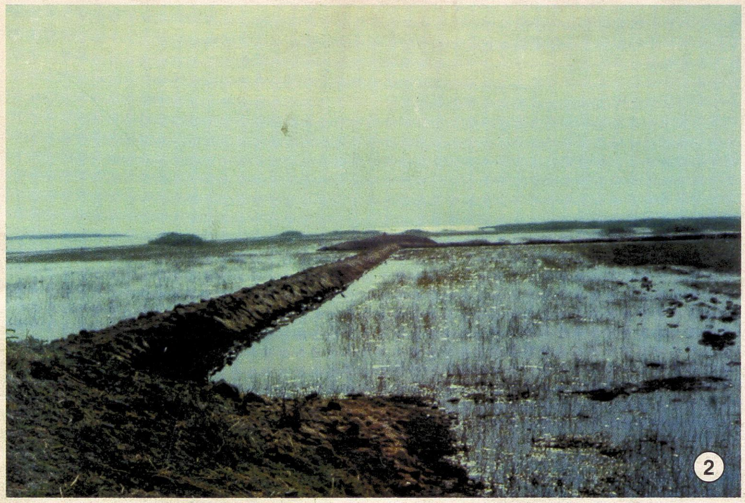

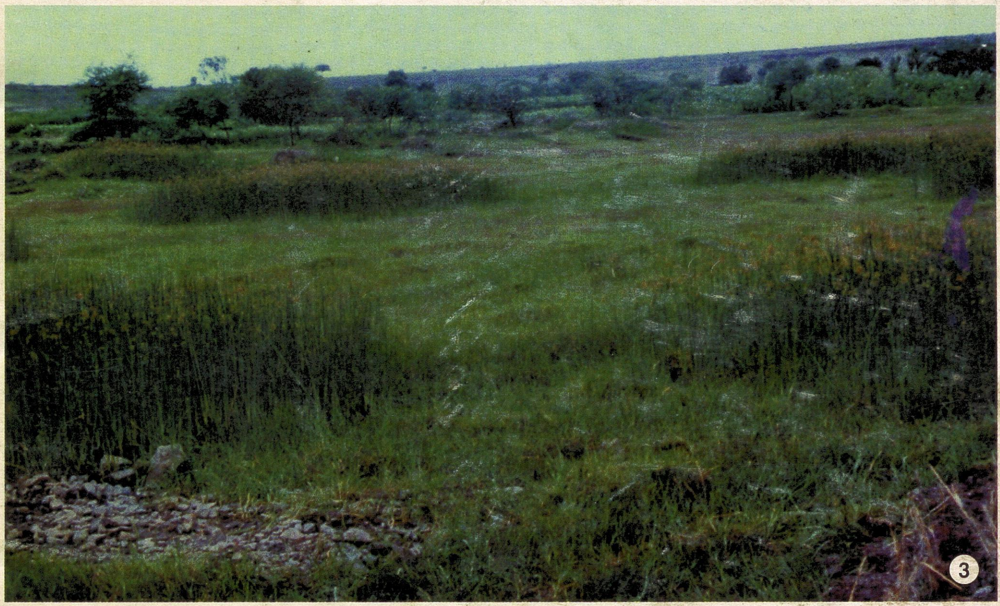

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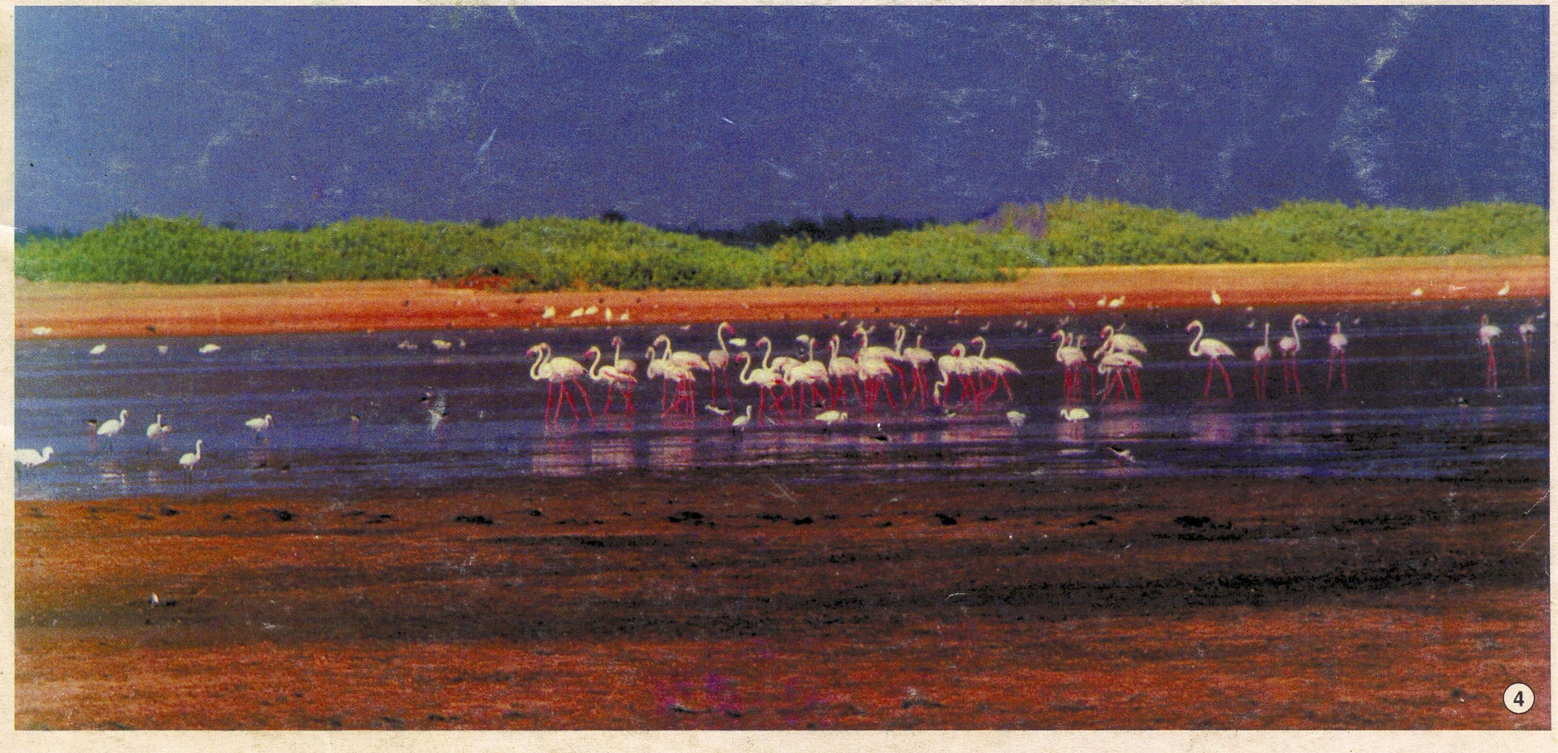

Managing
A Manmade Tropical Wetland

by
Prakash Gole

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Contents

Foreword

The present painstaking report on the multipurpose development of the Ujni reservoir research project by Shri Prakash Gole extending over a period of several months would clearly vindicate to all, planners and developers, the dire necessity not only of going forward with UJNI, but also of working along similar lines elsewhere, where so many new and existing schemes are being planned or functioning. This study on Ujni illustrates the benefits of co-existence for human as well as plant and animal life, for villagers as well as for trees and birds, a co-existence which would lead to prosperity for all.

The efforts of Shri Gole and his team have had to be terminated because of a misconceived agitation by people who did not understand the purpose of the project, nor its beneficial effects in the not too distant future. In fact a lot of misunderstandings of the kind encountered at Bhigwan and its environs would need to be avoided by explaining to villagers as well as to concerned functionaries the reasons for undertaking the project and then periodically demonstrating its advantages. Such an effort has to be a continuing one, with the fullest support from Gram Panchayats, MLAs, MPs, district officials of Irrigation and Revenue departments and also perhaps media-men.

The Ujni effort needs to be revitalized and copied elsewhere.

L. G. Rajwade,
I C S (Retd.)

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Chapter One

Introduction

Irrigation has changed the face of India's countryside. Dry riverbeds and stony uplands are replaced by sprawling reservoirs and farm greenery. Canals have brought water to parched lands and thirsty throats. Water is transported or lifted to drench soils in ravines and hilltops. A large portion of the river basins and stream catchments now lies submerged.

When hundreds and thousands of hectares of land are transformed, it is bound to affect the ecology of innumerable life forms that are or were the residents of the countryside. Also as the avowed aim of providing water is to bring about a change in people's lives, their activities bring about secondary and tertiary changes in the ecology of the countryside.

An opportunity to study these changes came when the Wetland Management Committee convened by the Ministry of Environment & Forests, Government of India, selected ten wetlands as Wetlands of National Importance. The Ujni reservoir on the Bheema river in Maharashtra was one of them. Action plans based on relevant research were invited from universities and research institutes for the balanced environmental development of these wetlands. The present study attempts to provide a framework for a multi-purpose development of the Ujni wetland.

What is a Wetland?

"Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life" (Niering 1989). They are a transitional habitat between upland and aquatic environments where the water table is at or near the surface of the land. According to the definition developed by the US Fish & Wildlife Service, in a wetland the land is covered by shallow water that may be upto six feet deep (Niering ibid). The Convention on Wetlands of International Importance especially as Waterfowl habitats popularly known as the Ramsar Convention defines wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters." (Scott 1989). It is therefore, best to understand wetlands as lands saturated with water. The term covers shallow water areas of streams and river courses, ponds and lakes, lagoons and estuaries, swamps and marshes, salt pans and sea shores and such man-made structures as reservoirs, sewage ponds, water-filled quarries and gravel pits. With the primary life supporting factors viz. sunlight, water and land present, wetlands are reputed to harbour a variety of life forms. As such they are recognized as having the potential to perform one or more of the following functions:

1. Groundwater recharge & discharge;
2. Shoreline anchoring and dissipation of erosive forces;
3. Sediment trapping;
4. Flood storage and desynchronization;
5. Nutrient retention and removal;
6. Food chain support;
7. Habitat for fish;
8. Waterfowl refuge;
9. Active recreation and
10. Passive recreation and heritage value (Larson 1988).

It is not the endeavor of this study to examine how far the Ujni reservoir succeeds in performing these functions. Instead assuming that a wetland needs to perform all or several of these functions, the study attempts an analysis of the existing conditions in and around the Ujni reservoir. The study then goes on to suggest how some of these conditions can be improved to perform more efficiently some of the above functions and lastly it analyses the effects of improvement measures carried out on the wetland to see if the desired results were achieved.

Methodology

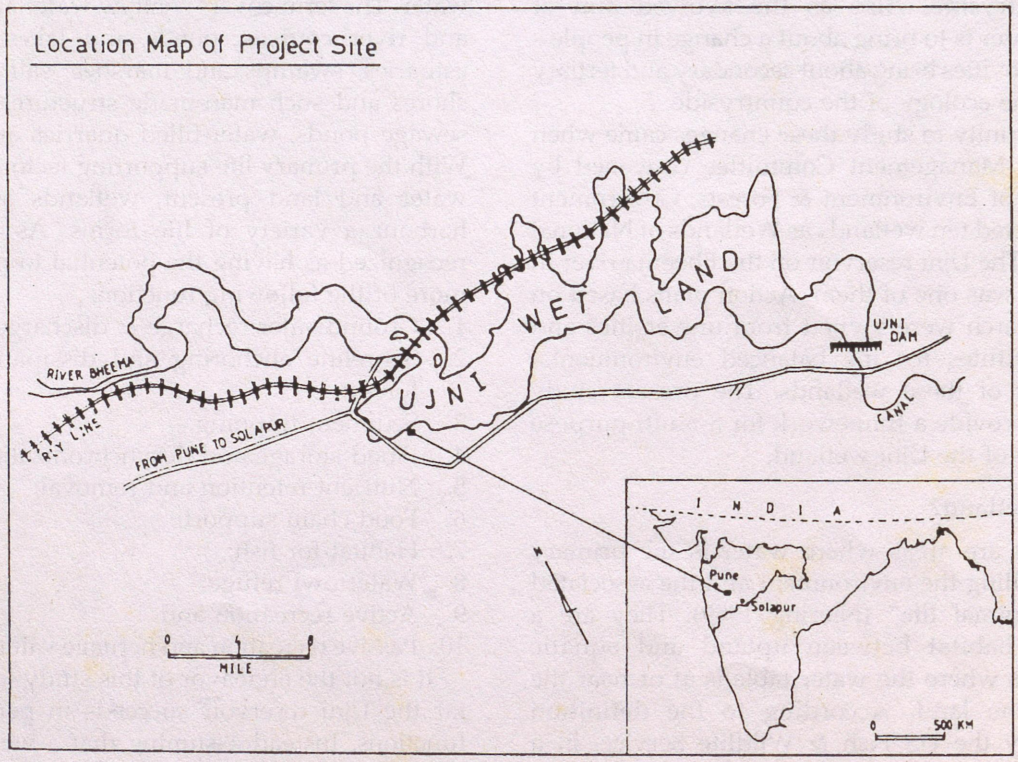
From a survey of existing literature an attempt was made in the beginning to gauge the conditions prevailing in the catchment area of the Ujni dam. Physical conditions of the course of the river Bheema, the vegetation and wildlife obtaining in the available habitats before submergence and peoples' occupations before many of them lost their lands under the reservoir were taken into account. To assess the physical conditions after the formation of reservoir, a project site on the periphery of the reservoir was selected and its topography, geology, climate, soil and vegetation and bird fauna were studied. Data about the water levels prevailing in each month of the period were obtained from the Department of Irrigation, Govenment of Maharashtra and a contour survey was carried out to mark the different water levels on the project site. How the water levels correlate with the distribution of flora and fauna on the project site was examined by keeping a daily record of the distribution of bird species in different sectors of the project site. A habitat suitability index was worked out for the project area.

A socio-economic survey of sample families from villages situated on both the banks of the reservoir was carried out to assess the needs of people living along the banks. Water levels in the village wells were monitored to examine if they bear any significant relation with the reservoir water level.

A plan of action to improve the habitat suitability index in the project area by manipulating the water depth on the project site was worked out and implemented. The last months of the period were spent in assessing the effects of the plan of action on the flora and fauna on and around the project area.

The plan of action essentially implied creation of a mosaic of habitats on the periphery of the reservoir replacing the existing uniformity in the belief that a varied habitat structure will be better able to meet the needs of the people and wildlife. While the monitoring succeeded in getting some idea of the fulfillment of the needs of wildlife, the fulfillment of the needs of people obviously will have to await the development of trees and plants and the settling down of the post-action plan conditions.

The study began on 1st June 1990 and ended on 31st March 1993.



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Chapter Two

The Ujni Reservoir

The Ujni reservoir was formed when a dam on the river Bheema (a major tributary of the Krishna river) was completed near the village Ujni (Lat. 18 04'24" N, Long. 75 07'15" E) in June 1980 in the Solapur district of Maharashtra. The catchment area of the dam is 9766 sq. km. with gross storage capacity of the reservoir being 3140 million cubic metres divided into 1440 mcm of live storage and 1700 mcm of dead storage. The dam was completed in 1980 and the reservoir filled to capacity, the following season.

The water levels of the reservoir are as follows:

Full Reservoir Level (FRL)	496.83 m.
High Flood Level (HFL)	497.50 m.
Maximum Draw Down Level	491.03 m.
(Source: Irrigation Dept., Govt. of Maharashtra)	

There is a difference of only 5.80 metres between the full reservoir level and the maximum draw down level showing that much of the reservoir is not deep. The inflow into the reservoir comes from the river Bheema and its tributaries. But there are a number of dams on the tributaries upstream of the Ujni dam and the level of the Ujni reservoir begins to rise when the floodwaters are released from the dams upstream. The number of villages that were submerged due to the construction of the reservoir was 52.

Birds have been using this sprawling, shallow water-body ever since its creation. But it was in the early eighties when large flocks of Greater Flamingo (*Phoenicopterus ruber*) were noticed on the reservoir for the first time (1982), that this man-made water-body became well known as a bird refuge. Flamingos frequented the reservoir's tail-end area in the vicinity of Bhigwan town, 100 kms southeast of Pune (see map), which began reflecting the glow of publicity inspired by birds. When the Chief Secretary of Government of Maharashtra took personal interest, official recognition did not lag behind, a bird sanctuary was declared at the place, its area demarcated and a secretarial committee appointed to chalk out management details. When the Central Government's Wetland Management Committee included this wetland in the list of 10 selected from among the wetlands of India, the Ujni reservoir was recognized as a wetland of prime importance.

The Nature of Man-made Lakes

The Ujni reservoir is a man-made lake. Lakes tend to have long water and substance residence time and behave as closed systems. Important physical properties of lakes are water residence time, water level changes and basin morphology. Development in the catchment areas and on the periphery of lakes often modify these properties. These developments may lead to increased loading of nutrients and organic matter in lakes. Lakes are also subject to sediment loading due to high rates of erosion in their watersheds. Many act as sinks since they are not flushed and therefore, trap large quantities of sediments (Cairns Jr. 1992).

The Ujni Lake or reservoir exhibits many of these attributes, as will be evident in subsequent sections.

A man-made lake like the Ujni is constructed to serve definite purposes. Its chief function is to provide water to dryland farming. In addition the water from the reservoir is also released for drinking to people living on the banks of the Bheema River and is lifted by villages on the periphery of the lake. The reservoir provides opportunities for fishing and to a limited extent, transport of men and material. As industry is being encouraged in the dam's command area, the reservoir water will be provided to them as they come up. Lastly the reservoir provides habitats to plants, birds and animals that attract visitors who come for recreation. Indirectly the lake adds diversity to the landscape.

All these uses of its water create certain stresses on the eco-system of the lake. Stresses to lakes arise from identifiable point sources such as municipal and industrial wastewater, from nonpoint degradation, from urban and agricultural run-off within a lake's watershed, and from insidious long-range atmospheric transport of contaminants. Major categories of stresses include excessive eutrophication from nutrient and organic matter loading, siltation from inadequate erosion control in agricultural, construction and mining activities; introduction of exotic species and contamination by toxic metals and pesticides. The Ujni lake exhibits stress from some of these impacts as will be seen below.

The restoration of river waters is a recent activity in India as exemplified by the project to improve the Ganga River waters. Lake Restoration has not been tried so far in our country to any extent. Historically the term restoration is used to designate Lake Management with a view to make it more suitable for specified human activities. Restoration meaning return to its pristine conditions may be appropriate to a natural lake. For a man-made lake restoration may involve reduction or elimination of all or most of the stresses to which it has become a victim.

The present study refers to some of the stresses faced by the Ujani Lake and tries to work out solutions which will reduce these stresses. To that extent it may be taken to be an attempt to apply some of the techniques of Lake Restoration.

