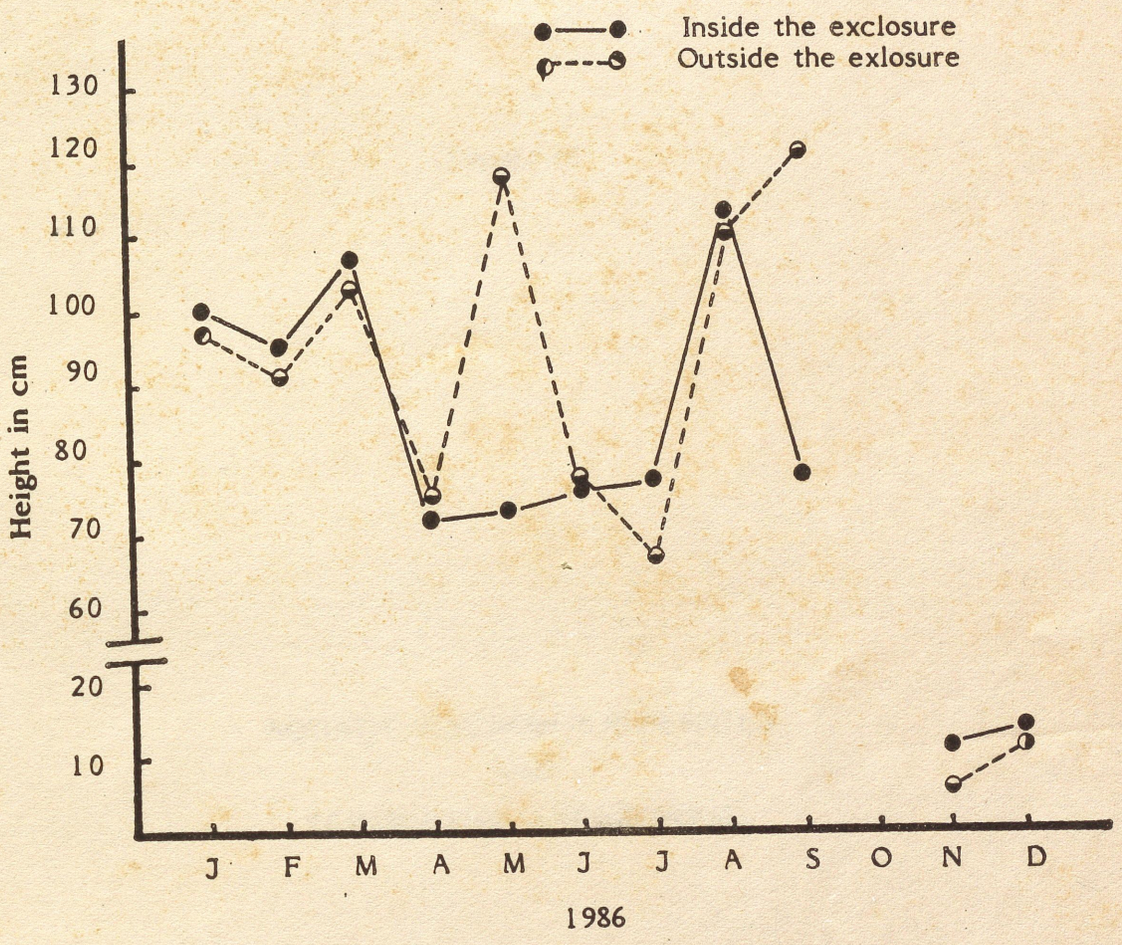


Fig. 19 Mean height of terrestrial grasses (inside and outside the exclosure)



Chapter III

AQUATIC MACROINVERTEBRATES AND TERRESTRIAL ARTHROPODS

MACROINVERTEBRATES OF COLUMN WATER

Seasonal and annual fluctuations in the aquatic macroinvertebrates have been studied since 1983. Samples were collected from 23 stratified random stations during the first and third week of each month as in 1985. In all, 46 samples from water column and 20 samples from benthic zone were collected and analysed every month during 1986. Water level was very low in all the blocks; most of the aquatic areas started drying during the latter part of the year. The number and biomass of aquatic macroinvertebrates showed a declining trend over the years 1983-86.

There was a sharp decrease in the number of all aquatic macroinvertebrates except the larvel forms of Ephemeroptera and Odonata during 1986. Unlike the previous years, these larvae were present in the park throughout the year.

Seasonal fluctuations of macroinvertebrates during 1986 showed the same pattern as that of 1985; the maximum number was in June and minimum in January (Fig. 20). There was a significant negative correlation between the depth of water and the number of macroinvertebrates ($r = 0.76$ $p < 0.001$). In peak summer, when the water level was low, the diversity of aquatic insects was also low, but their density was high as they congregated in pools. The biomass of aquatic macroinvertebrates also decreased during 1986. The maximum biomass was in November during 1986 (Fig. 21), whereas this was in May during 1985. It appears there is a relationship between biomass of macroinvertebrates and water depth.

BENTHIC FAUNA

The most common macroinvertebrate present in the mud was molluscs; oligocheates and dipteran larvae were also present but in smaller number. The peak period of availability of benthic fauna was in March (Fig. 22).

Fig. 20 Fluctuation in the number of aquatic macroinvertebrates

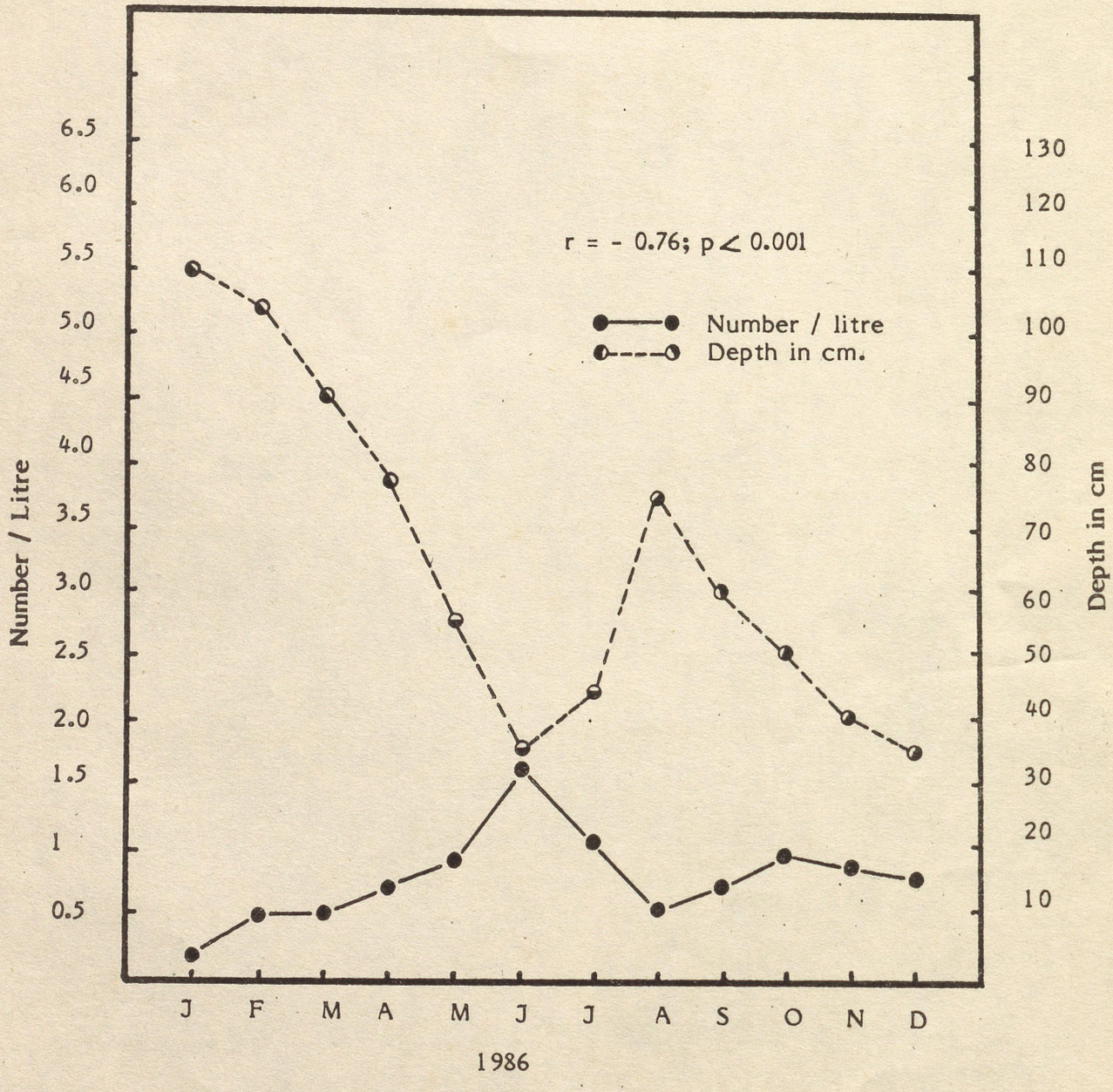


Fig. 21 Fluctuation in the biomass of aquatic macroinvertebrates

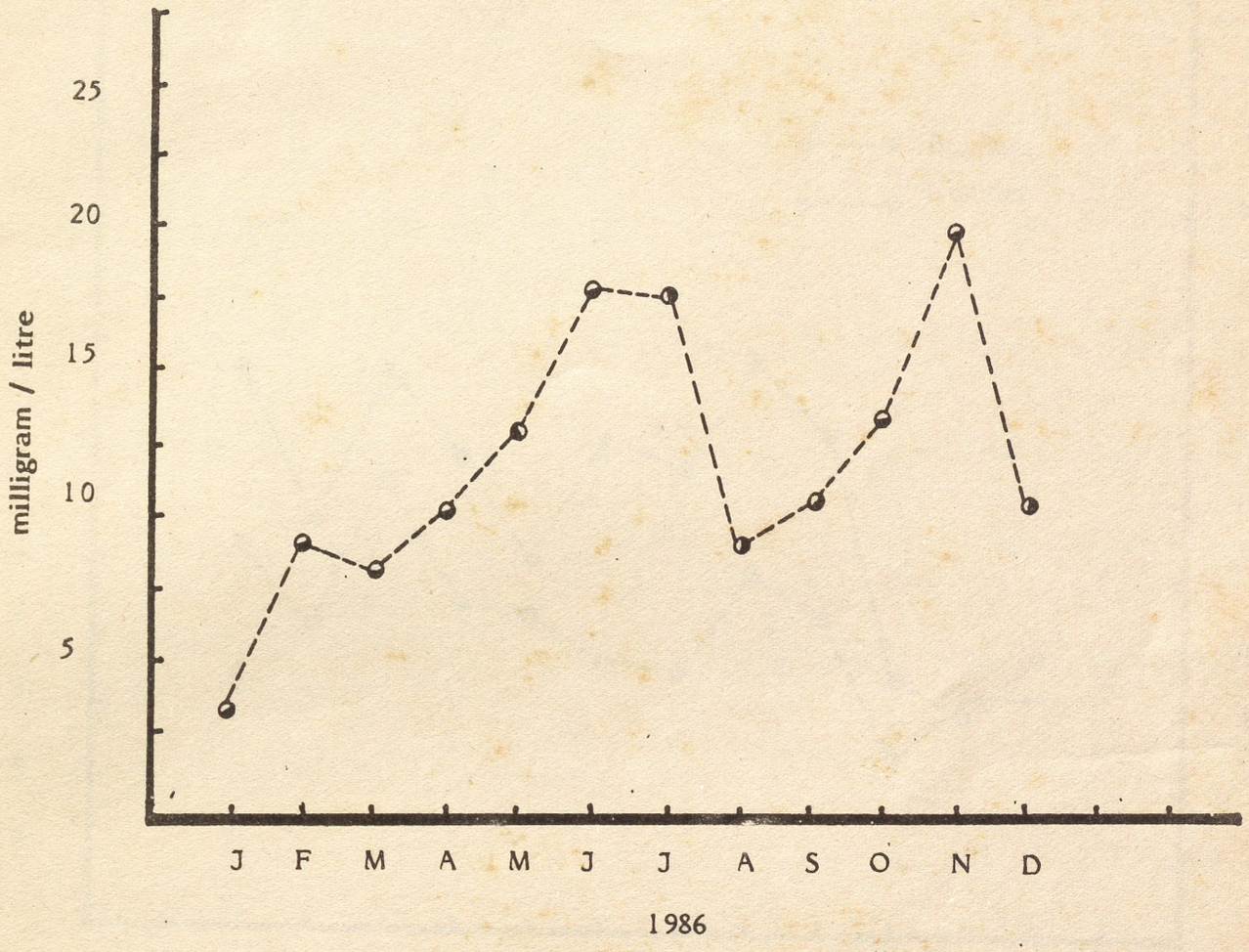
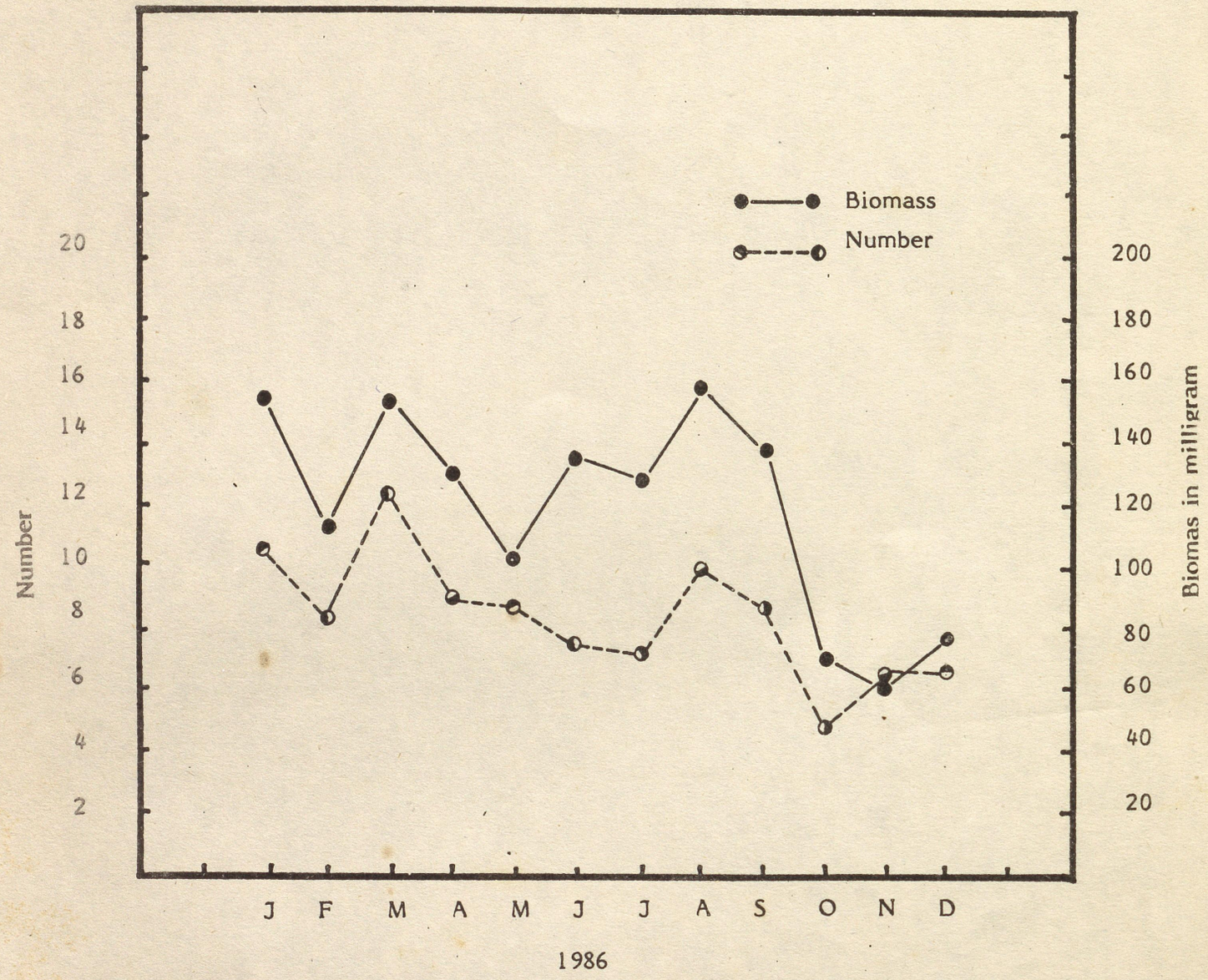


Fig. 22 Fluctuation in the number and biomass of benthic fauna



The number and biomass of bottom fauna also decreased slightly from 1985.

SEASONAL ABUNDANCE OF TERRESTRIAL INSECTS AND SPIDERS

The relative abundance of terrestrial arthropods was studied as in 1986, four sampling sites were selected and samples collected twice a month by the following methods: 1. transect count, 2. sweeping, 3. quadrat, 4. insect tray, 5. bark analysis, 6. dung analysis, and 7. litter analysis.

Comparative abundance of insects

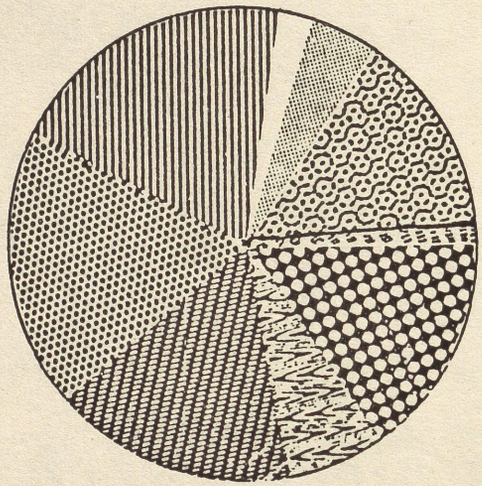
In all, eleven orders of insects were recorded; coleopterans and hymenopterans were the most abundant and dictyopterans the rarest (Fig. 23). Compared to the previous year there was a slight change in the composition. In 1985, in all, twelve orders of insects were recorded. Lepidopterans and hymenopterans were fewer than in 1985 while coleopterans and orthopterans were more. Abundance of all the other groups of insects was more or less the same as that of 1985.

Seasonal fluctuation of insect abundance

The maximum number of insects was in August and minimum in June (Fig. 24). There was a minor peak in March - April. The insect abundance was more during the latter part of the year than in the former. During October November 1986 the insect population was much lower compared to that of 1985 which may be due to the poor rainfall of the year.

Orderwise analysis shows that Diptera had two peaks, one in spring and the other in monsoon, while Orthoptera had only one, in monsoon (Fig. 25). Lepidopteran number increased during spring. The only group of insects whose number increased during summer was Hymenoptera.

Fig. 23 Comparative abundance of land insects - 1986



Coleoptera
Hymenoptera
Diptera
Lepidoptera
Hemiptera
Isoptera
Dictyoptera & Phasmida
Orthoptera
Odonata
Ephemeroptera & Thysanura

Fig. 24 Seasonal fluctuation in the abundance of terrestrial insects - 1986

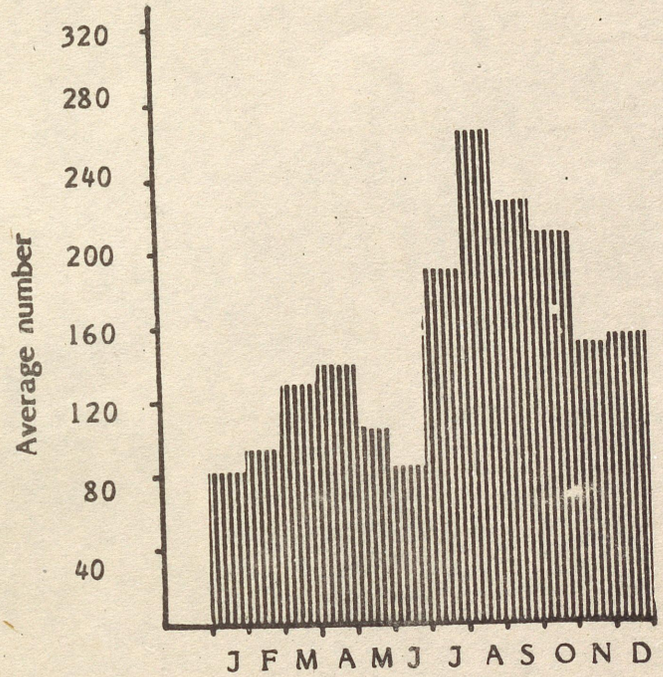
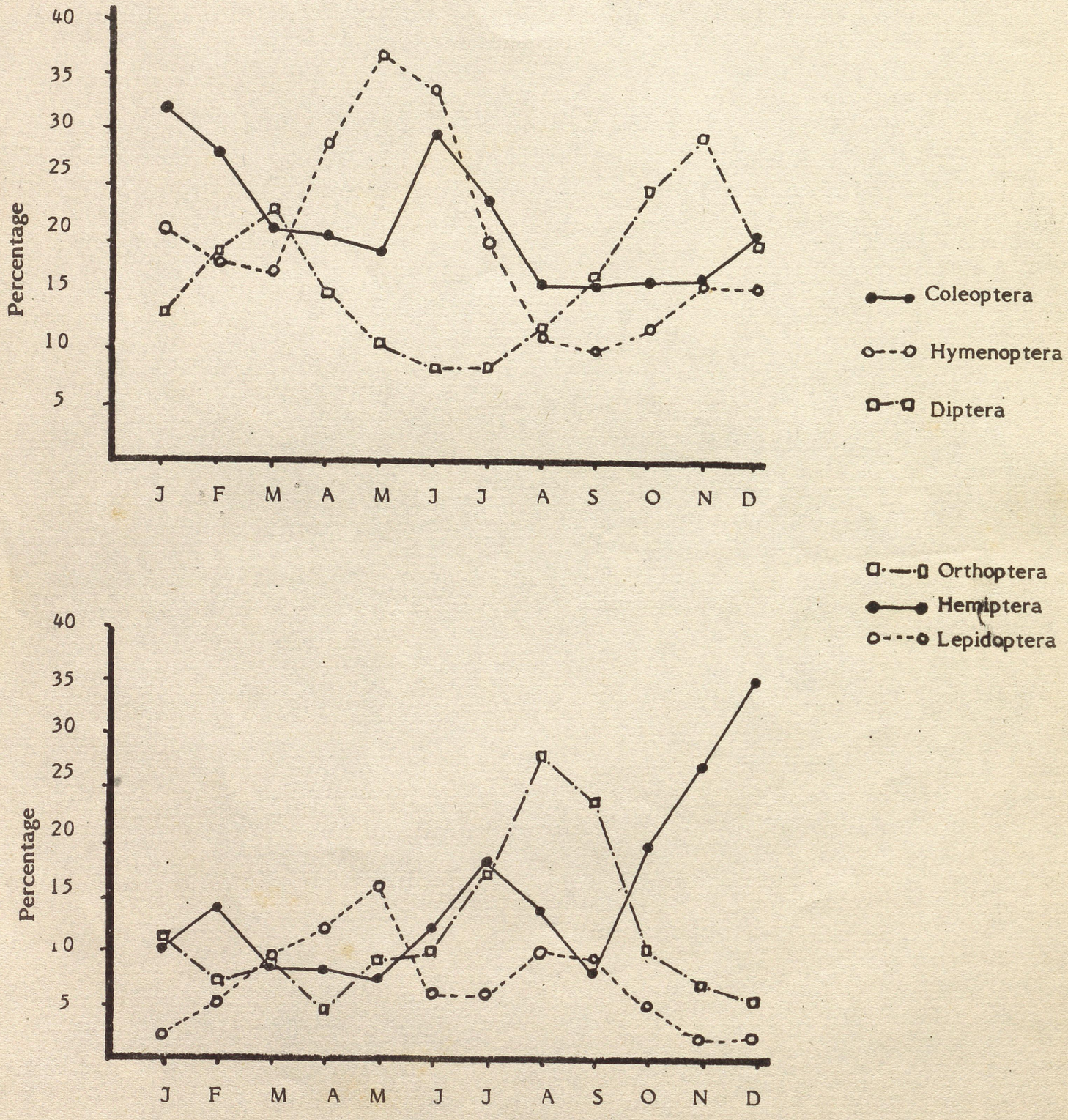


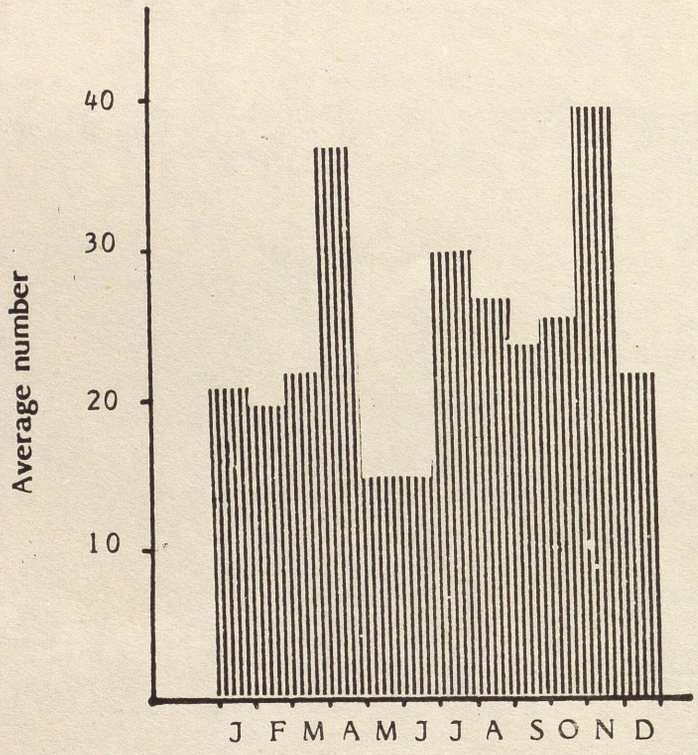
Fig. 25 Monthly variation in the abundance of common groups of insects - 1986



Relative abundance and fluctuation of spiders

Spiders were sampled along with the insects by sweeping, quadrat and insect tray methods. In general it followed the pattern of insect abundance. There was a decrease in the number of spiders during 1986 which may be due to the scanty rainfall of the year. A lean period of the spider abundance was observed during the peak of summer, May-June (Fig. 26). The ratio between the abundance of insects and spiders was 6:1.

Fig 26 Comparative abundance of spiders - 1986



Chapter IV

FISH FAUNA

All the parameters, namely variety, comparative abundance seasonal fluctuation, food, number of fish fry entering the park, breeding, and habitat preference were covered.

Forty species belonging to eight orders, 15 families and 29 genera were recorded during the present study from 1983 to 1986. Out of this, 13 species were new records to the park and 6 were new to the fish fauna of Rajasthan.

While the following species, namely Osteobrama cotio, Macrognathus aculiatus, Alia ciola, Crossochelius latius, Botio lohachata, Ompok bimaculatus and Gagata viridescens entered the park when the water was let in during 1985, they were absent in the water which was drawn in during 1986. This is intriguing as the water to the park this year was drawn only from the river Gambir. It may perhaps be useful to survey the fish fauna of both the rivers.

Estimation of fish fry entering the park

Altogether, approximately 10 million fish fry entered the park during 1986 as against the figure of 65 million calculated for 1985. The drastic reduction was due to the failure of monsoon resulting in the poor supply of water to the park. The two main instalments of water supply was from 10 th to 23 rd of August and from 8 th to 10 th of September; a total of only 0.017 million m^3 water was received in the park, wherease it was 15 million m^3 in 1985. The water was received only from river Gambir as river Banganga was dry.

It is, however, interesting to note that the average number per minute of fish fry entering the park was much higher during this year, 533.53 fry/minute. This may be because of the less supply of water to other areas from Ajan bund, the temporary reservoir, which would have reduced the chances of dispersal of fish fry.

Species of Cirrhinus, Chanda, Oxygaster, Labeo, Wallago, Pseudiotropis Catla and Amblipharingodon were the major fry recorded.

Comparative abundance of fishes

The most common species of fish in the park during 1986 were Channa punctatus followed by Heteropneustes fossilis and Colisa faciata. Ompok bimaculatus, Catla catla, Wallago attu, and Puntius sarana were rare.

All the species which were abundant during 1986 were air breathers. The low depth of water and the accumulated silt have made the habitat less suitable for gill breathing, fishes.

Species diversity of fishes for 1986 was 1.776.

Monthly fluctuation of fish abundance

Monthly abundance of fish based on the total catch showed an increase from January. Maximum abundance was in May-June (Fig. 26a). Their abundance was almost steady from July to December. The number of fish caught was inversely proportional to water depth because of the congregation of fish in the shallow pools and the high dispersal of them when the waterspread area was more, i.e. when the water depth was more.

The pattern of fluctuation of abundance of individual species was not much different from the common pattern.

Habitat preference

Habitat preference of the major species was studied intensively. The most preferred habitat of Channa punctatus was Ipomoea - Paspalum followed by Ipomoea - floating-submerged vegetation. They were abundant in places where the water flowed slowly, near sluice gates and also in drying pools.

Fig. 26(a) Monthly variation in the total catch of fish - 1986

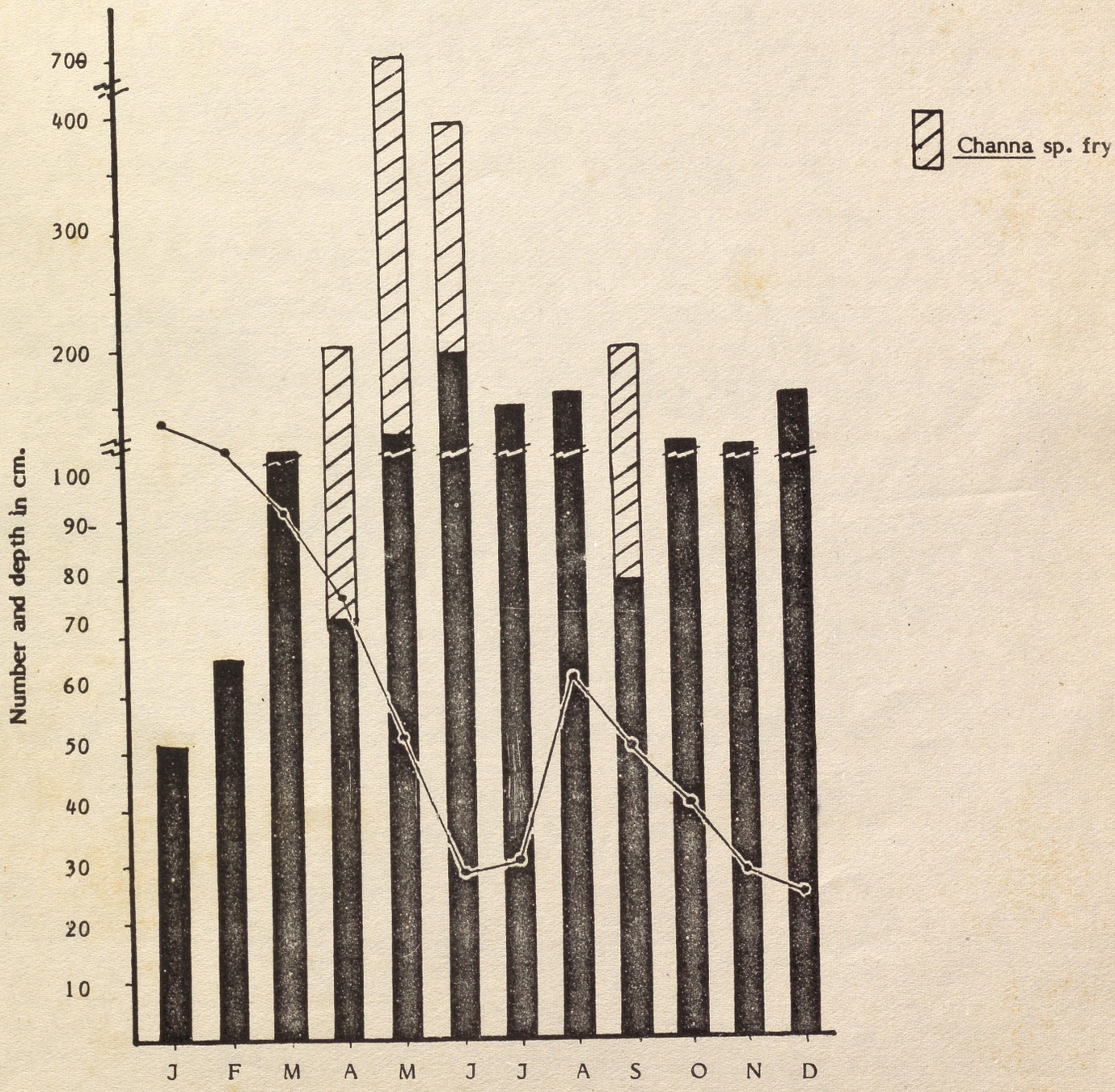


Table 5

Percentage frequency of fishes caught from different habitats

Species	OW	SF	FV	SV	S+F	Ei	Ipo	I+oth	Pasp	Sci.
C. punctatus	2.2	-	2.4	12.2	2.2	14.8	2.4	56.0	7.8	-
H. fossilis	21.2	10.2	16.3	10.2	10.2	0.6	1.8	24.1	5.4	-
C. faciata	20.2	-	-	27.4	-	-	3.6	36.9	-	11.9
L. rohita	25	-	-	56.25	18.75	-	-	-	-	-
C. mrigala	23.5	-	-	29.4	47.1	-	-	-	-	-
C. riba	60.2	-	8.4	28.9	2.4	-	-	-	-	-
N. notopterus	-	-	4.2	37.5	14.6	-	-	16.7	-	-
Oxygester Sp.	98.9	-	-	1.1	-	-	-	-	-	-
C. batrachus	31.6	-	26.3	-	26.3	-	-	15.8	-	-