But before we proceed to analyse the present conditions of the lake, it will be necessary to look into conditions that prevailed in the region before the reservoir was formed. This is necessary to gain a proper perspective.

The Background

Ujni dam is constructed on the river Bheema which is the chief river of Pune district. The Bheema rises on the crest of the Sahyadri near the famous temple of Bheemashankar (19° 4' N, 73° 32' E) about 80 km southeast of Mumbai. The main tributaries of the Bheema are the Vel and the Ghod on the left and the Bhama, the Indrayani, the Mula-Mutha and the Nira on the right. Now dams are in place across most of these tributaries. The dams on the Mula-Mutha and the Nira are over 100 years old. Some of the others have been constructed in the last 25 years, while some including one on the Bheema just where it comes out of the hills, are still under construction.

These dams and reservoirs have now changed to a great extent the character of the river courses and the basins. Some idea of their original topography can be gleaned from old Gazetteers published in the last century. The Poona District Gazetteer published in 1885 gives a graphic account of the course of the Bheema river: "From a height of about 3000 feet above the sea, the river falls over terraces of rock some 600 feet in the first 5 miles. Further east with a general course to the southeast, it flows thirty-six miles through the very narrow and rugged valley of Bhimner. The banks of the Bheema are generally low and after its meeting with the Indrayani are entirely alluvial. Here and there where the winding stream has cut deep into the soft mould, are steep banks of great height, but in such places the opposite bank is correspondingly low. In places where a ridge of basalt throws a barrier across the stream, the banks are wild and rocky, and the water dammed into a long, deep pool, forces its way over the rocks in sounding rapids. Except in such places the bed of the Bheema is gravelly and in the fair season has but a slender stream. Here and there muddy deposits yield crops of wheat or vegetables and even the sand is planted with melons."

This long quotation from the Gazetteer illustrates some of the habitats available in and around the course of the river; e.g. the alluvial banks, the long and deep pools, the sounding rapids, the gravelly bed and the sands along the stream. Most of these habitats, once used by human and non-human beings, now lie submerged or their character changed through the actions of man. This point will come up again when restorative techniques to be used along the reservoir will be discussed.

The river Bheema, as it reaches Ujni village, collects the outflows of several dams built in its upstream reaches. The major dams on the tributaries of the Bheema are Panshet and Varasgaon on the Mula-Mutha, Ghod on the river of the same name; Pawna and Mula on the rivers of the same names and Bhatghar (actually on a tributary of the Nira) and Veer on the Nira. The catchments of the Mula-Mutha, the Ghod and the Mula are densely populated. Moreover, several large and medium industrial plants are concentrated around Pune and Ahmednagar both situated in these catchments. The river also collects untreated effluents from these urban centres besides the inflow of treated and untreated effluents from industry. Non-point run off from agricultural fields growing irrigated cash crops, is also collected by the river as it enters the Ujni reservoir.

The Climate, the Rainfall & the Vegetation

The climate over the entire catchment varies from moist tropical in the source region of the rivers to dry tropical in the immediate vicinity of the Ujni dam. While the rainfall in the source region may exceed 600 cms per year, in the rain shadow areas of the Sahyadri near the Ujni dam, it is usually less than 50 cms per annum. Likewise the maximum and minimum temperatures vary from a minimum of 10° C. in January to over 40° C. in April-May. The vegetation in the catchments partakes the character of moist deciduous to semi-evergreen in the source region of the rivers; while as the annual precipitation declines the vegetation is reduced to dry deciduous and xerophytic in the vicinity of the Ujni reservoir. Let us consider in some more detail the character of the vegetation around the reservoir.

The dryness in the atmosphere coupled with sparse and erratic rainfall and the intense heat of the sun especially during summer tend to produce a xerophytic vegetation climax. A series of sub-climaxes dominated by shrubs and grasses is the result of the influence of human induced factors.

Before the dam was built the tree cover used to be dominated by *Acacia nilotica* and *Azadirachta indica* with *Tamarindus indicus* planted on roadsides and *Vitex negundo* & *Pongamia pinnata* in moister places along the river and streams. *Ficus bengalensis* and *Ficus inornata* could be seen on field boundaries and along the roads and in villages. When a portion of the Pune-Solapur road was submerged under the reservoir, a number of large Tamarind and Neem trees had to be felled.

Grazing and cutting of wood for fuel, timber and other needs were identified as the main human induced factors affecting vegetation. Dryland farming which reduces the total vegetation cover and exposes the soil to the elements all through the dry season must also be counted as a major human induced factor.

Not all the area however, was under dry farming before the dam was built. Water was lifted from the river by means of diesel pumps to irrigate sugarcane, wheat and gram. A number of lift sites and pipe lines carrying water had to be abandoned when the reservoir water engulfed them.

The shrub layer was formed principally of *Zizyphus* and *Capparis* species with heavily coppiced acacia interspersed in between. Heavy grazing by cattle and goats and cutting for fuel have however, reduced the shrub layer at present to such non-browsable species as *Cassia auriculata, Tephrosia purpurea, Calotropis procera,* and *Cryptolepis buchanani. Prosopis juliflora* has been introduced as alternative fuel wood and has now invaded large areas. The residents now regularly coppice it for fuel.

When the reservoir was formed fertile, deep soil lands along the river were submerged and cultivation shifted to light soils impregnated with gravel, i.e. to typical uplands and hill slopes. These lands now form the periphery of the reservoir. Sugarcane which used to be grown on deep soils, was now introduced to light soils with wheat and groundnut as the winter crops. Dryland farming for cereals Jowar (Sorghum) and Bajra (Pearl millet) continued in patches of poorer soils. Sunflower, pomegranate, and roses also came to be cultivated. Water is even lifted to the hilltops if soil cover is found to be adequate to grow sugarcane. Shevari or *Sesbania aegyptica* was planted on farm boundaries and here and there *Azadirachta indica* and *Acacia nilotica* are left standing to be cut as timber. An occasional mango and *Leucaena leucocephala* planted around the new homesteads with *Ficus* complete the vegetational scene at present.

Thus the vegetation cover today shows a paucity of woody species, high percentage of annuals and low of perennials showing less plant vigour and deficiency in diversity as the total number of plant species is low.

Outside the cultivated areas very little vegetation cover is apparent and utter desolation marks the landscape, as monsoon ephemerals wither and wilt in the intense heat.

Ipomoea carnea has invaded most of the shallow water areas and water edges. It is said to be propagated unintentionally by fishermen who tie its twigs to their nets as floats. These twigs are then discarded, take root and the reservoir and the water edges are overwhelmed by this weed.

As the level of water in the reservoir begins to rise and areas free of water in summer begin to get inundated aquatic and semi-aquatic flora begin to emerge. In deeper waters an aquatic community dominated by *Potamogeton crispus, Najas* and *Chara* takes shape. A semi-aquatic grass *Paspalum scrobiculatum* has invaded the reservoir since 1987 and is rapidly spreading, grows tall and its stands pop over the water surface where the depth of water is even 2.5 to 3 metres. This grass has also considerably reduced the occurrence of *Hydrilla verticillata* and *Vallisneria spiralis* which community dominated the waterspread till 1986.

Shallower waters are covered by an aquatic plant community whose principal components are *Ipomoea aquatica, Limnophyla indica, Eclipta alba* and *Bacopa monnieri*. Clumps of sedges such as *Cyperus triceps* and *Scirpus argenteus* remain rooted at places. Like the terrestrial realm, the aquatic realm exhibits low species diversity. The dominance of weeds such as *Paspalum* and *Ipomoea carnea* has proved inimical to the growth of a varied aquatic flora.

Birds and the Habitat Pattern

The area of water-spread seems to be the decisive factor in determining the habitat pattern.

When water reaches the full reservoir level (FRL) a narrow strip of shallow water is formed near the edge of cultivation. Amphibious and emergent vegetation come to occupy various niches in this temporary marshland. Invertebrates, especially water-skaters, beetles and even fish find food and shelter in the vegetation. Birds such as egrets, jacanas, storks and ibises are attracted and as winter begins hordes of yellow wagtail forage among grasses and sedges. In quieter time, especially during the noon, and in late evenings, ducks such as common teal, rest here and stilts, sandpipers, snipes and lapwings wade in the shallows searching for food.

As certain tall trees are engulfed by the water, temporary roosts become available to storks and ibises. Likewise *Ipomoea* clumps standing in water provide refuge to great reed warblers, purple moorhens and perches for little cormorants.

Beyond this wet meadow, lie shallow pools ranging in depth from 30 to 60 cms. As water stays at this depth for some time, this zone comes to be covered by emergents such as *Paspalum, Cyperus* and *Scirpus*. Grey and purple herons, moorhens and cotton teals, spotbills, ruddy shelducks and garganey frequent this zone. Besides aquatic insects such as chironomous larvae, seeds of sedges and marsh plants are consumed by birds. Herons catch small fish, which are found abundantly. From above, marsh harriers swoop down on unwary avians.

As water depth increases, stands of *Paspalum* become scattered and are replaced by mats of floating and submerged vegetation. These mats are formed in water 2 to 3 metres deep, the principal component of which being *Potamogeton sp., Hydrilla, Najas* and *Chara*. These attract coot, dabbling ducks like wigeon and shoveller and diving ducks such as tufted and pochards.

Gulls are attracted by debris from fishing boats and ospreys, and river and gullbilled terns dive for fish. Great stone plovers gather in small groups on islands in the midst of the lake looking for fish debris, insects and frogs.