OW = Openwater
SF = Slow flow
FV = Floating vegetation
SV = Submerged vegetation
S+F = Submerged + Floating vegetation
Ei = Eichhornia
Ipo = Ipomoea
I+oth = Ipomoea + Other vegetation
Pasp = Paspalum
Sci = Scirpus

The highly preferred habitat of Heteropneustes fossilis was open water followed by floating vegetation, and Ipomoea - floating vegetation. Colisa faciata was more in Ipomoea - Paspalum vegetation while Labeo rohita, Cirrhinus reba, C. mrigala were so in submerged vegetation, open water, and submerged - floating vegetation. (Table 5)

Food and feeding habit

Food and feeding habit of five major species were studied. Two of them were animal feeders while three were ominvorous (Table 6)

Table 6

Food preference of five major species of fishes

Species	Fish	Moll.	Inse.	Larv.	Lemna	F.Sc.	Debr.	Plan	Misc.
Channa punctatus	28.4	23.5	24.1	21.6	-	-	-	-	2.5
C. striatus	60	20	20	-	-	-	-	-	-
Clarias batracus	-	7.7	19.2	53.9	-	-	11.5	7.7	-
Notopterus notopterus	-	-	57.6	12.1	12.1	9.1	9.1	-	-
H. fossilis	-	12.2	12.2	33.3	-	-	16.6	13.3	12.4

Note : Moll = mollusc; Inse = Insects; Larv = Insect larve, F.Sc. = Fish Scales; Deber = Debris; Plan = Plant materials; Misc = miscellaneous.
(All figures are in percentage).

The most preferred food of C. punctatus was fish followed by insects and molluscs. C. striatus was more pisivorus than C. punctatus, Notopterus notopterus, fed more on insects, whereas Clarius batracus on insect larvae.

Breeding

As in the previous years, Channa sp. bred in April just before the peak summer. Large number of fry was seen in blocks E,D,K and L.

Chapter V

HERPETOLOGY

PYTHON STUDIES

The study, covering population, distribution and habitats of python in Keoladeo National Park was commenced in November 1985.

Methodology

A complete survey was made on foot and the locations where pythons were seen were marked on a map. Population assessment was done during winter when pythons come out of their hole for basking. A whole or a cluster of holes in a given locality where python is seen regularly is termed as python point. An estimate of their population was made by checking these points repeatedly and counting the snakes. The maximum number of pythons recorded was considered as the population of that particular point. The total population was accounted by summing up the maximum number of snakes seen at all the points. The possible draw backs of this method of estimation are :

1. Hibernating or partial hibernating individuals, if there are any, will escape the count.

2. Possibility of missing young pythons is more as they merge well with the surroundings. It is to be noted that the ratio of young pythons in our count is very low.

3. Inter-hole movements of pythons may lead to overlap in counting.

Marking of individual python appears to be the only solution to this.

Population

The estimated population is 144. 15 dead snakes were recorded from November 1985 to March 1987. Maximum number of snakes at a particular point was 12. Out of the 46 points recorded, 11 points had more than five snakes at a time, and seven had only signs of the snakes. Maximum number

of snakes recorded was in block I (Table 7). Although there were 46 python points, two of them, one in block M and the other in block H, ceased to be functional owing to various anthropogenic disturbances.

Distribution

Python points are distributed almost throughout the park (Fig. 27). Of the 46 points recorded, five were in aquatic area and the rest on land. In the aquatic area its hole was either on a tree or on a termite hill, but in the land it invariably used porcupine burrows. Maximum number of points was in blocks B and O (Table 7). It appears that there is a relation between the frequency of python points and saline patches.

Habitat

Vegetation at the python point was scrub jungle, consisting of Salvadora persica, S. oleoides, Capparis sepiaria, Prosopis juliflora and Acacia nilotica, S. persica was the most abundant.

Feeding Records

The following species were seen preyed on by python inside the park: spotbill, purple moorhen, crow pheasent, red start, cotton teal, rufoustailed hare, and five-striped squirrel. To gather more information on the food of python their droppings are being collected and analysed.

Co-habiting species

Signs of porcupine were noticed in 40 points (90%). Also, porcupines were observed coming out of the same hole where python was seen. Bicoloured leafnosed bats were seen in 15 holes (33.3%) along with python and porcupine. Jackal was observed going into the python hole thrice in January.

Fig. 27 Distribution of python points in the park



Table 7

Number of python points and maximum number of python recorded in each block

Block	Number of points	Total number of Python seen	Average no. of python
A	5	9	2
B	6	18	3
C	2	15	8
D	2	2	2
E	1	2	2
F	4	13	3
G	1	4	4
H*	4	7	2
I	5	30	6
J	1	-	
K	3	8	3
L	-	-	
M*	4	19	5
N	1	1	1
O	6	15	3
Canal	1	1	1
Total	46	144	

* One point distrubed in each

Predation

Scales of python were recorded from the droppings of jackal, whether jackal kills python or scavenges on dead snakes is not clear. However, jackal attacking python was recorded. Common monitor was observed pilfering the eggs of python in July. Trampling by ungulates may be one of the major reasons for the mortality of python inside the park. Hoof marks seen on eight, out of 15 dead snakes support this view. Hoof marks were recorded also on a live snake.

Ecto-parasites

Four genera of ecto-parasites (ticks) were identified from python: 1. Aponomma sp; 2. Hyalomma sp; 3. Haemophysallis sp; and 4. Amblyomma sp.

HERPETO-FAUNA OF KEOLADEO NATIONAL PARK

Although no intensive attempts were made to record the herpeto fauna of the park, available opportunities were used to make the faunistic list.

Frogs and, reptiles (except snakes) were hand caught and identified upto species level. Dead snakes were collected from the field. Status of most of the species inside the park is not known.

Altogether 33 species coming under 24 genera and 15 families have been identified as listed below.

Of the seven species of turtle recorded, two, namely spotted black terrapin (Geoclemys hamiltoni) and peacock soft-shell (Trionyx hurum) are additions to the Rajasthan fauna.

HERPETO - FAUNA OF KEOLADEO NATIONAL PARK

Amphibians (Frogs and Toads)

FAMILY : RANIDAE (Frogs)

1.	Rana cyanophlyctis		Skipper frog.
2.	Rana tigerina	-	Indian bull frog.
3.	Rana limnocharis	-	Indian cricket frog.
4.	Rana breviceps	-	Indian burrowing frog.

FAMILY : BUFONIDAE (Toad)

5.	Bufo stomaticus	-	Marbled toad

Chelonians (Turtles)

FAMILY : EMYDIDAE (Hardshells)

1.	Kachuga tecta	-	Indian sawback
2.	Kachuga tentoria	-	Indian tent turtle.
3.	Hardella thurgi	-	Brahminy river terrapin
4.	Geoclemys hamiltoni	-	Spotted black terrapin

FAMILY : TRIONYCHIDAE (Soft shells)

5.	Lissemys punctata	-	Indian flap-shell
6.	Trionyx gangeticus	-	Ganges soft-shell
7.	Trionyx hurum	-	Peacock soft-shell

Lizards

FAMILY : GECKONIDAE (Geckos)

1.	Hemidactylus flaviviridis	-	Northern house gecko
2.	Hemidactylus brooki	-	Brook's gecko
3.	Hemidactylus triedrus	-	Termite hill gecko

FAMILY : AGAMIDAE (Agamids)

4. Calotes versicolor - Common garden lizard

FAMILY : SCINCIDAE (Skinks)

5. Mabuya dissimilis - Sand skink
6. Riopa punctata - Snake skink

FAMILY : VARANIDAE (Monitor Lizards)

7. Varanus bengalensis - Common Indian monitor.
8. Varanus flavescens (?) - Yellow monitor

Ophidians (Snakes)

FAMILY : TYPHLOPIDAE

1. Typhlina bramina - Common worn snake

FAMILY : BOIDAE

2. Python molurus - Indian python
3. Eryx conicus - Russell's earth boa
4. Eryx johni - John's earth boa

FAMILY : DIPSADIDAE

5. Lycodon aulicus - Common wolf snake
6. Oligodon arnensis - Common kukri snake

FAMILY : NATRICIDAE

7. Xenochropis piscator - Checkered keelback water snake

FAMILY : COLUBRIDAE

8. Ptyas mucosus - Rat snake
9. Psammophis leithi - Leith's sand snake

FAMILY : HOMOLOPSIDAE

10. Boiga trigonata - Common cat snake

FAMILY : ELAPHIDAE

11. Bungarus caeruleus - Common krait

12. Naja naja - Common cobra

13. Vipera russelli - Russell's viper.

Chapter VI

ORNITHOLOGY

POPULATION OF AQUATIC BIRDS

Census of aquatic birds was conducted simultaneously from all the blocks, once in fortnight as in 1985.

Altogether, 92 species of birds were recorded in the aquatic area during 1986; the highest was in January and lowest July (Fig. 28). Species diversity was 3.5 for 1986 which is slightly higher than that of 1985. The trend of fluctuation of the number varied from 1985, especially after the monsoon which failed in 1986.

The population of aquatic birds was 26,320 in January which was the highest figure for the past four years. It is to be noted that the major increase was in the third week's count. It might be because of the convergence of a large number of migrants which were on their return from the south or other parts of the peninsula. Moreover, increased waterspread area of the year, owing to the release of more water had enlarged their habitats. Most of the land areas of blocks LW, B and K were inundated, and had only 30 to 50% of grass cover which was ideal for grass-loving species. While their number showed an increase, proportion of diving ducks to others was still less during this year (Table 7a).

The pattern of fluctuation of population was the same as in the former years. (Fig. 29). The number declined after the third week of February owing to the probable return migration. Population was the lowest in July and, much was not built up afterwards because of the failure of monsoon which was only 364 mm as against the 520 mm of 1985. As the monsoon was so poor in the catchment areas of the two rivers from where the park receives water through Ajan bund, the Park could receive only 0.01.7 million m^3 of water as against 15.32 million m^3 of 1985. 70% of the areas were dry during the latter part of the year. However, the number of species increased, even-though the total number of birds remained very low. The total population of aquatic birds during December was only 3481 which was about five times

Fig. 28 Fluctuation in the number of species of acquatic birds - 1986

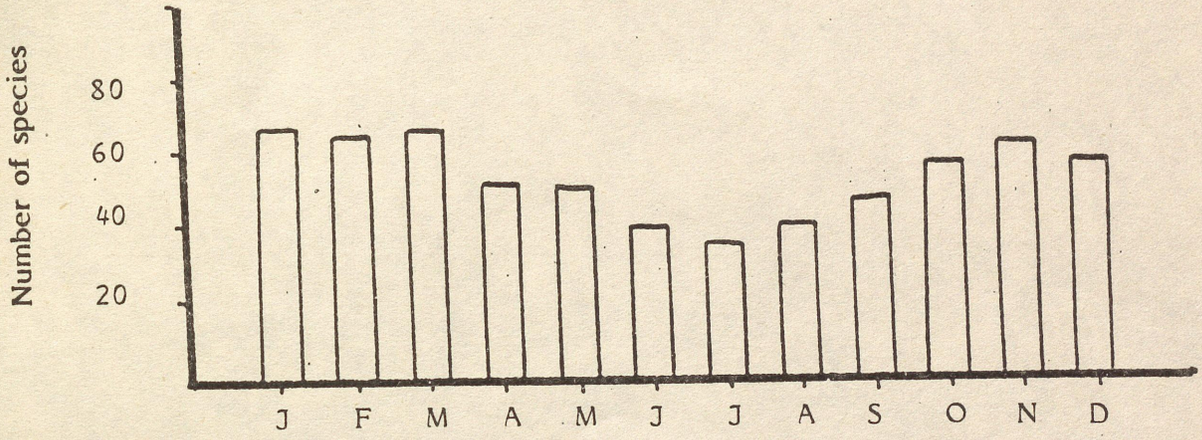


Fig. 29 Fluctuation of the abundance of aquatic birds - 1986

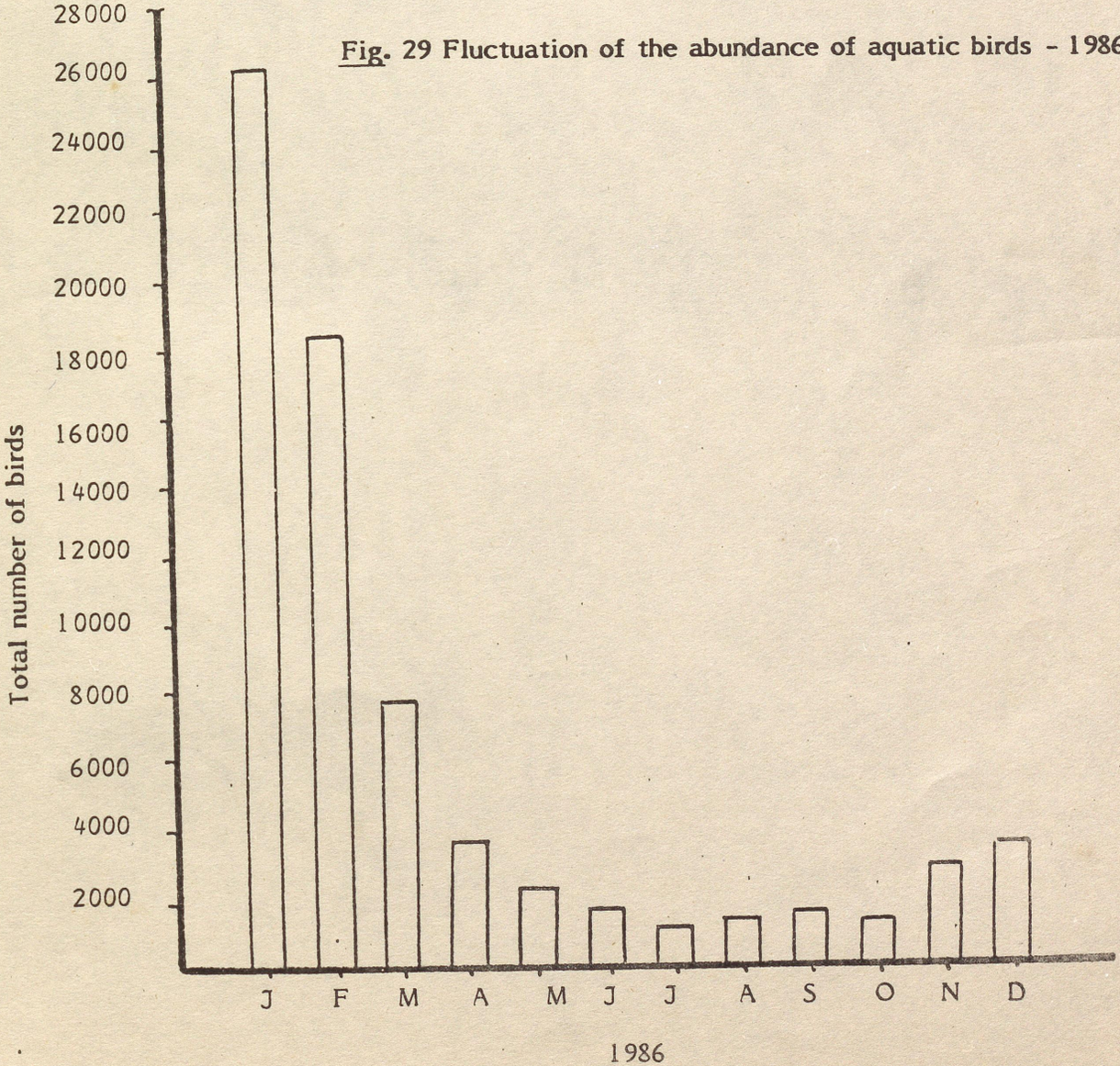


Table 7a

Population of major waterfowl species in 1986

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Greylag goose	4005	3049	35	0	0	0	0	0	0	6	151	463	7709
Barheaded goose	785	1085	108	1	0	0	0	0	0	0	0	22	2012
Lesser whistling teal	101	90	102	82	82	88	35	55	38	23	4	2	702
Brahminy duck	14	37	1	0	0	0	0	0	0	0	4	4	60
Pintail	7423	3089	160	0	0	0	0	0	13	17	111	358	11172
Common teal	3422	1665	442	17	0	0	0	0	42	143	717	753	7201
Spotbill	324	272	395	328	187	110	12	19	23	26	160	89	1945
Gadwal	701	385	61	0	0	0	0	0	0	2	24	116	1289
Wigeon	158	295	109	0	0	0	0	0	0	1	10	52	625
Garganey teal	32	56	179	20	8	1	0	0	3	25	11	0	335
Shoveller	1010	1269	363	1	0	0	0	0	0	11	96	194	2944
Redcrested pochard	210	19	0	0	0	0	0	0	0	0	0	7	236
Common pochard	219	47	0	0	0	0	0	0	0	4	1	0	271
White-eyed pochard	1	1	11	0	0	0	0	0	0	0	1	0	14
Tufted duck	31	40	20	0	0	0	0	0	0	0	2	2	95
Cotton teal	191	137	97	161	172	184	122	136	174	50	60	36	1520
Comb duck	27	36	35	24	11	7	9	1	3	1	0	0	154
Whitebreasted waterhen	36	22	29	56	36	34	42	46	44	34	42	16	437
Indian moorhen	1222	1490	990	636	14	1	0	1	41	76	160	150	4781
Purple moorhen	1112	1099	981	359	98	38	76	55	23	40	40	19	3940
Coot	3199	2087	1015	21	0	1	0	0	0	63	446	457	7289
TOTAL	24225	16270	5133	1706	608	464	296	313	404	522	2040	2751	54732

smaller than the bird population of December 1985. There is a positive correlation between water depth and population of aquatic birds ($r = 0.774$, $P < 0.01$) during 1986. Also there is a direct positive correlation with the number of birds and the quantum of water supplied ($r = 0.904$, $P < 0.05$) during 1983 to 1986.

The most abundant species of the year was pintail followed by greylag goose. Mallard, falcated teal, marbled teal and baikal teal were recorded during January. The solitary baikal teal seen in block L during January seemed to be a hybrid of wigeon and baikal teal since it had the characters of both the species, almost equally.

ECOLOGY OF PISCIVOROUS BIRDS

The study on the breeding of colonial water birds has been expanded to encompass the general ecology of all the piscivorous birds of the Park. Major objectives are to quantify the fish demand of each species and to work out the quantum of fish required for the Park annually. Apart from this, the study aims at monitoring the breeding population, habitat requirements, time budgeting and association of all the piscivorous birds. The study was started in January 1986.

Breeding of colonial birds

Of the 25 species of piscivorous birds, 15 were colonial breeders, namely large cormorant, shag, little cormorant, darter, purple heron, grey heron, cattle egret, median egret, large egret, little egret, night heron, painted strok, openbill stork, white ibis and spoonbill.

Season : All the species except the grey heron and purple heron had only one breeding season which is in the monsoon. The grey hereon and purple heron breed in summer also.

Breeding population : Breeding season in monsoon began on third June. All the species started nesting on the regular location, in blocks D, LW and Sapan mori. However, their number was very small because of the failure of monsoon. Later, all of them deserted the colonies in block LW and Sapan mori and moved to block D. Altogether, the year had only 610 nests compared to 6407 nests in 1985. The highest number was of white ibis and lowest large egret and painted stork. Large cormorant, little cormorant and spoonbill had no nest at all. (Table 8)

Table 8

Total number of nests and nestings of heronry species during 1986.

Species	No. of Nests	No. of Nestlings
Large cormorant	-	-
Shag	29	6
Little cormorant	-	-
Darter	48	3
Purple heron	11	11
Grey heron	35	3
Cattle egret	16	2
Large egret	9	-
Median egret	118	36
Little egret	57	2
Night heron	72	6
Painted stork	9	-
Openbill stork	80	9
White ibis	126	-
Spoonbill	-	-
TOTAL	610	78

Altogether 78 chicks were produced during the year, out of which 46 % were median egret (Table 8). The poor nesting success is related to the low water level and inadequate number of fingerlings.

Food and feeding habits

Food and feeding habits of piscivorous birds were studied by observing the birds directly. Observations were made during different hours of the day, as far as possible, for each species. Individuals were followed continuously till the bird disappeared from sight. This provided information on activity pattern also. Peck rates were classified into successful and unsuccessful; prey species were identified whenever possible and, their length was gauged against the bill length of the bird. In all, 12,111 observations were made covering all the seasons of the year.

Cormorants, darters and pelicans fed exclusively on fish, whereas cattle egret, little egret, and median egret did so on insects and openbill on molluscs (Table 9). Variety of food items was more for grey heron, white-necked stork, and blacknecked stork.

Habitat preference

In all, the following 16 habitats were identified according to plant associations and, birds seen in each of the habitats were recorded.

1. Open water
2. Open water - floating vegetation.
3. Shallow water - sparse rooted vegetation.
4. Grass patch.
5. Ipomoea patch.
6. Grass + Ipomoea
7. Typha
8. Tree
9. Boughs overhanging water.

Table 9

Percentage frequency of food items consumed by the piscivorus birds.

Species/Food	Insect	Mollusc	Frog	Fish	Snake	Bird	Turtle	Miscellaneous	Total observation
Large cormorant	-	-	-	100	-	-	-	-	893
Shag	-	-	-	100	-	-	-	-	1321
Little cormorant	-	-	-	100	-	-	-	-	983
Darter	-	-	-	100	-	-	-	-	531
Grey heron	4.4	-	0.2	85.3	3.2	-	0.3	6.6	985
Purple heron	14.9	-	-	69.6	0.9	-	-	14.6	907
Pond heron	18.9	0.6	1.1	79.3	0.2	-	-	-	1233
Cattle egret	78.0	2.9	-	6.6	-	-	-	12.4	1069
Large egret	17.8	-	-	62.7	0.4	-	-	19.1	466
Median egret	41.3	0.5	-	41.3	0.4	-	.	16.5	560
Little egret	59.3	0.2	-	15.3	0.5	-	-	24.7	541
Night heron	-	-	-	100	-	-	-	-	31
Painted stork	2.5	1.1	0.7	84.1	-	-	-	11.6	283
Openbill stork	-	87.4	-	6.3	-	-	-	6.3	367
Whitenecked stork	11.9	17.6	1.1	47.1	1.1	-	3.4	17.6	176
Blacknecked stork	-	0.1	1.9	70	10.1	5.7	3.8	8.4	315
Adjutant stork	-	-	-	100	-	-	-	-	13
Spoon bill	-	-	-	20.5	-	-	-	79.5	404
Pied kingfisher	8.5	-	-	58.1	-	-	-	33.4	246
Common kingfisher	25	-	-	58.1	-	-	-	16.9	124
Whitebrested Kingfisher	13.7	6	-	52	0.6	-	-	27.7	350
Pelicans	-	-	-	100	-	-	-	-	12
White ibis	10.2	-	-	10.6	-	-	-	79.2	301

10. Mound
11. Cyperus sp.
12. Eleocharis sp.
13. Edge of the dyke.
14. Pole.
15. Eichhornia
16. Miscellaneous

In all, 13,998 observations were made on piscivorous birds to assess the habitat preference during 1986. The piscivores, according to their feeding habits, are divided into swimming, diving and wading birds.

Swimming birds : Large cormorant, Indian shag, little cormorant, pelicans and Indian darter.

Diving birds : Pied kingfisher, common kingfisher, and whitebreasted kingfisher.

Wading birds : Grey heron, purple heron, pond heron, night heron, cattle egret, large egret, median egret, little egret, painted stork, openbill stork, whitencked stork, blacknecked stork, adjutant stork, white ibis and spoonbill.

The swimming birds preferred mainly openwater floating vegetation, and shallow water - sparse vegetation. These habitats were comparatively deeper areas of the wetland. Only submerged and floating vegetation such as Hydrilla sp., Naja sp., Azolla sp, Lemna sp. and Nymhaea sp. were common in these areas. Apart from these, they used the over hanging boughs and mounds for sunning, preening and resting (Table 10).

The diving birds were usually recorded on the over hanging boughs, poles and trees. (Table 11). These habitats were used as a perch for food searching and they fed mainly from openwater, and shallow water - sparse vegetation, which are nearer to the perch.

Table 10

Percentage frequency of swimming birds recorded at various habitats

Habitat/Species	Large cormorant	Shag	Little cormorant	Darter	Pelicans
Open water	48.0	33.5	31.7	26.3	54.1
Open water - Floting vegetation	25.3	24.1	15.0	19.0	45.9
Shallow water - Sparse vegetation	-	8.1	14.0	13.2	-
Grass + Ipomoea	-	-	0.5	6.4	-
Tree	16.0	15.5	13.5	14.5	-
Over hanging boughs	2.2	11.3	15.0	10.0	-
Mound	6.1	2.1	3.0	3.0	-
Edge of the dyke	-	-	-	5.0	-
Pole	-	3.2	6.0	2.6	-
Eichhornia sp.	2.1	2.2	1.3	-	-
Miscellaneous	-	-	-	-	-
Total No.of observations	538	406	608	706	159

Table 11

Percentage frequenty of diving birds recorded at various habitats

Habitat/species	Pied Kingfisher	Common kingfisher	Whitebreasted kingfisher
Typha	6.0	1.3	6.5
Tree	17.1	13.0	45.5
Over hanging boughs	35.6	45.5	24.0
Pole	38.5	40.0	17.5
Grass + Ipomoea	1.1	-	6.5
Miscellaneous	1.2	-	-
Total observations	542	215	433

The wading birds were more common in Ipomoea sp. grass - Ipomoea sp, shallow water - sparse vegetation, edge of the mound and dyke, Typha sp, Cyperus sp, Eleocharis sp and Eichhornia sp (Table 12). All the species were seen walking and picking up items such as fishes and insects. Trees, mounds and boughs were used mainly for resting and preening.

COMPARATIVE ECOLOGY OF RESIDENT DUCKS

Field study on the ecology of resident ducks was completed in December 1986; a detailed analysis is in progress.

The highest number of resident ducks during this year was about 100, 350, 170 and 35 for whistling teal, spotbill, cotton teal and comb duck respectively. However, their population reduced considerably after the monsoon, towards the end of December. Except spotbill ducks all, the other three species decreased drastically.

There was only a slight variation in their habitat preference; cotton teals and whistling teals were more in Nymphoides habitats during 1986 than in the last year.

Micro-habitat analyses of their feeding sites, covering water chemistry, abundance of macrophytes and macroinvertebrates,, were carried out. More droppings were collected this year for micro-histological estimation of food of each species.

Post-monsoon breeding was not very successful this year, probably because of the failure of monsoon. Most of the nests were located only during the beginning of summer. Altogether, eight nests of spotbill, five nests of whistling teal and two nests of cotton teal were recorded. Nests of comb ducks were not seen this year as in 1985. Intra and interspecific competition for nesting holes was noticed in cotton teals this year, but the frequency of competition was less than during the previous year.

Table 12

Percentage frequency of wading birds recorded at various habitats

Species/Habitats	Grassy patch	Ipomoea patch	Grass Ipomea	Tree	Over hanging boughs	Shallow water sparse vegetation	Mound	Miscella-neous	Total observa-tion
Grey Heron	11.0	23.5	26.4	8.7	1.0	4.5	7.4	17.5	1189
Purple heron	18.0	22.7	25.6	7.1	0.5	3.1	3.5	19.5	1183
Pond heron	11.0	24.1	18.0	6.0	10.7	9.0	4.0	17.2	1548
Cattle egret	64.0	6.5	4.3	10.5	-	-	-	14.5	478
Large egret	7.7	23.8	47.0	1.7	-	9.3	-	5.3	432
Median egret	14.0	20.7	17.8	6.3	6.2	11.1	6.5	17.0	1461
Little egret	6.2	12.5	20.5	18.5	4.2	-	6.2	31.9	504
Night heron	-	-	4.0	82.0	4.0	-	-	10.0	927
Painted stork	-	-	5.1	5.1	-	61.5	13.6	14.7	704
Openbill stork	-	10.8	8.5	33.7	-	33.7	-	13.3	306
Whitenecked stork	22.4	11.0	12.0	-	8.3	-	-	46.3	192
Blacknecked stork	7.3	11.4	22.5	1.0	-	11.4	11.4	35.5	316
Adjutant stork	60.5	15.8	23.7	-	-	-	-	-	38
White ibis	20.5	10.8	25.5	10.8	0.5	-	0.5	31.4	795
Spoonbill	-	-	12.0	11.3	-	42.8	-	3399	318

ECOLOGY OF MIGRATORY WATERFOWL

This study covered the following aspects of waterfowl ecology: 1. population, 2. feeding pattern, 3. habitat utilisation, 4. vegetation in waterfowl habitat, 5. water depth in the foraging sites, 6. association of waterfowl, and departure time of migrants.

Methodology

Aquatic areas, according to dominant plant associations, have been classified into 10 habitas:

1. Small leaf floating vegetation - submerged vegetation
2. Broad leaf floating vegetation - submerged vegetation
3. Open water - submerged vegetation
4. Open water
5. Ipomoea
6. Eleocharis
7. Cyperus
8. Areas having density of grasses less than 30%.
9. Areas having density of grasses between 30 and 50%.
10. Areas having density of grasses between 50 and 75%.

Feeding methods of waterfowl were classified into:

1. Diving
2. Upending
3. Neck submerged
4. Head submerged
5. Bill submerged
6. Straining from surface
7. Picking from surface
8. Grazing
9. Pulling out.