Water level begins to recede as water begins to be drawn down for the dry season. As jowar and bajra ripen, munias, weaverbirds, rosy pastors come to feed on the ripening grain. At the water edge wagtails and bluethroats flit through the semi dry areas among stands of amphibious vegetation. Jacanas probe in the spirals of *Ipomoea aquatica* and egrets and pond herons jab for small fish, large insects and frogs.

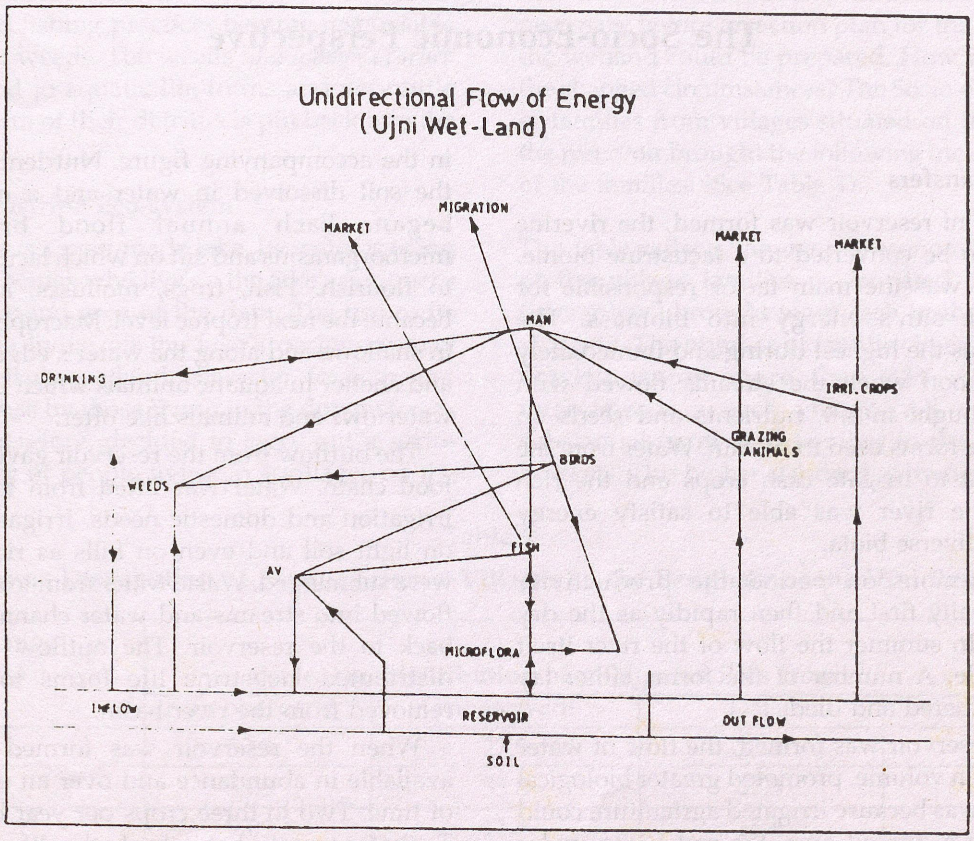
Another flush of insects heralds the beginning of winter and egrets and mynas and babblers invade bushes and surround feeding cattle to grab beakfuls of flies, midgets, grasshopper's etc. Wagtails do the same among grass tussocks and low bushes.

As water continues to retreat the stands of *Paspalum* become the haunt of purple moorhens. With much squabblings and mock fights territories are established and eggs laid in nests built inside dense stands of *Ipomoea carnea*. Some spotbill pairs also nest in these clumps. As cattle enter the fast drying grasslands, cattle and little egrets, glossy and black ibis and openbill and whitenecked storks search for food in the wet meadows.

In the last few years *Paspalum* and *Ipomoea* have continued to invade and mudflats have shrunk. Greater flamingos have to search for suitable areas of mud to forage. Where small areas of mud still exist, blacktailed godwit, sandpipers and little stints and little ringed plovers probe for food.

During the 1991 summer, water level continued to be high inundating islands where river terns, little pratincoles and little ringed plovers nested in 1990. No nesting therefore, took place till late May. In early June unseasonal heavy rains flooded and washed away the nests of terns and pratincoles. *Ipomoea carnea* covered most of the islands too. There were no mud flats to attract greater flamingos who twice came in large flocks in February and March but went away for lack of suitable habitat. Even in May the water level was so high that flamingos and other waders could not gather and we missed the spectacle of huge bird assemblages that made our project site so attractive in May 1990.

This.account highlights the salient features as well as the deficiency in the avaliable habitats. To begin from land, one is struck by the absence of large trees and other woody growth. This has deprived birds of roosting and nesting places. Likewise near the water's edge, there is lack of cover of any sort except clumps of *Ipomoea*. These clumps though providing shelter and nesting sites for some species, do not provide food such as invertebrates. In the shallows the invading *Paspalum* has effectively curtailed the growth of other aquatic plants except *Cyperus sp.* The area of open water has also been reduced as Paspalum has spread even in waters as deep as 2 to 3 metres. Diving and dabbling ducks who used to rest near the project site in open waters have now retreated to open water areas in the middle of the lake. The growth of this grass and the high water level in 1990-91 excluded mudflats altogether. This has reduced the number and variety of waders. As marshy habitat was also restricted and was mostly occupied by weeds there is a restricted variety of marsh plants available in these habitats.



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Chapter Three

The Socio-Economic Perspective

The Energy Transfers

When the Ujni reservoir was formed, the riverine biome began to be converted to a lacustrine biome. Formerly river was the main factor responsible for converting the sun's energy into biomass. The productivity was the highest during and immediately after the monsoon when the streams flowed with vigour and brought in silt, nutrients and seeds on which many life forms used to sustain. Water from the river was lifted to irrigate cash crops and the rich alluvium of the river was able to satisfy energy demands of a diverse biota.

In the post-monsoon period the productivity declined gradually first and then rapidly as the dry season began. In summer the flow of the river itself became a trickle. A number of life forms either lay dormant or withered and died.

Before the reservoir was formed, the flow of water though limited in volume, promoted greater biological diversity. This was because irrigated agriculture could be practised on a limited area, the rest being under precarious rain-fed farming or allowed to lie fallow. The restricted human activity on these lands allowed scope for other life forms to flourish. Fallow and non-culturable waste lands promoted growth of grasses, herbs and shrubs which afforded food and shelter to diverse species such as the blackbuck and wolf among animals, bustard and sandgrouse among birds and a host of reptiles. Grazing by cattle and sheep was limited, as their numbers were low. The practice of sheep and cattle migration, as forage of one region was exhausted, permitted regeneration of flora and its exploitation by other creatures occupying other niches.

What happened when a substantial portion of the river basin and its surroundings was flooded, is shown in the accompanying figure. Nutrients released from the soil dissolved in water and a new food chain began. Each annual flood brought seeds, microorganisms and silt on which lacustrine life began to flourish. Fish, frogs, molluscs, and crustaceans became the next trophic level. Macrophytes took shape in shallows and along the water's edge affording food and shelter to aquatic animals which in turn attracted waterfowl and animals like otter.

The outflow from the reservoir gave rise to another food chain. Water was lifted from the reservoir for irrigation and domestic needs. Irrigated crops began on light soil and even on hills as rich alluvial soils were submerged. Waste water from towns and villages flowed into streams and water channels and headed back to the reservoir. The outflow from the canal distributed lacustrine life forms to lands further removed from the river basin.

When the reservoir was formed water became available in abundance and over an extended period of time. Two to three crops per year became routine. To that extent the habitats of other life forms vanished. Agriculture extended from tip of the water body to crests of the hills surrounding it. Even trees and bushes had to give way. The number of cattle increased but grazing lands shrunk. Stony uplands and lands under temporary submergence were left as the only areas available for grazing.

Though possibilities of fishing increased, the fish were not conducive to building up of food chains as they were imported from other river systems like the Ganga and the Brahmaputra and the Kaveri by the Fisheries Dept of the Government to be released annually and harvested as they grew. All the natural habitats necessary for spawning of fish such as long, deep pools, rocky barriers, affording crevices and a gravelly substrate vanished as they came under loads of silt and a permanent sheet of water. Though shallow water areas attracted waterfowl, birds could not nest as nesting trees and bushes were scarce. Animals, reptiles and birds which were residents of barren and wastelands were driven away. Biological diversity declined and was replaced by a uniformity of habitat. Food chains became simplified and unidirectional, much of the energy concentrated in cash crops and fish went out of the lacustrine eco-system as bulk of the produce was transported to the market to be consumed by outside agencies. Effluents from farms and villages and fishing practices became responsible for the spread of weeds. The weeds like *Ipomoea carnea* do not offer food to aquatic life forms and very little energy in the form of their detritus is put back into the eco-system.

Man & the Lacustrine Eco-system

Ujni reservoir is a man-made lake. Its water is being used by human beings who live on the lake's periphery and in the command area of the dam. The use of its water by people living on the lake's periphery may influence the lake's wetland character to a greater extent than the use by those living in the down-stream areas. It was therefore, decided to carry out a socio-economic survey of people living in 4 villages on the reservoir periphery. Three villages viz. Kumbhargaon, Bangarwadi and Dalaj are located on its southern shore while the fourth Chincholi is located on the northern shore of the lake. From the convenience point of view they were the nearest from our project site.