The study was commenced in November 1985. Altogether, 1,100 observations were made on habitat utilization and feeding techniques from November 1985 to April 1986. During the winter of 1986-87 only 280 observations could be made owing to the poor population of waterfowl.

For one dimensional niche segregation, niche breadth and niche overlpap have been calculated for both feeding habitat and feeding pattern using the formulae

$$B = \frac{1}{n \sum_{i=1}^{n} P_i^2} \qquad (1) \qquad \alpha xy = \min (Pxi, Pyi) \qquad (2)$$

respectively.

Feeding technique

Altogether, nine feeding techniques were observed in 21 species of waterfowl. The most preferred techniques for each species have been worked out based on the frequency of technique used by each of them (Table 13). One dimensional niche breadth using feeding techniques, has been worked out and, it has been found out that the most specialised among them are white-eyed pochard and tufted duck followed by wigeon whose niche breadth variation was only 0 to 0.0035. The maximum niche breadth was for garganey and shoveller, 0.236 and 0.207 respectively (Table 14) which indicates their ability to employ a variety of feeding techniques.

Based on the various feeding techniques adopted by waterfowl, three main and four sub-guilds could be distingushed (Table 15).

Habitat Utilisation

In all, 10 habitats were utilised by waterfowl during the winter of

Table 13

Preferred feeding technique and habitat of waterfowl during 1986

Species	Preferred feeding technique	Preferred habitat
Greylag	Grazing	Grass 30 to 50%
Barheaded	Grazing	Grass 30 to 50%
Whistling teal	Diving	Broad leaf vegetation
Pintail	Upending	Grass 30 to 50%
Common teal	Bill submerged	Small leaf vegetation & grass
Spotbill	Bill submerged	Small leaf vegetation & grass
Gadwall	Bill submerged	Small leaf vegetation
Wigeon	Bill submerged	Small leaf vegetation & grass
Garganey	Straining from surface	Small leaf vegetation
Shoveller	Upending	Small leaf vegetation & grass
Redcrested pochard	Diving	Broad leaf & small leaf vegetation
Tufted pochard	Diving	Broad leaf vegetation & Openwater
Common pochard	Diving	Broad leaf & Small leafed vegetation
White-eyed pochard	Diving	Ipomoea
Cotton teal	Bill submerged	Small leaf vegetation
Coot	Bill submerged	Small leaf vegetation
Indian moorhen	Picking from surface	Small leaf vegetation
Purple moorhen	Pulling out	Grass
Little grebe	Diving	Small leaf vegetation

Table 14

One dimensional niche breadth of waterfowl feeding pattern and habitat

Birds	Feeding pattern	Feeding habitat
Greylag	0.037	0.155
Barheaded	0.075	0.113
Whistling teal	0.062	0.065
Pintail	0.016	0.341
Common teal	0.185	0.352
Spotbill	0.097	0.338
Mallard	0.051	0.085
Gadwall	0.024	0.138
Wigeon	0.0035	0.395
Garganey	0.236	0.160
Shoveller	0.207	0.378
Redcrested pochard	0.041	0.157
Tufted pochard	0	0.253
Common pochard	0.024	0.187
White-eyed pochard	0	0.264
Cotton teal	0.031	0.046
Coot	0.174	0.116
Indian moorhen	0.029	0.145
Purple moorhen	0.006	0.189
Little grebe	0.019	0.052

Table 15

Guild structure of waterfowl based on feeding techniques

Guild	Birds	$\bar{X}$ overlap	Feeding technique
I	Greylag	0.87	Grazing
	Barheaded		
II	Pochards	0.91	Diving
	Whistling teal		
	Little grebe		
III	Mallard	0.87	Bill submerged
	Spotbill		
	Gadwall		
	Wigeon		
	Cotton teal		
IV	Common teal	0.70	Straining from surface
V.	Pintail	0.58	Upending
	Shoveller		
VI.	Coot	-	Diving & bill-submerged
VII.	Indian moorhen	-	Picking from surface

I,II,III - Main guilds

IV,V,VI,VII - Sub guilds

Table 16

Guild structure of waterfowl based on feeding habitats

Guild	Birds	$\bar{X}$ overlap	Habitat	Status of habitat
I	Gadwall	0.80	Floating vegetation	
	Garganey		small leaf-	Rare
	Cotton teal		Submerged vegetation	
	Coot			
	Indian moorhen			
II	Greylag	0.79	Grassy patch	
	Barheaded			Common
	Pintail			
	Mallard			
III	Common teal	0.84	Floating vegetation	
	Spotbill		small leaf-	Rare
	Wigeon		Submerged vegetation &	
	Shoveller		Grassy patch	Common
IV	Redcrested pochard	-	Small leaf &	
			broad leaf	Rare
	Common pochard		vegetation	

I & II - Main guilds

III & IV - Sub guilds

1985-86. Their preferred habitat indicates that only three species, the barheaded and greylag goose and the pintail fed on grassy areas having 30-50% of grass cover (Table 13). Most of the waterfowl preferred habitats having small leafed floating vegetation. The maximum niche breadth, using habitat as a dimension, was in wigeon, whereas the minimum in cotton teal (Table 14).

Frequency utilisation of various habitats by different waterfowl indicates their common interests in many of the habitats. Based on these, two main and two sub-guilds could be formed (Table 16).

ECOLOGY OF THE SIBERIAN CRANE

Studies on the wintering ecology of the Siberian crane were continued covering the following aspects: arrival and departure; distribution inside the park; food and feeding habits, habitat preference and activity pattern; roosting behaviour and interspecific association.

Population, distribution and habitat

Population of the Siberian crane during the winter of 1985-'86 was 37 with 6 juveniles and that of 1986-'87 was 38 with 6 juveniles; the juvenile adult ratio in the two winters was 1:5.2 and 1:5.3 respectively. Casualities during migration might be the main reason for the almost steady population, inspite of the annual recruitment. No mortality was recorded at the park. 1985-'86 population was distributed in their traditional areas, blocks E,F,K and L (Fig. 30) as the waterspread area was more as a result of heavy monsoon and letting in of more water. Many of the cranes occupied the same areas for most part of the season; the birds moving with the receding water, preferring areas of 20 to 30 cm deep water. Most of these areas had Scirpus spp. - Ipomoea - Paspalum dominant community. They left the park during 5th to 9th March and, the wintering population of 1986-'87 started arriving from 19th October but most of them reached the park only during 10th to 12th November and two on 3rd December. Most of the birds were confined

to block E (Fig. 30) which had some open water area. The middle of this open water area had submerged vegetation and bordering areas had sparse growth of emergents such as Paspalum distichum, Ipomoea aquatica, and Cyperus alopecuroides, mostly with 10 to 30 cm. of water. Eichhornia crassipes was also common. Roosting area was also the same, with slightly deeper water.

Ducks, teals, geese, white ibis, and sarus crane were found in close proximity feeding or resting along with the Siberian crane and not much altercation was noticed with any of these except with the sarus at the beginning and end of the season.

Food and feeding habits

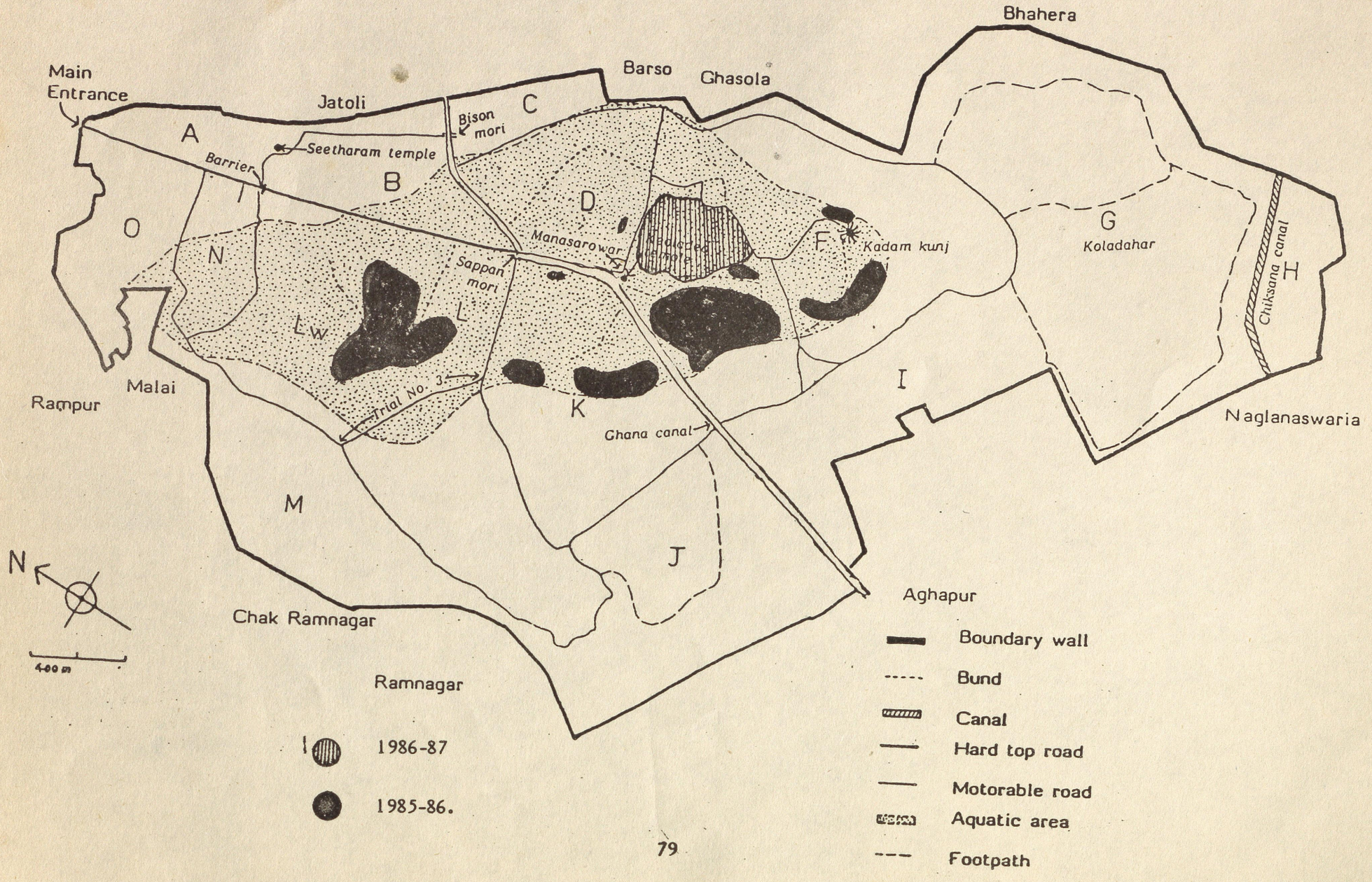
Major food items recorded during 1985-'86 were tubers of Scirpus tuberosus, Cyperus rotundus, Nymphaea spp. ; rhyzomes of Scirpus littoralis, Eleocharis plantaginea, tips of these reeds, and aquatic insects. But during 1986-'87 most of them fed on aquatic molluscs, worms and insects; tubers and rhyzomes of Nymphaea spp., Eleocharis spp., S. tuberosus, Hydrilla verticillata The feeding frequency was very high (about four times more) compared to the previous years, as it was less productive feeding on small items from the open water area. Digging bouts were proportionately of shorter durations as the items were smaller. In 1985-'86 the items were larger and it was difficult to extricate them through the litter and grass, and hence took more time.

Activity pattern and time budget

Focal animal sampling and scanning methods were followed. About 200 hours were spent on intensive observations.

The Siberian cranes spent most of the time for feeding. Time spent for other activities was much less except for preening and resting. Precentage

Fig. 30 Habitat and distribution of Siberian crane



of time spent by different individuals in each hour for feeding as well as percentage of individuals feeding in each hour showed that they had higher feeding activity all through the day with three main peaks, early morning, before noon and evening (Fig. 31,32,33). Feeding was comparatively less in the afternoon hours when they preened and rested. Feeding time was 10% more during the winter of 1986-'87 than that of 1985-'86 (Table 17.) which might be due to the scarcity of the preferred larger tubers. There is a significant correlation between the feeding time of the male and female parents ($r = 0.87$, $p < 0.02$).

Table 17

Average time spent for feeding by the Siberian crane during 1986

Month	% of time spent for feeding by individuals.					% of birds feeding (general activity)
	Family			Pair		
	♂	♀	Juve - nile	♂	♀	
January	64.1	69.0	75.3	68.7	62.9	70.3
February	63.7	67.3	72.8	54.9	41.8	-
March	No data			36.6	36.3	37.9
November	61.6	72.9	76.6	No data		70.9
December	77.0	78.3	76.4	No data		77.9

The average feeding time of the parents was significantly less than that of the juvenile (standard error of difference between means) except in December 1986. However, variation in the feeding pattern between them (Table 18) during different hours was not significantly different (Kolmogorov-Smirnov Test).