A questionnaire was prepared and 193 families were randomly selected from the three southern villages while 101 families were interviewed from the larger northern village. The questions related to family structure, the extent of landholdings before and after the construction of reservoir, the cropping pattern, the use of irrigation, fertilizers and insecticides, the average yield of crops per hectare, the number of cattle and other animals, the consumption pattern, the use of electricity, vehicles, cooking gas and sanitation in the villages, how needs such as of fuel, fodder, building material were satisfied, the information about other occupations practised by families, their income structures and the improvements in terms of amenities that they desired. All this information was thought necessary before an action plan for the multiple use of the wetland could be prepared. How is man faring in the changed circumstances? The Socio-economic survey of families from villages situated on the periphery of the reservoir brought the following income distribution of the families: (See Table 1)

The table reflects the overall economic improvement of the village families as irrigated cash crops and fishing have brought more cash in the pockets of the villagers. The number of families in the lowest income bracket is not more than 33% of the families interviewed in each village. All villages have a substantial number of families in the middle income brackets. This higher standard of living is undoubtedly the result of the abundance of water available for cultivation. But how far is this an increase in real terms? Are they in a better position to enjoy the fruits of modern civilization? If the most common amenities that a modern civilization offers are: 1) independent piped water supply connection, 2) cooking gas, 3) electricity in the home and 4) possession of an auto-vehicle, how the village families fare in terms of these? The next table shows the percentage of families from

Table 1

Income Distribution of Families from 4 Villages on the Periphery of the Ujni Reservoir

Income Range (per month) Rs.	**Percentage distribution of village families from**			
	Kumbhargaon	Bangarwadi	Dalaj	Chincholi
0 to 1000	33.3	27.9	23.5	29.7
1001-2000	53.5	55.8	47.3	47.5
2001-3000	9.09	11.6	15.6	12.86
3001-4000	4.04	4.6	7.8	4.90
4001 & above	-	-	5.8	3.9
Total No. of families	99	43	51	101

LOCATION OF VILLAGES SURVEYED

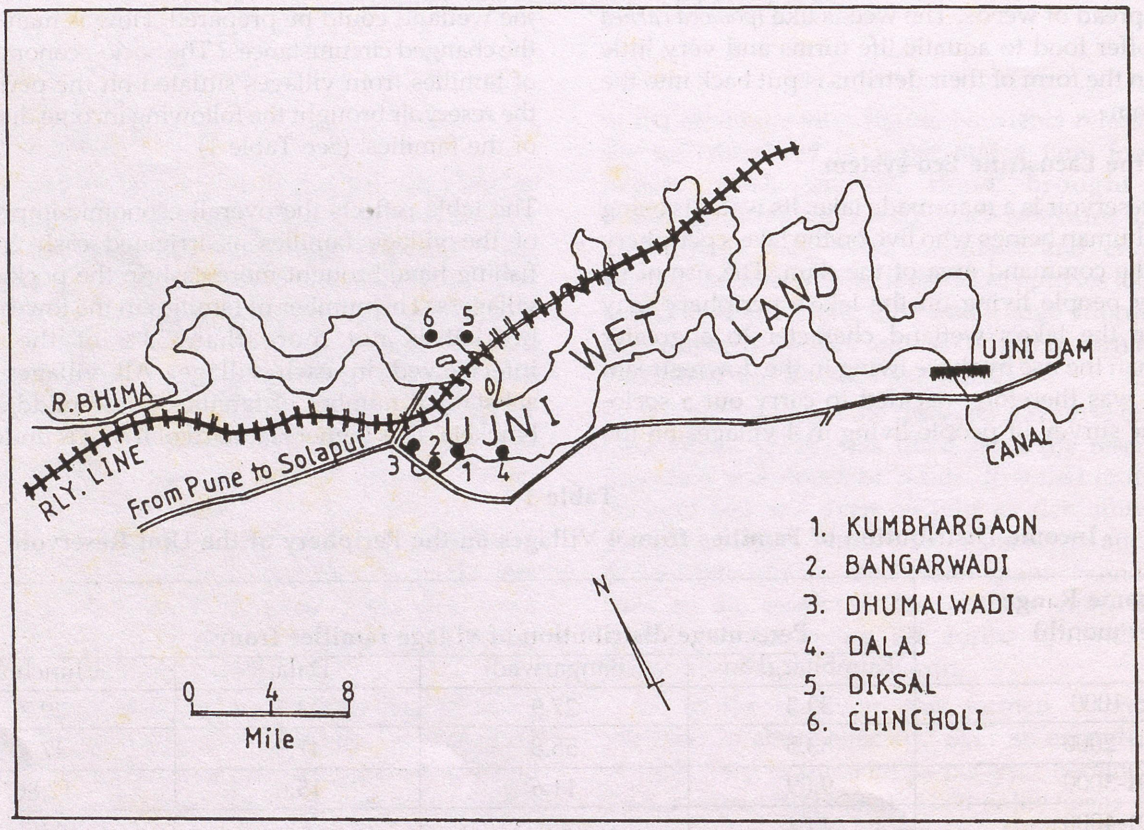


Table 2
Percentage of Village Families Enjoying Modern Amenities

Name of Village	Percentage of Families Enjoying:				
	Piped water	Cooking gas	Electricity	Auto vehicle	No amenity
Kumbhargaon	Nil	Nil	26.2	7.0	67.0
Bangarwadi	Nil	Nil	20.9	2.3	76.7
Dalaj	Nil	Nil	50.9	19.6	29.4
Chincholi	Nil	Nil	49.5	7.9	43.5

each village enjoying these amenities:

The percentage of families that cannot enjoy any of these amenities is quite high in Kumbhargaon and Bangarwadi. None of the families in any of the villages can boast of an independent piped water supply connection. Piped water is available in Kumbhargaon and Dalaj but only through a few taps spread over the villages, which are used in common by a number of families. People in Bangarwadi depend mainly on water supply from wells and all the residents of Chincholi had to haul water from the reservoir.

Cooking gas remains a dream for the village families. For fuel, all families depend on kerosene and biomass collected from farms, fallow lands, common pastures and wastelands. Families who cultivate sugarcane utilize the waste material left in the field after the harvest. People, who do not possess this source, depend on collection of biomass from the wild to as much as 90%of their fuel needs. These families include those from the lowest income group as well as salaried people such as village school teachers, peons, policemen, forest guards, tractor drivers, petty shopkeepers, artisans and those who do not own any land. Their income does not allow them to depend wholly on kerosene. They have to collect biomass to satisfy 25 to 50% of their fuel needs.

On fallow lands, common pastures and wastelands, vegetation that can be used as fuel mainly consists of scattered stands of *Prosopis juliflora* which are extensively used by villagers as fuel. Social forestry plantations have been initiated recently near Bangarwadi and Kumbhargaon. They have yet to make any impact in satisfying the fuel needs of the local people.

Though fuel needs are satisfied to a certain extent by the locally available biomass, wood required as household timber or for making agricultural implements etc., is locally available to a much lesser extent. For these needs people have to depend on the market at Bhigwan 10 kms away. The high prices of any quality of wood in the market places this source beyond the reach of even the middle income group families. Biomass in the form of usable wood (woody species) is therefore, an urgent necessity in the villages.

Scarcity of cattle forage also appears to be acute in the villages. More than a thousand domestic animals are owned by the families in the four villages surveyed so far. Their percentage distribution is given in the following table:

Cows, goats and sheep constitute the majority of animals in the villages. Not all the families however, own domestic animals. The next table shows the

Table 3
Percentage Distribution of Domestic Animals in the Villages

Name of the Village	Cow	Oxen	Buffalo	Sheep	Goat	Horse	Total
Kumbhargaon	27.8	12.3	4.90	30.6	23.80	0.3	342
Bangarwadi	13.7	10.3	1.30	46.2	28.00	0.4	225
Dalaj	35.0	16.2	9.80	6.40	29.90	0.4	234
Chincholi	31.4	27.9	6.80	—	33.70	—	261

distribution of animal-owning families according to income per month:

Families who own animals belong to the low and middle-income groups: those who have small landholdings and depend on animal produce for their livelihood. Many of these families own sheep and goats besides cows. But the number of animals per family rarely exceeds 5 in these groups. There are however, in each village a few families that own large animal herds numbering 30 to 70 animals in each herd. In Kumbhargaon the owners of such large herds come from the lowest and the higher income groups. In Bangarwadi also they are from these groups; in Dalaj they belong to the middle income group; while none of the families in Chincholi owns more than 10 animals

Table 4
Income Distribution of Families Owning Domestic Animals

Income range (Rs)	Kumbhargaon	Bangarwadi	Dalaj	Chincholi
0 to 1000	9	11	5	24
1001 - 2000	32	19	15	37
2001 - 3000	6	5	7	14
3001 - 4000	4	2	4	3
4001 & above	-	-	3	3

For forage all animal-owning families informed that they depend on the fodder from fields, meaning thereby common pasture, wasteland and area under partial submergence besides agriculture. Even the owners of large herds, though they possess large landholdings, pasture their animals on common sources. This is mainly because the main produce of their farms is cash crops like sugarcane, sunflower, groundnut and wheat. Only a small portion of their land is devoted to production of cereals such as jowar and bajra, which produce cattle feed after the harvest. Indeed the percentage area under cash crops in the total cropped area in each village is so large as to leave very little land for cultivation of fodder. The following table makes this point clear: (See Table 5)

Table 5
Percentage of Area under Cash Crops in the Total Cropped Area in the Village

Name of Village	Percentage of Land under Cash Crops
Kumbhargaon	75
Bangarwadi	82
Dalaj	70
Chincholi	90

The main source of forage for the cattle appears to be the post-monsoon flush of grass on common pastures, wastelands and fallow lands and *Paspalum* and other aquatic vegetation after the lowering of the reservoir level. In the dry season this latter source is the only forage available and animals tend to concentrate on lands which have remained submerged in winter. Even in this area proliferation of weeds has severely restricted the quantity of forage. As the fodder available on agricultural lands is also limited, the pressure on common pastures can well be imagined. Development of grasslands, meadows, dry and wet, producing good fodder, is thus an urgent necessity.