Fig. 31 Feeding rhythm of Siberian crane

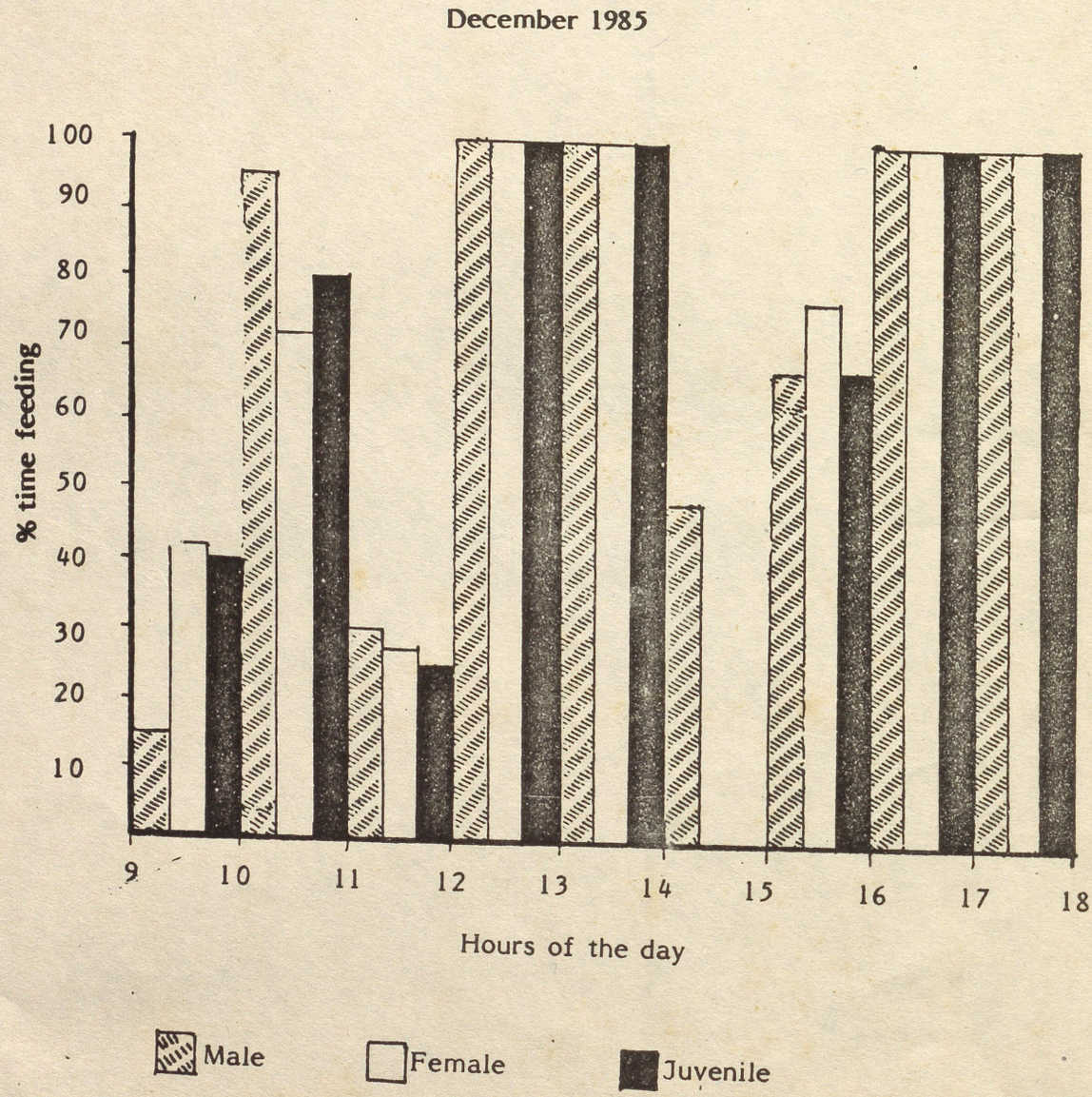


Fig. 32 Feeding rhythm of Siberian crane - 1986

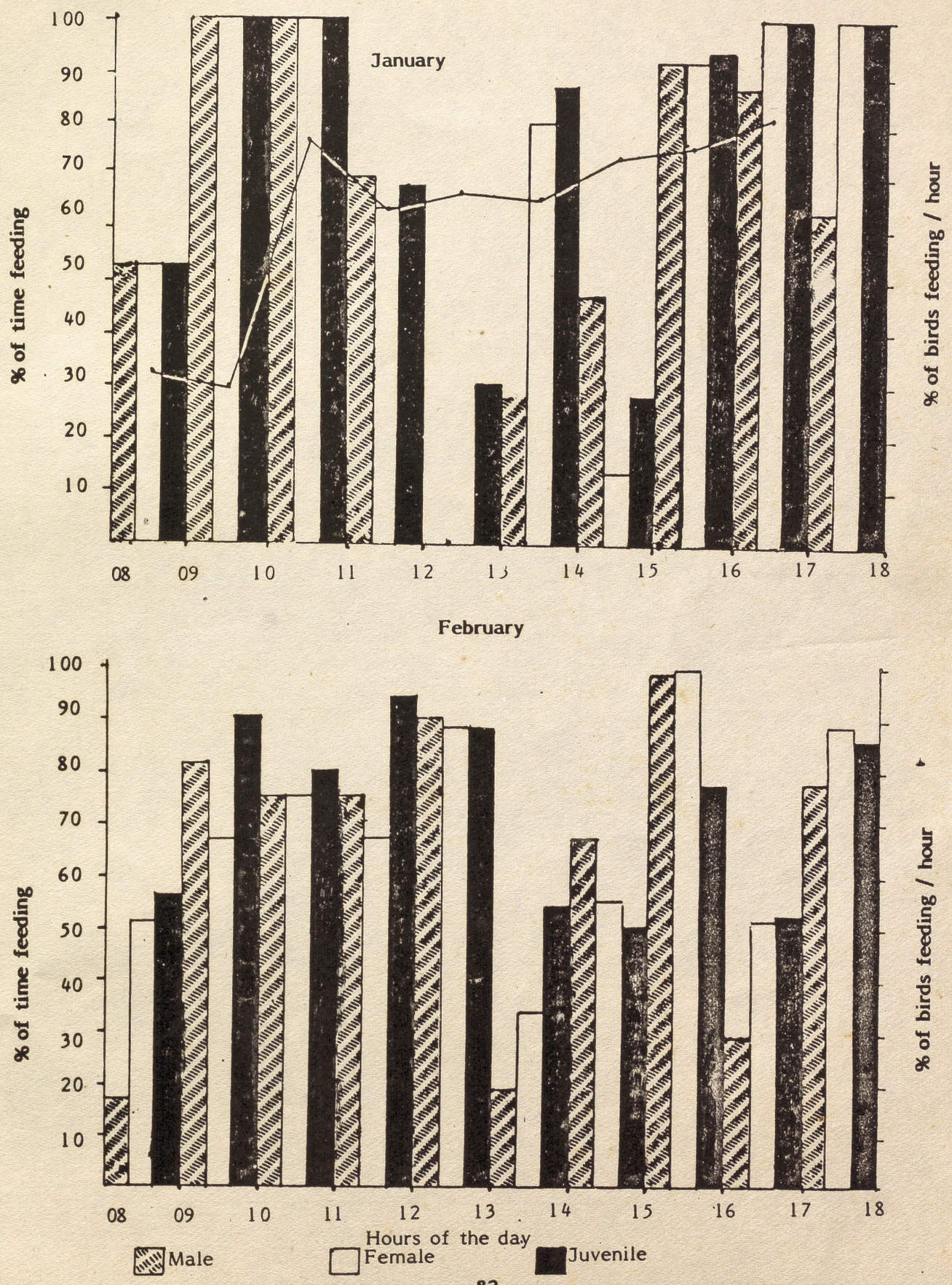


Fig. 33 Feeding rhythm of Siberian crane - 1986

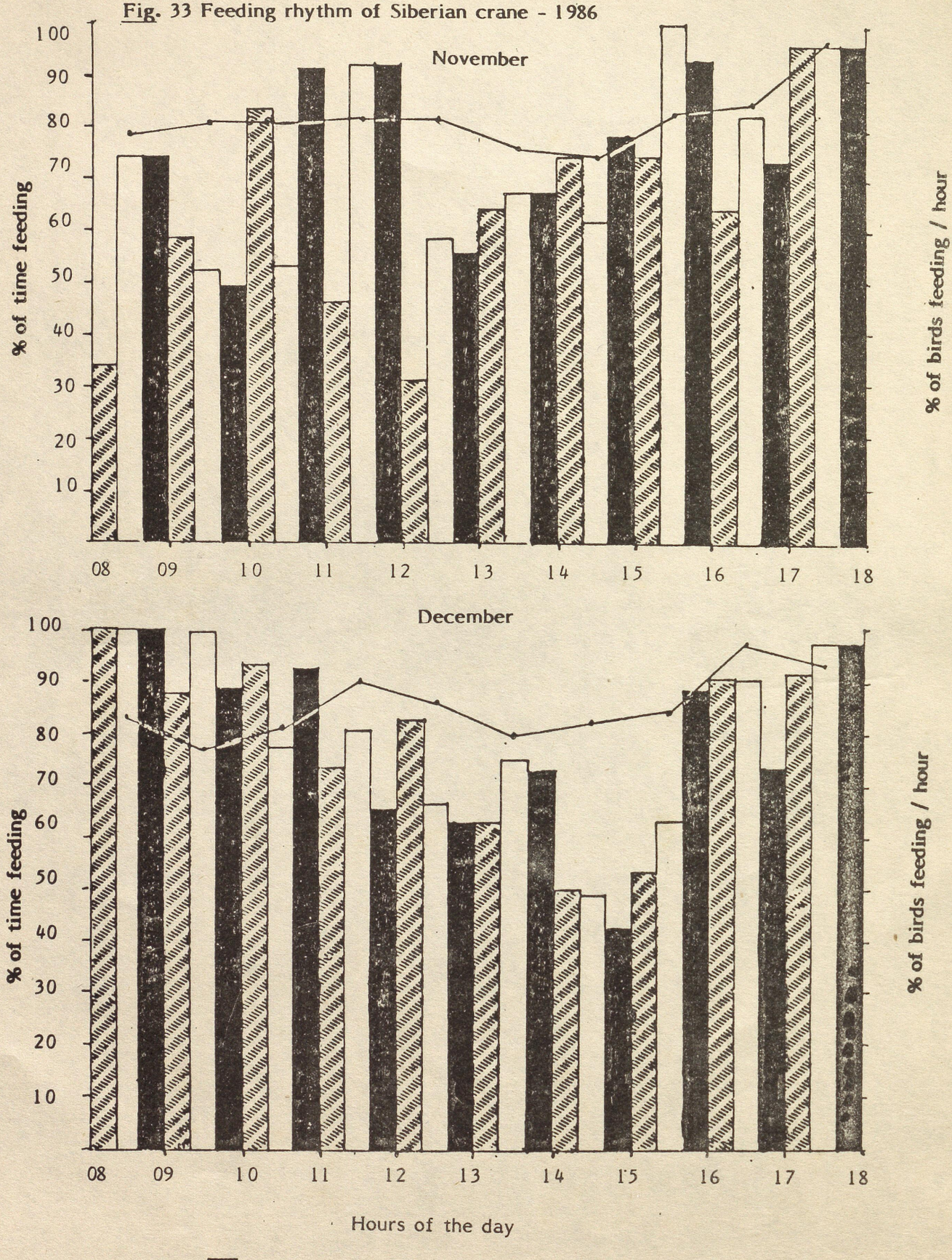


Table 18

Percentage of time feeding by parents and juvenile of the Siberian crane during 1986

Month	Individuals	Hours												
		08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	X	±	SD
January	P.	53.3	100	100	66.7	0	53.3	30	91.67	93.3	81.7	57.2	±	36.67
	J.	53.3	100	100	68.3	30	86.67	28.3	93.3	100	100	66.19	±	35.93
February	P.	34.3	73.8	75	68.5	88.75	26.67	60.8	98.7	40	82.7	64.92	±	24.17
	J.	55.7	90.0	80	94.17	87.5	54.17	50	76.67	51.67	85.3	73.12	±	16.93
November	P.	53.93	55	68.04	68.84	44.4	65.56	67.5	86.95	73.06	96.36	67.97	±	15.35
	J.	73.57	49.4	90.56	92.22	55	66.67	77.78	92.78	73.3	96.36	76.76	±	16.39
December	P.	100	93.8	86.25	77.5	75	69.17	49.59	58.48	90.0	94.0	79.38	±	16.53
	J.	100	89.17	92.5	65.83	62.5	73.33	41.67	87.5	73.33	97.33	78.32	±	18.36

Note : P = Parents; J = Juvenile.

COMPARATIVE ECOLOGY OF THE PHEASANT-TAILED (*HYDROPHASIANUS CHIRURGUS*) AND BRONZEWINGED JACANA (*METOPIDIUS INDICUS*)

One of the main phenomena noticed in the park as a result of drastic changes in the habitat was the fluctuation of the population of those species of birds which prefer floating and emergent vegetation, and those prefering open water areas. Intensive studies had to be launched on the representatives of both these groups to monitor the changes in the population and also to determine the deleterious or otherwise effect of habitat alterations on the ecology of these two groups of birds. Jacanas were selected as representatives of the group which prefer floating and emergent vegetation.

The study commenced from June 1986 and had the following specific objectives: 1) to determine the population and distribution of both species of jacanas inside the park, 2) to evalauate the habitat preference, 3) to determine the food and feeding habits, 4) to investigate the activity rhythm and, 5) to study the breeding biology of both species.

Population and distribution were assessed by weekly census carried out in the morning using dykes as transects. Individual birds were classified as adults, chicks and immatures. Chick-immature classification was based on their dependence on parents. Distribution was marked on block-wise maps of the park.

Habitat preference was studied to evaluate the utilization of each habitat by the jacanas and also to determine the function of each habitat in the survival of jacanas. Availability of each habitat was assessed every week and the number of individuals and its activity at the time of observation on the particular habitat were recorded along with habitat types. All the habitat types were visited regularly.

Activity rhythm was recorded by full-day observations, carried out

throughout the day in each month. The segment objectives of this were to find out the time allocation for each activity and to single out the cause and priorities for this pattern of allocation. The method of study was sampling the activities with pre-determined time intervals.

Food of both the species was determined by observation through telescope. Samples of macro-invertebrates were taken from both the feeding and non-feeding sites. Vegetation of these areas was studied by Quadrat Charting Method.

Result and discussion

Population and distribution : Bronzewinged jacanas were more than the pheasant tailed jacanas during the study period, June to December. The maximum number of bronzewinged was in June-July and the minimum in November (Table 19). The more or less stabilized population in the first three months can be attributed to territoriality and breeding. The decline in September-October may be due to dispersal of the newly born chicks or mortality, and the sharp fall from November was obviously due to local movements caused by drought.

The highest number of pheasant-tailed jacanas recorded was only 13. As they were rare and were not breeding inside the Park, much data could not be collected on this species.

Habitat preference

Bronzewinged preferred floating vegetation such as Ipomoea aquatica and Eichhornia crassipes for breeding.

Food and feeding habits

Two modes of feeding were recognized for both the species: "Ducking

and feeding", and "walking and feeding", the former was employed when there was no substratum (grass-mat), floating vegetation or dense submerged vegetation) and the latter when there was substratum.

The following food items were identified for bronze-winged jacana; molluscs (Lemnaea sp. Planorbis sp.), arachnids (aquatic spiders), hemipterans (Ranatra sp.) and coleopterans (Cassida circumdata).

Table 19

Population of the bronzewinged and pheasant-tailed jacana (June-December 1986)

Month	Average number recorded	
	Bronzewinged jacana	Pheasant-tailed jacana
June	71	0.5
July	71	0.75
August	68.5	0
September	58.2	0.75
October	59.6	6.33
November	27.6	7.33
December	29.4	10.2

Note : Figure indicates mean of the four counts made each month.

Activity rhythm

Both the species spent more time for feeding. Synchoronization of activities among the individuals was more in pheasant-tailed than in bronzewinged jacana. The former was often in flocks, varying from three to thirteen individuals. Bronzewinged was more isolated and less social.

Breeding

Bronzewinged bred inside the park but not pheasant-tailed. Breeding season extended from May to September. Nests appeared poorly built and were placed on floating vegetation such as Ipomoea aquatica and water hyacinth. Inner lining of the nest was of Hydrilla. Families with three chicks were more abundant (Table 20)

Table 20

Frequency of families of bronzewinged jacana with varying no. of chicks

No. of chicks	No. of families	%
1.	8	30.78
2.	6	23.08
3.	10	38.46
4.	2	7.69

Territories were well defined and protected from intruders, especially from the same species. Both the male and female actively defended the territory. No sooner had the parents realized a threat than they moved to a nearby open space, exposing themselves and leaving the chicks in the cover of vegetation. The chicks always followed the male eventhough the female was present nearby.

BIRD COUNT IN A GRASSLAND HABITAT AT KOLADEHAR

Bird community of a grassland habitat in the Park (Koladehar has been studied since January 1985. The main objective of the study was to determine the bird community of this habitat in different seasons and the effect of fire on it. The study was taken up just after the fire in this area in January 1985.

At Koladehar about five sq.km area is typical open grassland with mainly two types of grasses: (1) tall grasses viz: Vetiveria zizanioides (c. 2.5 m tall) and Desmostachya bipinnata (c 1.5 m tall), and (2) short grasses viz: Cynodon sp and Dicanthium sp. Apart from this, small patches of reeds (Scirpus sp. and Cyperus sp.) are also seen. The shallow depressions usually get flooded during monsoon. This area was flooded extensively during and after the monsoon during 1985-'86 which remained upto February 1986.

Methods

A transect of one kilometre was covered in one and a half hours in the morning, an hour after sunrise on every second and fourth Monday. All the birds encountered were counted (including aquatic birds and those of the ecotone bordering the grassland), noting the number and also the horizontal distance (at right angle) from the trial, so that density could be estimated. Data is treated separately and also together for estimating the total avifauna of the study area, and avifauna of the grassland. Species diversity according to Shannon-Weiner index H ($H' = -\sum_{i=1}^{ST} pi \ln pi$) and equitability or eveness 'E' ($E = \frac{H'}{H' \max}$) are calculated. An attempt is made to find out the relationship of grass biomass and insect abundance with the bird community.

Results and discussion

In all, 131 species of 40 families were sighted; of which 11 families were of aquatic birds and 20 of grassland birds (with 15 passerine families). Major families recorded throughout the year were : Columbidae (doves), Muscicapidae (warblers, thrushes, chats, babblers) and Alaudidae (larks, finch-larks). Members of the following families were absent for one to four months. Sturnidae (myna), Dicruridae (drongos), Ploceidae (munias, sparrows), Accipitridae (kites, eagles, vultures) Lariidae (shrikes) and Corvidae (crows).