Availability of electricity is better in villages situated near the main supply lines than in villages away from them. In Kumbhargaon and Bangarwadi, though rich farmers can afford to bring electric lines to run their lifts on the reservoir, they could not extend these to their homes located at some distance from the reservoir. Street light remains the main source of electric light to many families in these villages. Domestic electric supply still remains elusive for many a prosperous family from the villages.

High consumption of electric units or possession of gadgets run on electricity cannot yet become a mark of prosperity in these villages. The prestige symbol is then the possession of an auto-vehicle: a jeep, a motorbike or even a moped. The greater availability of these vehicles in the market and loan facilities offered by banks and finance companies to buy vehicles, have brought this amenity within reach of the prosperous rural families.

It appears therefore, water though now available in plenty, has not led to greater production of biomass that will satisfy the basic needs of the people. Cultivation of cash crops has led to an increase in the cash income of rural families but without a parallel increase in real incomes. The market economy appears to be unable to meet the fuel, timber and fodder needs of the village families, neither is the social production of this biomass adequate for this purpose. The gap between the amenities available to the urban and rural middle and higher income classes appears to be glaring.

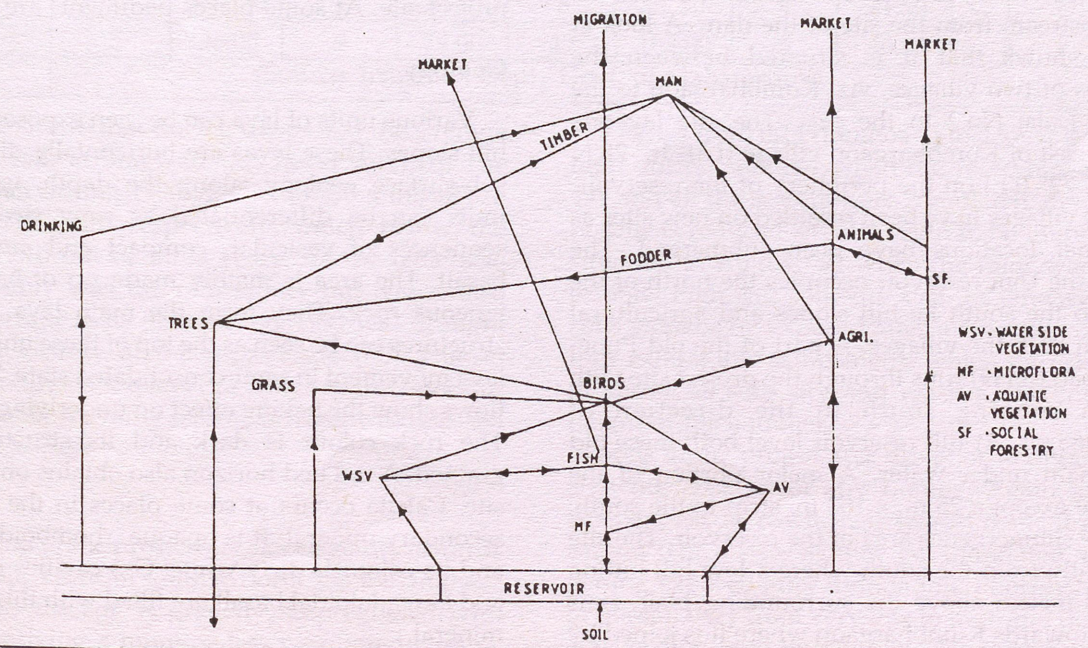
It is therefore urgently necessary to take steps that will lead to the generation of usable biomass for fuel, fodder and timber needs of the people. Obviously this can be achieved by enhancing the number and variety of primary producers. If a varied habitat pattern is established on the reservoir periphery, not only will it make usable biomass available within the village boundaries but it will also benefit the non-human creatures that are utilizing the reservoir water at present.

Usable biomass can be increased by restricting the hectarage under cash crops. Farmers however, may not immediately agree to do this. They will have to be convinced of the necessity of bringing about a varied landscape. Perhaps the experience in similar landscapes in other parts of Maharashtra may prove helpful. It indicates that persistent cultivation of sugarcane on light soils leads to salinity. Horticulture, production of wood for timber and other needs, cultivation of better forage have to be propagated as alternatives as they facilitate better protection of soil and greater stability of income.

The water-edges at present, without any vegetative cover or occupied by weeds, need to be protected by suitable vegetation including aquatic and semi-aquatic plants, and grasses that will help reduce erosion at the lake periphery.

Likewise the area of partial submergence presently also occupied by weeds need to be made more productive by improving the quality of vegetation and by offering shelter and breeding places to non-human creatures using the reservoir.

Multidirectional Flow of Energy
(Ujni Wet-Land)



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Chapter Four

The Project Site

When it became apparent that a mosaic of habitats is likely to satisfy better the needs of the people, a project site was selected to launch the experiment of setting up a varied habitat pattern on the lake periphery. The site selected was not far above the full reservoir level (FRL), much of it getting submerged at one time or the other during the year. It gradually sloped towards the center of the reservoir allowing us to experiment in varying depths of water. It was frequented by a large variety and number of birds giving us an opportunity to test the reaction of non-human beings to the intended changes in the habitat.

The Location

The project site lay in the backwaters of the reservoir 50 kms upstream from the site of the dam. A look at the map shows that it is situated between the boundaries of two villages, viz. Kumbhargaon to the west and Dalaj No.2 to the east. The site lay one kilometre east of Kumbhargaon village (Lat. 18° 25′N and Long. 72° 0′E) on the periphery of the reservoir. Both these villages have been resettled on new sites as their former locations have been submerged. The spread of the Ujni rèservoir occupies the north of the site and to the south lie hill slopes and agricultural lands from both the villages. A part of the old Pune-Solapur road (NH9) runs through the project site with a branch running south in the direction of Walchandnagar. At full reservoir level both these old roads remain under water. A major portion of the project site except a 25 m. x 100 m. strip to the south, falls in the submergence area of the reservoir. The site slopes gently from the south where a low hill jutting about 100 metres above the surrounding plain runs east west towards Kumbhargaon where it is joined by another spur running south - north. The gentle slope runs towards north to the centre of the reservoir.

Topography

The hills on the south form a local catchment of the streams that flow down from the hills in the direction of the river basin. On the southwest the hill slopes are degradational as they are being eroded by streams flowing during the rainy season. Aggradational landforms are along the river Bheema, i.e. towards the centre of the reservoir, where streams deposit sediments. During each flood the river channel expands and deposits of clay, sand are spread over the area of submergence. Dendritic drainage pattern covers the project site. At some places pediments are also seen.

Geology

Various units of lava can be seen exposed along the hill slopes. These lavas are horizontally displaced. In sub-surface geology, along the depth, various lava units can be differentiated as ropy structure, and sequences of vesicular, compact and amygdaloidal basalt. The area is mainly made up of basalt: basic, igneous rock. They form the main lava unit. Ropy structures can be seen as the top of these units showing lava movement in semi-consolidated state. Young lava flows show the baking effect on underlying lava units. The rock colour is dark and its structure is fine grained. A red bed horizon also obtains on the project site. Calcite occurs at some places in the basalt as a secondary mineral. It is opaque, rhomboidal in shape and its colour is dirty white. Gas cavities in vesicular and amygdaloidal basalt are filled with this secondary mineral.

Climate

The temperature on the project site varies between 35° C to 41° C during the summer and 12° C to 30° C. during the winter. The summer highs are reached between 15th April and 15th May and the winter lows fall generally between late December and early January. The large difference between maximum and minimum temperatures coupled with low humidity make for a dry tropical climate most of the year.

Rainfall

The nearest rain-gauging station is at Bhigwan 10 kms west of the project site. The average annual rainfall recorded at Bhigwan is 500 mm. There are however, large variations from year to year. The major portion of precipitation is derived from storms that burst in the pre-monsoon period (April-May) and in September-October. There are also wide variations at the micro-level. Rain at Bhigwan does not necessarily mean rain on the project site and vice versa. The rainfall recorded at Bhigwan during the project period (1990-92) was distributed as follows:

Table 6
Distribution of Rainfall during the Period (1990-93)

Year	June		July		August		September		October	
	Rainy Days	Total Rain	Rainy Days	Total Rain	Rainy Days	Total Rain	Rainy Days	Total Rain	Rainy Days	Total Rain
1990	7	79.10	10	18.70	16	158.70	7	48.30	6	134.50
1991	7	104.50	4	29.70	8	21.50	4	21.50	1	38.00
1992	3	36.00	9	79.00	12	103.00	5	60.00	3	37.00
	(Source: Irrigation Dept., Govt. of Maharashtra)									

The table shows that during the period the average of 500 mm rain at Bhigwan was never reached. The actual rainfall during 1990-92 was 437.30 mm., 193.75 mm. and 315 mm. respectively, much below the average in two out of three years. As the table also shows not only was the rain scanty but it was also extremely erratic in its distribution. 1991 was drought year in the vicinity of the project site (PS). Due to drought conditions the level of water in the reservoir fell rapidly after the rainy season as water was released early in the season.