Population of the total avifauna was at the peak in November 1985 with 2474 birds of 53 species when population of grassland species, alone was also high (Table 21) because of the wintering and local migrants. However, the number of grassland species was more in March (28) and February (27). The minimum number of birds for the total avifauna and the grassland species was in April and August respectively, while the minimum number of species was in August for both (Fig. 34).

Species diversity for the total data was at the maximum in February 1986 while it was in March 1986 for the grassland birds. Dominance index ($C = \sum_{i=1}^{ST} pi2$) was also calculated for the total birds observed which showed strong negative correlation with species diversity ($r = 0.871$, $P < 0.001$). Species diversity was the lowest in October for the total avifauna and November for the grassland birds, which was because of the increase in the population of a few species. The mean diversity was higher for the total avifauna (2.763) than for the grassland species (2.419). The changes in diversity of the total avifauna and the grassland species followed the same pattern, the correlation being strongly positive ($r = 0.646$, $P < 0.01$). Equitability was low for the total avifauna during October and November similar to that of the diversity index. 'E' value was low in November for the grassland species also. The maximum equitability was in April and March as the population became almost stable and evenly distributed as many species started breeding. Although species richness or abundance had no direct correlation (r values not significant) with rainfall, temperature, grass growth or insect abundance, it was partly dependent on these, and also the migratory and breeding seasonality of the birds.

Species richness and diversity were less immediately after fire mainly because of the low heterogeneity of the habitat caused by the extensive fire. If fire is used judiciously, burning the patches selectively in rotation, it might improve the bird community as heterogeneous patches will be available. Newly burnt or opened up areas attract species preferring open habitats,

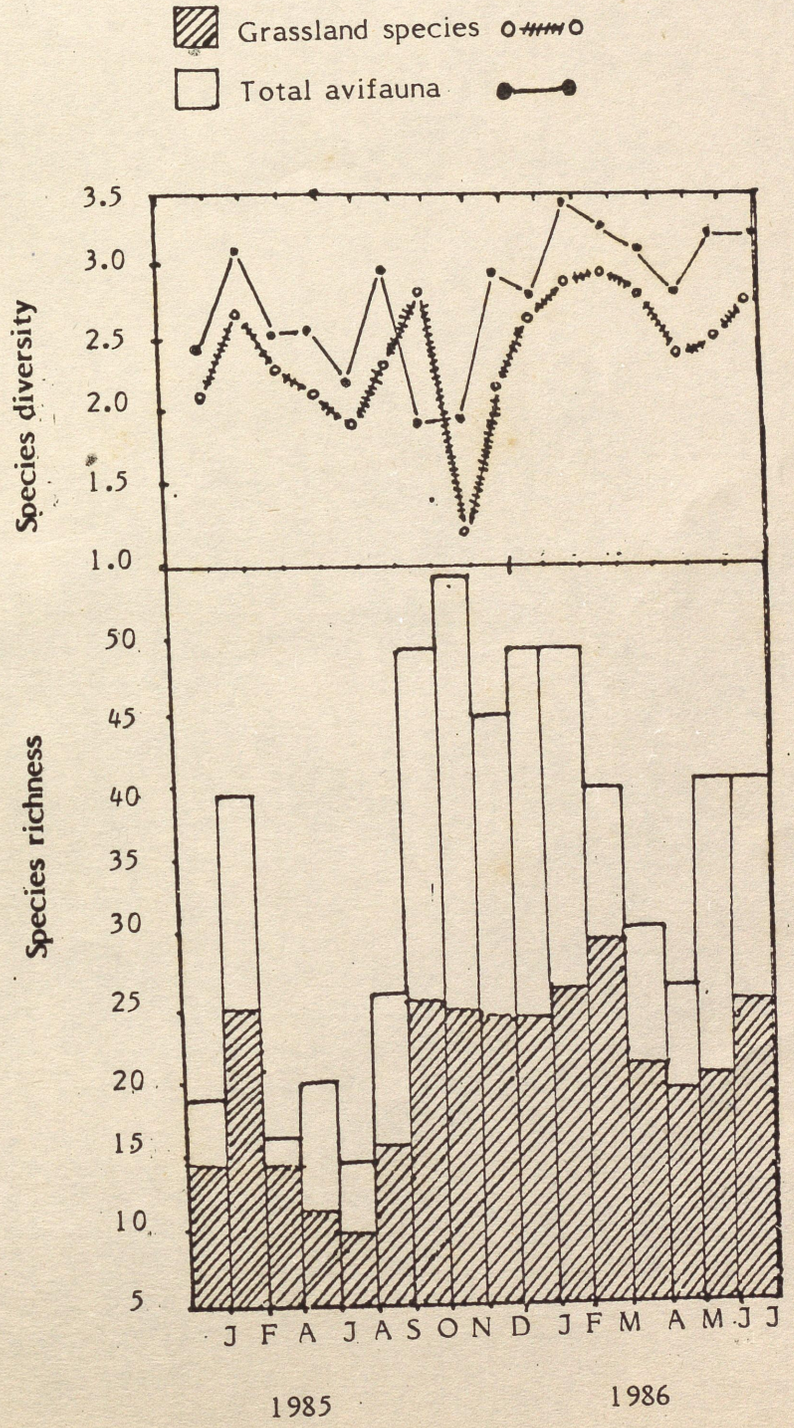
Table 21

Bird count in a grassland habitat (Koladehar)

Month & Year		No. of birds		No. of species		Species diversity H (-)		Equitability	E=H/H max
		1	2	1 (N=131)	2 (N=60)	1	2	1	2
1985	Jan.	81	17	18	14	2.37	2.09	0.94	0.91
	Feb.	108	75	39	25	3.15	2.72	0.99	0.97
	April	60	56	17	14	2.51	2.32	1.02	1.01
	July	81	65	20	12	2.52	2.14	0.97	0.99
	August	77	48	14	9	2.17	1.94	0.95	1.02
	Sept.	74	53	26	16	2.96	2.34	1.04	0.97
	Oct.	744	67	48	25	1.89	2.84	0.56	1.02
	Nov.	2474	324	53	24	1.94	1.17	0.56	0.42
	Dec.	216	121	44	23	2.92	2.16	0.89	0.79
1986	Jan.	237	88	48	23	2.81	2.65	0.84	0.97
	Feb.	183	95	48	27	3.43	2.92	1.02	1.02
	March	164	130	39	28	3.26	2.95	1.02	1.02
	April	119	104	30	22	3.09	2.82	1.04	1.05
	May	113	85	27	18	2.82	2.39	0.98	0.95
	June	157	122	40	20	3.18	2.50	0.99	0.96
	July	153	106	40	25	3.20	2.75	1.00	0.98
	Mean	315.1	100.5	31.94	20.3	2.763	2.419	0.93	0.94
	SD	598.0	64.9	13.79	5.8	0.48	0.461	0.15	0.15

Note : 1 is for the total birds counted in the area and 2 for the birds of the grassland habitat only.

Fig. 34 Bird community in a grassland habitat



whereas short, tall older grasses attract various other species. When the area is flooded in patches, many aquatic species are attracted to this, further increasing the bird species diversity. During March 1986 when a fireline was made by bulldozing , sand-grouse and singing bush-lark were found in the opened up area as observed after fire during January to April 1985. For increasing the bird diversity in the grassland, selective burning is recommended.

BREEDING SEASONALITY OF TERRESTRIAL BIRDS

Keoladeo National Park, although famous mainly for its waterfowl population and mixed heronries, has a terrestrial area more than double the size of the wetland with double the number of bird species. Very little is known about the birds of the terrestrial habitats. The present study had the following objectives: 1. to record the species of terrestrial birds breeding in the Park, 2. to evaluate the breeding requirements, 3. to assess the major breeding season of each species, and 4. to study the nesting details and productivity of the major species.

Methods

Nest searching was done in the study area for 10 to 15 days (50 to 75 hours) each month, depending on the amount of nesting activity. Individual birds and their behaviour also were followed to locate the nests and breeding condition. The active nests found were numbered and the following details recorded: 1. nesting species, 2. species of the nesting tree 3. height of the tree. 4. canopy size 5. nesting height 6. position of the nest in relation to the canopy 7. type of the nest 8. shape of the nest, and 9. habitat of the nesting site. Checking the nest was done by using an adjustable mirror attached to the tip of an aluminium rod of 3 m. which was attached to another rod of 3 m. The study was from May 1985 to July 1986.

Study areas

Three major habitats were selected: 1. Habitat having mixed vegetations; a five hectare plot in block B extending from the roadside along the border of the acquatic and terrestrial habitats. It has woodland of Mitragyna-Zizyphus-Acacia community with undergrowth, open light scrub of Zizyphus-Salvadora-Capparis - Acacia community with grass patches in between and, thick scrub of Capparis - Zizyphus - Salvadora - Balanites with a few trees of Acacia nilotica, Acacia leucophloea and Prosopis sp.

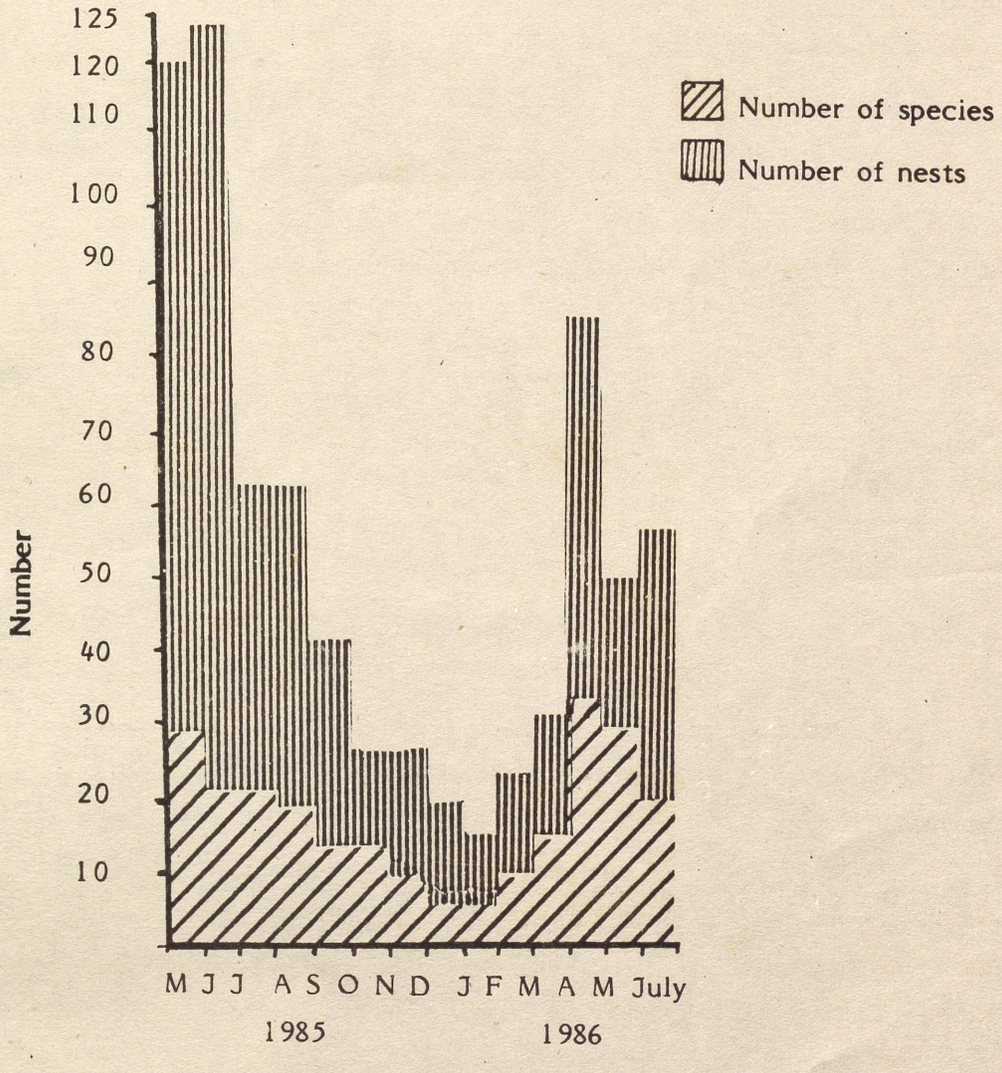
2. Ecotone formed by the dykes in the wetland area along blocks D and N covering about 10-12 hectraes. Trees (Acacia) and bushes (Capparis, Salvadora, Lawsonia with some climbers) are abundant along the sides of the dyke.

3. Grassland, mainly of tall grasses, Vetiveria and Desmostachya, patches of short grasses (Cynodon) and sedges (Scirpus and Cyperus sp.). The study plot is of about 2 hectares through the middle of which runs a fireline.

Results

67 species of birds bred in the study areas during May 1985 to July 1986 with a total of 709 nests. The number of species breeding was the maximum in April 1986 (32) and minimum (5) in December and January (Fig 35). As egg-laying is considered to be the standard stage for determining breeding seasonality, specieswise frequency of nests at this stage in each month was tabulated and, it was found that the breeding season of landbirds extends throughout the year with a major peak fluctuating from April to July. The maximum percentage of species laid was in April (45) during 1986 and July (38.3) during 1985 (Fig. 36), whereas the percentage of nests was the most in June during 1985 (21.9) and April during 1986 (14). In passerines (35 species and 322 nests), the peak of species breeding in 1986 was in May

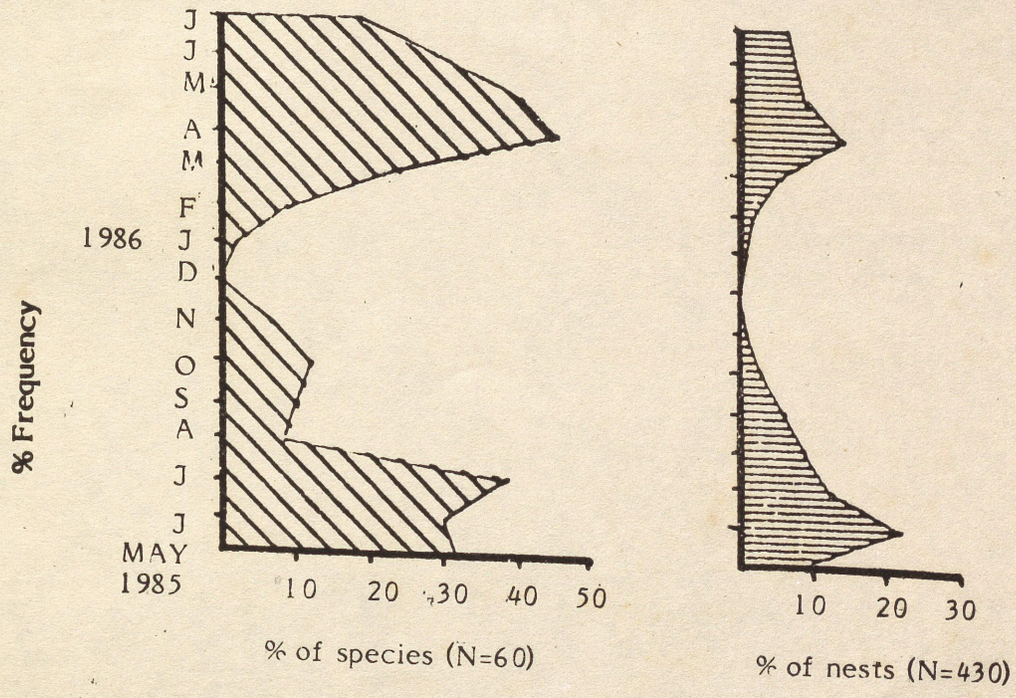
Fig. 35 Frequency of species and nests of terrestrial birds.