Soil

The ground of the project site slopes gently towards the river basin, i.e. from south to north. On the southern upper slopes the soil is gravelly, impregnated with murrum overlying a more or less weathered basaltic base. The gravelly horizon is not more than 30 cm deep with weathered rock below it. Solid rock is encountered between 1 and 1.5 metre depth. As one enters the submergence area the proportion of gravel is reduced and that of silt and clay increases. The clay-silt layer is 0.5 metre deep in sector III (see figure) while it is 3 metres deep in sector VII near the original river basin. This silt-clay layer may denote the accumulated sediment in the reservoir.

Soil samples were collected in sectors I, III, IV and VI in August 1991, January 1992, April 1992, July 1992 and November 1992 for analysis. They represented soils that were completely dry (sector I), dry for 8 months of the year (sector IV), dry for 6 months of the year (sector III) and dry for 4 months of the year (sector VI). The table below shows the character of soil obtained through the analysis of soil samples.

The soil in the project area appears to be alkaline as the pH varies from 7.4 to 8.6. Alkalinity of the soil is high especially during the height of the summer and the autumn when soils are beginning to be inundated. In semi-dry soils alkalinity was also high as the water began to recede from the sector. The salt content of the soil varies from 0.14 (mmhos-1) to 0.97. It is uniformly high during summer when the reservoir level fell to 491 and all the sectors were completely dry. The level of salts is reduced as soils begin to be inundated. The situation in August '92 when the rains were delayed exhibits high salt contents also. In January 92 when soils were being exposed after inundation in October, they exhibit low salt contents which start rising again in spring as soils dry and reach a maximum in the height of the summer.

Soils in the project area are poor in organic carbon showing absence of any humus. Again in summer soils appear to reach their lowest content of organic carbon which rises as they get inundated, or are just getting exposed after inundation. Phosphate contents of the soil vary from very low to high and do not show any relation with inundation. The potash level in the

Table 7
Qualities of Soil at the Project site

PH Nature of Sample	Collected in				
	Aug 91	Jan 92	Apr 92	Jul 92	Nov 92
I Dry	8.4	7.7	7.9	7.8	8.3
II Semi-dry	7.9	8.3	7.8	7.5	8.5
III Semi-wet	8.3	7.9	8.0	7.5	8.2
IV Wet	8.0	8.6	8.1	7.4	7.9
EC					
I Dry	0.22	0.38	0.44	0.45	0.20
II Semi-dry	0.79	0.15	0.52	0.92	0.15
III Semi-wet	0.84	0.33	0.75	0.88	0.38
IV Wet	0.55	0.14	0.29	0.97	0.45
C					
I Dry	0.42	0.42	0.24	0.31	0.49
II Semi-dry	0.39	0.35	0.42	0.14	0.31
III Semi-wet	0.24	0.24	0.21	0.17	0.27
IV Wet	0.27	0.39	0.17	0.45	0.42
P(kg per ha)					
I Dry	13	4	4	27	31
II Semi-dry	4	20	22	31	20
III Semi-wet	27	4	13	4	9
IV Wet	31	13	9	20	23
K(kg per ha)					
I Dry	767	381	202	358	594
II Semi-dry	382	168	314	638	989
III Semi-wet	510	382	470	79	874
IV Wet	470	213	280	241	538

soil varies from moderate to very high. They are particularly high just after inundation, i.e. when the draw down begins.

The process of inundation and drawdown seems to have a noticeable effect on soil quality at the project site.

Wet soils are those which are under water for 6 months every year. This has been happening at the project site for the last 12 years. Have the wet soils therefore, developed any characteristics that are markedly different from those of the dry soil? As far as the pH is concerned, wet soils appear to be less basic than dry soils during the period of inundation. There is a minor reduction in alkalinity during this period. On the other hand wet soils tend to exhibit more salt content than dry ones; the salt content of the former is less during and immediately after draw down but it is higher when wet soils become completely dry or during the 6-month dry phase of the wet soils. Wet soils are showing lower organic carbon than dry soils except immediately after draw down when probably nutrients are released from the soil with the deterioration of organic matter. As far as phosphorus contents are concerned, wet soils are placed better than dry soils. It is possible that this phosphorus content in the soil has a relation with run-off from agricultural fields where inorganic fertilizers are being used. The contents however, are not exceptionally high but vary between low and high levels designated by soil scientists. Potassium contents are higher in dry soils than the wet ones, except during the period immediately after draw down when again nutrients are being released from the soil with its exposure to weather. Generally black soils are rich in potash. The dry soil on the project site is not black; its high potash contents may again have something to do with the use of inorganic fertilizers in surrounding agriculture.

the upstream portion of the river Bheema and its tributaries. Some of these dams have their catchments in high rainfall areas & their reservoirs fill to capacity even before the Ujni dam catchment receives any rainfall. The inflow of water into the reservoir during the period together with the rainfall at Bhigwan in the catchment of the dam are shown below:

The table shows that the major inflow into the reservoir results from rainfall conditions in the upstream area beyond the immediate catchment of the Ujni dam.

The reservoir water is released into the canal and the river downstream and some of it is lost due to evaporation. Evaporation rates are high in summer and low during the rainy season and immediately thereafter. They varied from a low of 0.1 mcm per month in October 1990 to a high of 56.54 mcm in May 1992.

Table 8
Inflow of Water into and the Amount of Rain in the Catchment Area of the Ujni Dam

Month	Year 1990		Year 1991		Year 1992	
	Rain (cms)	Inflow (mcm)	Rain (cms)	Inflow (mcm)	Rain (cms)	Inflow (mcm)
June	79.10	930.80	104.5	842.90	36.0	—
July	18.7	282.5	29.75	2434.3	79.0	550.0
August	156.7	810.03	21.7	1990.5	103.0	245.0
September	48.3	407.75	21.5	248.3	60.0	130.0
October	134.5	498.85	38.0	133.5	51.0	279.8
(Source: Irrigation Dept., Govt. of Maharashtra)						

In conclusion it may be stated that soils which are largely composed of mineral material and have a low organic content exhibit early development stages of a wetland. The creation of a reservoir normally results in drawdown zones. They create severe conditions of flood and drought that are not generally suitable to the development of varied wetland and aquatic flora. Even terrestrial plant species find it difficult to survive there. Therefore, in the early development stages of such man-made wetlands only certain opportunistic species such as *Ipomoea carnea* can colonize them. This is exactly what is seen on the Ujni reservoir.

Hydrology

Hydrology of a wetland is the flow of water (precipitation, ground water and surface water) into, through and out of a wetland, its characteristics and interaction with the wetland (Kusler 1987). In the short-term hydrology determines vegetation, fauna and most wetland functions. In the longer term it also determines the shape, size, depth and location of a wetland (Kusler ibid). The inflow of water in the Ujni reservoir is governed mainly by dams and barrages in

The gross storage capacity of the reservoir is 3140 mcm of which the usable storage is 1440 mcm. The dead storage of 1700 mcm is larger than the live storage. It is therefore, likely that the reservoir acts as a sink for the sediments and suspended substances.

The groundwater relationships are difficult to analyze, as they require several years of monitoring with a series of consecutive wells. During 1991 and 1992 a number of wells in villages around the project site were monitored. The number of wells monitored from each village during the 2 years is as under:

Name of Village	No. of Wells Monitored
Kumbhargaon	10
Bangarwadi	8
Dhumalwadi	5
Dalaj	5
Diksal	9

Information about the depth of each well was obtained from the owners. The height of the water column was measured every month 3 to 5 times. When wells of similar depth were located in each village, measurements were concentrated on them. The table below presents the height of the water column (percentage of the maximum height of the water column in each well), together with the reservoir level and water inflow into the reservoir during each month. The depth of wells is 35 feet in each case.

other. It may therefore, be assumed that the reservoir functions, both as a recharge and discharge area at different times.

Water Quality

The reservoir water showed large variations in temperature. In summer when the atmospheric temperature was 40°+ C. shallow water (15 to 30 cms deep) temperature was above 35° C and it was difficult to wade through such warm waters. Water

Table 9

The Reservoir Level, the Monthly Inflow and the Percentage Height of the Water Column in the Wells around the Project Site.

Date	Reservoir level (in meters)	Inflow (mcm)	% height of water column				
			I	II	III	IV	V
1.1.91	496.26	Nil	85	86	71	88	86
1.2.91	496.25	Nil	60	88	62	86	80
1.4.91	495.17	0.16	55	71	60	68	74
1.6.91	493.74	842.90	85	77	91	88	86
1.11.91	496.29	18.20	80	74	94	91	94
1.1.92	495.11	16.22	80	85	80	90	85
1.2.92	494.76	4.00	70	80	70	85	80
1.4.92	493.29	3.65	65	65	55	40	65
1.6.92	491.63	550.00	75	75	60	70	70
1.11.92	495.74	—	85	80	80	92	90

In the above table wells are from I = Kumbhargaon, II = Bangarwadi, III= Dhumalwadi, IV = Dalaj and V = Diksal. From the data presented here it is diffcult to say whether the reservoir is acting as a recharge area in certain times and a discharge area in others. The high levels in the reservoir are not necessarily correlated with high water levels in the wells. A number of other variables are involved in such an analysis. Net groundwater recharge or discharge for a specific wetland has most often been estimated by completing the other 'knowns' in a wetland water budget analysis and attributing the remaining water to groundwater flow (Kusler ibid). The 'knowns' generally are direct precipitation, surface inflow and outflow and evapotranspiration. In addition the morpholpgy of the basin also affects the flows. Water may be discharged along the high gradient side of the wetland and then reenter the ground at the low gradient side. The banks of the river Bheema are known to be steeper on one side and lower on the

temperatures in winter varied between 20° and 25° C a few degrees lower than air temperature during the day. At night water temperature must be higher than the air temperature.