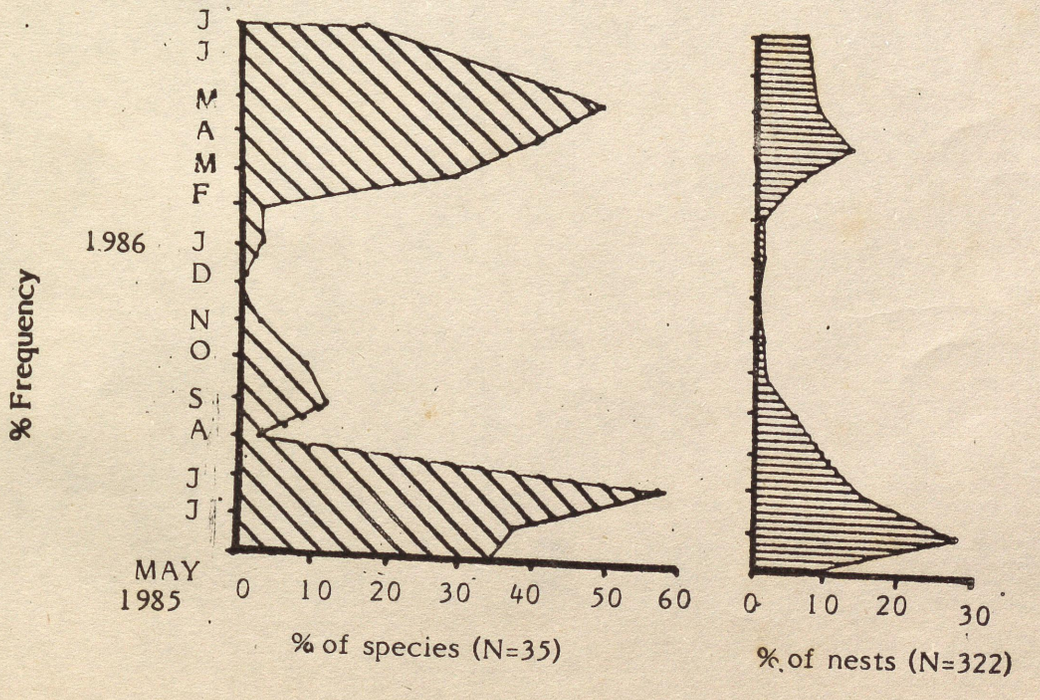
instead of April and, it was less than that of July 1985. However, there is no change in the peak of the number of nests in both the cases (Fig. 36). Variation in the peak of breeding season depends on the season of individual species which in turn is influenced by environmental conditions. For example, some species of raptors are autumn breeders while some are spring or summer breeders, (certain species of eagles and owls, and the whitebacked vulture). Doves breed throughout the year with one or two peaks. Most of the passerines have a peak in summer or monson, varying with rainfall, temperature and moisture of the habitat. Change in the peak of breeding between the years 1985 and 1986 might be mainly because of the availability of moist habitat. In 1984, the rainfall and the subsequent flooding of the terrestrial habitat were comparatively less so that the area dried up faster, whereas in 1985 the rainfall was higher leaving the area flooded till December. Phenology of the plants also showed the same pattern for flowering and fruiting. A similar phenomenon was noticed in Delhi area by A.J.Gaston (per.comm.).The decrease in percentage of nests during the peak of 1986 is mainly due to the poor rainfall.During this year, the rain and gale which occured twice in May, destroyed many nests and nesting trees causinsg a set back in nesting activity during late May and June.This is similar to the phenomenon noticed in southern India where breeding of most of the species is terminated at the time of South West monsoon. Some of the common passerines show slight individual variation in their breeding season. Most passerines with more than five laying records have only one main season, April to July. Breeding productivity and factors relating to individual families and species are yet to be analysed in detail. Productivity of species such as the bay-backed shrike and black drongo was higher during 1986 which might be due to early nesting. The ecotone between the aquatic grass - land and woodland was the preferred habitat for passerines such as bay-backed shrike, wood shrike, yellowthroated sparrow and small minivet.

Fig. 36 Frequency of species and nests in the egg laying stage

For the total fauna



For the passerines



RAPTORS

The General study on raptors began in September 1985 was completed by August 1986. Major objectives of the study were: 1. to estimate the population of birds of prey and its seasonal fluctuation inside the Park, 2. to find out the distribution pattern of raptors inside the Park, 3. to study the impact of the fluctuation of prey species on the number of birds of prey, and 4. to assess the nesting distribution of birds of prey in the Park.

Methodology : Population was estimated by direct count, twice a month, throughout the study period from September 1985 to August 1986. The birds were counted while walking or cycling down the roads and dykes. The exact position of each bird sighted was marked on the map. Aquatic birds were also counted twice a month from 200 sq.m., in each block where maximum concentration was noticed. To study the nesting distribution, the nests were systematically searched all over the Park twice a month. All important parameters such as the species of tree, tree height, location of nest, nest height, stage of nest, nesting success were taken into account. The trees on which the nests were found were marked on the maps. Vultures and owls were excluded from the population study.

Results : 26 species of family Accipitridae and four species of Falconidae were recorded. Red kite, Pied harrier, black-eared kite, booted eagle and hen harrier were also recorded first time from the Park. The population of raptors was the highest in December (79) and lowest in July (23). Shannon-weiner index of species diversity was the maximum in October and minimum in June, 2.7802 and 1.5 respectively. J value was the highest in June (0.83) and lowest in December (0.429). This shows that the population was more steady in June and was fluctuating during December. The waterfowl form the principal food of raptors. Their population increases with the advent of migrants. A very significant positive relationship between the number of raptors and the number of waterfowl was noticed ($r = 0.95$, $P < 0.001$). Availability of fish seems to be an important factor affecting the breeding

of Pallas's fishing eagle.

Nesting distribution Ten species of raptors of the family Accipitridae and four species of Strigidae were found nesting in the Park. Data are being analysed more throughly.

Chapter VII

MAMMALS

MAMMALS

Population, habitat utilization, distribution and food preference of the amjor herbivores, and activity pattern of sambar were studied during 1986. A few scats of fishing cat and otter were analysed to bring out the food of these rather secretive animals.

Methodology

Visual estimate of the population was made covering the entire Park either on foot or by jeep. Each animal when sighted, its sex, age and activity were recorded on the data sheet. The Park was divided into several blocks and each block was sub-divided into smaller compartments for convenience; altogether 24 compartments of one sq.km. each were identified. Each compartment was covered by zig-zagging the area. A simultaneous count was also organised with the help of all research staff. Distribution of each species was determined by marking the location of each sighting on the map. Habitat utilization was assessed by visual observation. Three major habitats were distinguished; woodland, grassland and aquatic. Transects varying from 1.5 to 2.5 km. were laid in each habitat. A total of 11.5 km (4.4 km in woodland, 4.7 km in grassland, and 2.4 km in aquatic area) was covered. Each transect was traversed twice a month and the frequency of animals sighted on both sides was recorded. To find out the micro-habitat, vegetation on either side of each transect was studied intensively; the data are being computerised.

Population

Population of sambar, black buck and wild boar does not show much variation from that of 1985, while that of nilgai and chital indicates a slight increase (Table 22). Notable increase was in the case of feral cattle. The ratio between adult male and female was the highest in the feral cattle, 1:4.2 followed by blackbuck 1:4. In chital it was 1:2.8 and in nilgai and wild boar 1:2. Sambar has the least ratio of male to female 1:1.5. Ratio

of young to female was : chital 1:4.4, sambar 1:6, blackbuck 1:12, nilgai 1:5.8, feral cattle 1:1.8 and wildboar 1:.9. Density was the highest for feral cattle and lowest sambar (Table 22)

Table 22

Population and density of ungulates during 1986

Species	ADULT		Young	Total	Estimated Total	Density per km
	Male	Female				
Chital	43	124	28	195	200-225	6.9
Sambar	4	6	1	11	18- 20	0.37
Blackbuck	3	12	1	16	20- 25	0.54
Nilgai	42	82	14	138	140-150	4.6
Feral cattle	97	410	225	732	750-800	24.72
Wild boar	44	87	95	226	300-325	7.63

Distribution

Chitals were mainly in scrub grassland where Zizyphus sp. was common while sambar were in the aquatic are where the mounds of Acacia sp. were common. Blackbucks were mainly in the open plains where the height of grass was not more than about 30 cm. Nilgai were recorded mainly in open grassland as well as woodland area. Feral cattle were also seen in open grassland. In contrast to other ungulates wild boar were mainly in woodland areas.

Habitat utilization

Preferred habitats of the ungulates were :

Chital : scrub gassland.

Sambar : aquatic area. They moved towards the woodland when the aquatic area dried up in June, probably for more profitable foraging.

Blackbuck : open plain grassland.

Nilgai : open grassland, woodland and aquatic area.

Feral cattle : grassland

Wild boar : woodland.

Food preferences

Food of ungulates were studied by direct observation. Altogether, the food plants include, 11 trees, 21 shrubs and 16 herbs. For further information on the food habitats, micro-histological study of dung has been initiated.

Activity pattern of sambar

Activity of sambar was studied from February to September. They were active mainly in the early morning and late evening. However, they fed on the macrophyte from water during the day as well as night. This study had to be discontinued after September as sambar were disturbed owing to the mass manual grass removal programme.

Scat analysis of fishing cat and otter

Scat analyses are being carried out to assess the major food of these species. Results obtained so far indicates that fishing cat feeds apart from fish, a large number of birds, insects, reptiles, and grains and grasses. Once it scavenged on dead cattle, probably because of non-availability of usual food owing to drought.

Scats of Otter contained remais of fish, insects, and grasses.

Impact of fire on ungulates

The first grassland fire of the year, spreading over two hectares, occurred in October 1986. However, the fire could not be intense, thanks to the Park managers in their efficiency to extinguish it. The blades and culmes were not burnt off completely. Regular observations were made in this area and it was interesting to note that nilgai were feeding there on the very third day of the fire. Chital, Bluckbuck., wild boar, and feral cattle began feeding after 15 days of the fire. They were feeding mainly on the sprouting Vetiveria zizanioides, Desmostachya bipinnata, and Cynodon dactylon.

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List of papers, reports, short notes published/communicated/ accepted for publication from the Hydrobiology Project, Bharatpur as on 31.1.1987

Reports

1. Hydrobiological (Ecological) Research at Keoladeo National Park. Ist Interim Report 1983.

2. Recommendations for Management of Keoladeo National Park. May 1985.

3. Keoladeo National Park Ecology Study. Summary Report 1980-1985. March 1986.

Papers presented at Salim Ali Festchrift Seminar, November 1986.

1. Physicochemical properties of the waters of Keoladeo National Park.

2. A study of the plankton in Keoladeo National Park.

3. Primary productivity in the waters of Keoladeo National Park.

4. A study on the biomass of aquatic macrophytes of Keoladeo National Park.

5. Seasonal and annual fluctuations in the aquatic macroinvertebrates of Keoladeo National Park.

6. Some aspects of the population density, growth and feeding rate of Cassida circumdata Herbst (Coleoptera: Chrysomelidae) in Keoladeo National Park.

7. A study on the fish fauna of Keoladeo National Park.

8. Status, distribution and habitats of Indian Python (Python molurus molurus) with some notes on its ecology in Keoladeo National Park.

9. Turtle records from Keoladeo National Park.

10. Population of aquatic birds in Keoladeo National Park.

11. A study of the heronries of Keoladeo National Park.

12. Wintering ecology of the Siberian crane (Grus leucogeranus).

13. Distribution and general ecology of Sarus crane (Grus antigone).

14. Population, habitat and resource utilization pattern of waterfowl.

15. A general study of the birds of prey of Keoladeo National Park.

16. A general account of the vegetation of Keoladeo National Park.

17. Phenology of terrestrial plants of Keoladeo National Park.

18. Standing biomass of grasses in Keoladeo National Park.

19. Seasonal abundance of terrestrial insects and spiders of Keoladeo National Park.

20. Bird count in a grassland habitat of Keoladeo National Park.

21. Bird count in a woodland habitat of Keoladeo National Park.

22. Breeding of terrestrial birds of Keoladeo National Park.

23. A study of the ungulates of Keoladeo National Park.

24. Some aspects of the conservation of Keoladeo National Park.

Papers published elsewhere

25. Occurrence and life history of Cassida circumdata Herbst in Keoladeo National Park, Bharatpur. (Accepted for publication).

26. Observations on the mating, egg laying and feeding behaviour of Cassida circumdata Herbst in Keoladeo National Park, Bharatpur. (Accepted for publication)

27. Wetland flora of K[illegible]deo National Park. (Communicated)

28. Fish fauna and their source in Keoladeo National Park. (Communicated)

29,. On conserving the bird fauna of Indian wetlands. Proceedings of the Indian Academy of Science, 1986.

30. Population and distribution of raptors in Keoladeo National Park, Bharatpur. Communicated for presentation in International Symposium on Raptors, Israel, March 1987.

Short notes

1. A note on the Asiatic Rock Python feeding on the Spotbill duck.
J. Bombay Nat. Hist. Soc. Vol. 81 (1984)

2. The Python-coucal incident.
J. Bombay Nat. Hist. Soc. Vol. 81 (1984)

3. Occurrence of Baer's pochard in Bharatpur, Rajasthan.
J. Bombay Nat. Hist. Soc. Vol. 82 (1985)

4. The rufoustailed flycatcher in Bharatpur, Rajasthan.
J. Bombay Nat. Hist. Soc. Vol. 83 (1986)

5. Association of rock python with Indian porcupine.
J. Bombay Nat. Hist. Soc. Vol. 83 (1986)

6. Tortoise beetle, Cassida circumdata as a biological control on the growth of Ipomoea reptans in Keoladeo National Park, Bharatpur
J. Bombay Nat. Hist. Soc. Vol. 83 (1986)

7. Freshwater turtle capturing coot.
J. Bombay Nat. Hist. Soc. Vol. 83(1) : (1986)

8. Adjutant Gobbles Ducklings.
Hornbill : 2 (1986)

9. Neptunia oleracea - a new record for Rajasthan.
J. Econ. Taxon. Bot. 1987

10. Lesser spotted eagle (Aquila pomarina hastata) nesting in Keoladeo National Park, Bharatpur. (accepted)

11. An instance of active predation by Scavenger vulture (Neophron percnopterus) on Checkered Keelback Watersnake (Xenochropis piscator) in Keoladeo National Park (accepted).

12. Greater spotted eagle (Aquila clanga) breeding in Keoladeo National Park, Bharatpur. (accepted)

13. Indian scavenger vulture (Neophron percnopterus) scavenging on a dead whitebacked vulture (Gyps bengalensis). (accepted)

14. Additional records of the Black drongo feeding on birds. (accepted)

15. Egg moving by a Spotbill duck. (accepted)

16. Snake-grey heron incident. (accepted)

17. Cannibalistic behaviour of freshwater turtles in Keoladeo National Park, Bharatpur, Rajasthan. (accepted)

18. Observations on unusual behaviour of Imperial eagle in Keoladeo Naional Park, Bharatpur, Rajasthan. (accepted).

19. Ring-tailed fishing eagle feeding on wasp larvae. (accepted)

20. An hitherto unknown record of redvented bulbul nesting on water hyacinth. (accepted)

21. An incident of a male nukta Sarkidiornis melanotes mounting on a Spotbill Anas poecilorhyncha. (communicated)

22. Indian python feeding on purple moorhen (Porphyrio porphyrio)

23. A note on the Rhesus macaque feeding on calotes. (accepted)

24. Aerial feeding by median egret, little egret, and pond heron. (accepted)

25. Freshwater turtle capturing aquatic birds. (accepted)

26. Courtship and mating in the Spotbill duck. (communicated)

27. Occurrence of bicoloured leaf-nosed bat in Rajasthan. (communicated)

Theses

1. Ecology of purple moorhen Porphyrio porphyrio during winter in Keoladeo National Park, Bharatpur. M.Sc. Dissertation. Bharatidasan University. 1985.

2. Wintering ecology of coot Fulica atra in Keoladeo National Park, Bharatur, M.Sc. Dissertation, Bharatidasan University, 1985.