The percentage of dissolved oxygen in the reservoir water varied with the season. It was high during the monsoon months but dropped immediately in the post-monsoon period. It rose slightly in December and January but thereafter dropped significantly till June. It rose slightly again in late June probably because of the effect of wind mixing.

The pH of water was above 7 in all the seasons showing its basic character. In February 1991 shallow waters recorded the highest pH exceeding 9 and 10 while in water which was 3 metres deep with dense growth of *Hydrilla sp.* it was again 7 and in shallow waters overgrown with *Najas*, *Chara* and *Spirogyra* it was somewhat higher than 7.

Potassium contents were low in water samples indicating that potassium was not leached in substantial quantities from the plant tissue, nor was it getting dissolved from the substrate. The invertebrates must however be successful in extracting calcium from water and from sediments as after a drawdown the exposed lake bottom was found to be littered with molluscs and shells of all sizes.

Total coleiform contents of the water were found to be very high showing that the reservoir water was not fit for drinking. BOD was seen to be high showing fecal contamination. Birds using this water may also be partly responsible for this. *Potamogeton pectinatus* and *P. natans* are both known to be pollution tolerant species (Elder 1987). Their wide prevalence in water may indicate pollution of the waters. The Socio-economic survey of village families brought to our notice the high incidence of water-borne diseases among them. Typhoid and jaundice are the most common diseases around the periphery of the Ujni Lake.

Chapter Five

The Significance of the Water Level

The Water Level at the Project Site

The most notable feature of the project site is the fluctuating water level of the reservoir. The area of the waterspread varies from season to season and indeed from month to month as water is let in and let out of the reservoir. The floods generated by the southwest monsoon rain are impounded in the first week of August when the practice is to lower the dam gates. With this impoundment the area of the water-spread rises till the full reservoir level (FRL) is reached, normally in late September or October. The draw down commences at the end of the Rabi season usually in late December or January. But if drought conditions prevail in the command area, water is released early, even in October, as did happen in October 1991.

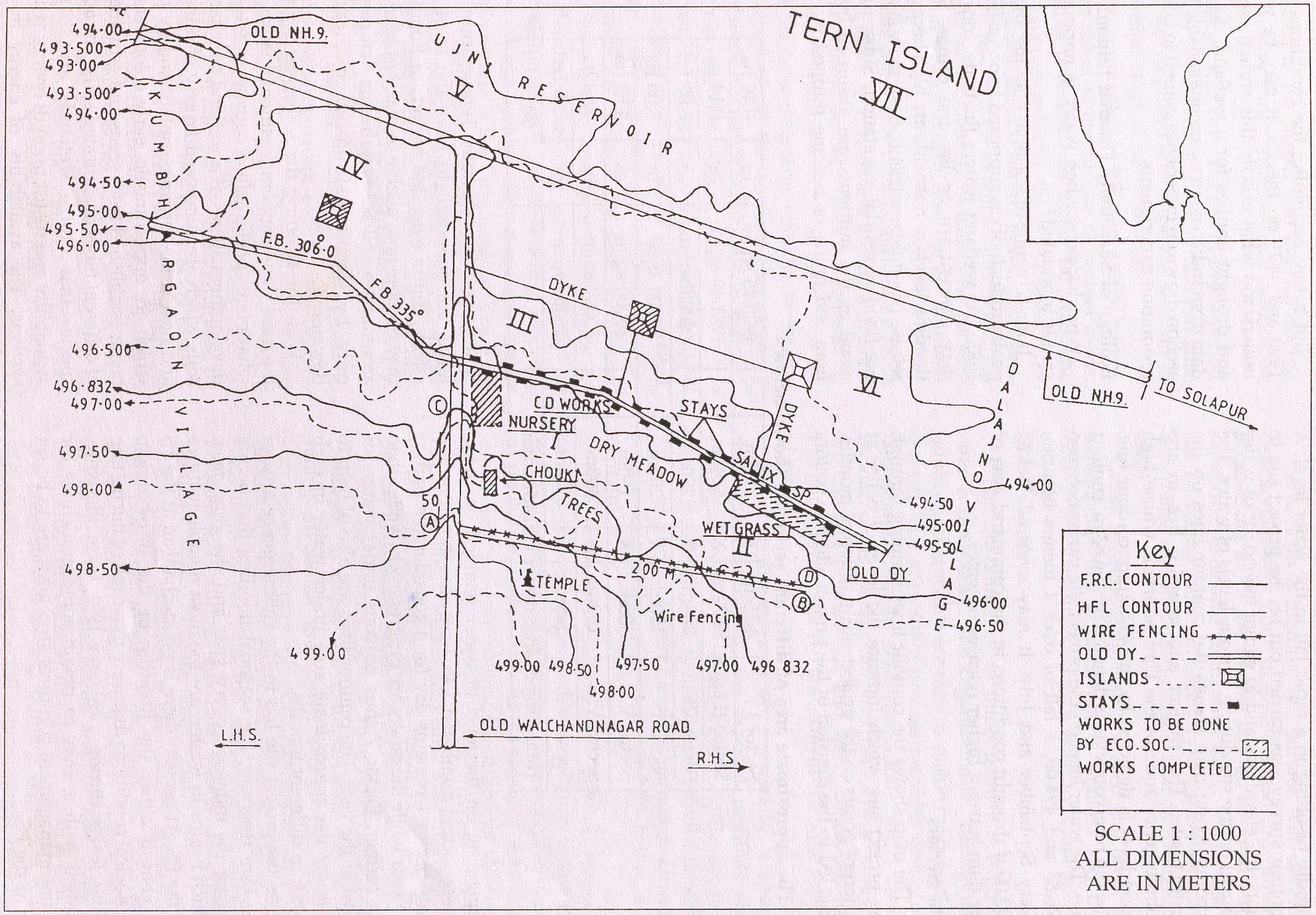
Table 10 illustrates the fluctuating water level in the Ujni reservoir since the beginning of the study in June 1990.

It appears from the table that in 1990-91 fluctuations in the water level were more gradual than in 1991-92 especially from October onwards. In other words water was released only gradually after October 1990 but from October 1991 onwards water was released

Table 10
Fluctuating Water Levels in the Ujni Reservoir since the Beginning of the Present Study

Month	1990	1991 (Mean level in metres)	1992
April	494.02	494.82	493.29
May	493.35	494.09	492.30
June	495.50	493.93	491.63
July	493.35	494.57	491.60
August	495.12	495.14	494.16
September	496.10	496.06	496.38
October	496.57	496.41	496.62
November	496.57	496.05	496.07
December	496.57	495.57	495.47
January	495.08(1993)	496.26	495.12
February	494.40(1993)	496.04	494.63
March	493.90(1993)	495.22	494.05
(Source: Irrigation Dept., Govt. of Maharashtra)			

PROJECT AREA, SECTORS & WATER LEVELS



rapidly resulting in a rapid fall in the water level. A contour survey was carried out on the project site to mark the elevations and to gauge the extent of water spread on the site during various levels of water. The accompanying map shows the contour lines on the project site. The project site actually lies in the submergence zone of the Ujni reservoir whose high flood level is depicted by the 497.50 m. contour line. The full reservoir level is denoted by 496.83 m. contour line. The water level on the project site varies between 496.83 and 494.00, a fall of over 2 meters between every September and July. It may even fall below 493.00 if drought conditions in the command area of the dam warrant higher releases of water.

The Sectors

The map shows the contour lines running through the project site which indicate the level of water at different points on the project site in different months. This led to the division of the project site into sectors depending on the level of water retained on them. These sectors numbered 1 to 7 are also shown on the map. Sector 1 remains dry for a considerable part of the year while the others are progressively wetter than the former. Sector 7 thus remains under water for most of the year. The contour lines are also of help to estimate the approximate area under water in each sector in different months.

As the project site lies in the submergence area of the Ujni reservoir, the seasonal flooding that occurs during the monsoon every year and the *draw down* which begins in winter, are the most notable features of the PS. At present there is no mechanism at the PS to control either the flooding or the draw down. Ecological conditions that were the result of fluctuating water levels during 1990 and 1991 were therefore, studied with a view to obtain some guidelines for future management if control structures are to be set up at the PS.

The approximate area of different sectors is shown below:

Sector I :	40.5m.	X	12.5m	=	4920.75 sq.m.	or	0.49 ha.
Sector II :	81.74m	X	23.46m	=	1981.40 sq.m.	or	0.19 ha.
Sector III :	300m.	X	200m.	=	60000 sq. m.	or	6.00 ha.
Sector IV :	150m.	X	200m.	=	30000 sq.m.	or	3.00 ha.
Sector V :	300m.	X	150m.	=	45000 sq.m.	or	4.50 ha.
Sector VI :	100m.	X	400m.	=	40000 sq.m.	or	4.00 ha.
Sector VII:	50m.	X	500m.	=	25000 sq.m.	or	2.5 ha.
Total project area under consideration				=			20.68 ha.

But before examining the conditions prevailing in 1990 and 1991 on the PS, it may be worthwhile to understand what exactly this annual regime of flood and drought implies for a wetland. As comparative data from Indian sources are unavailable the following section draws on experience gained in USA in wetland restoration experiments.

Ecology of Seasonally Flooded Impoundments

What happens when water is impounded and an area is inundated?

If it is a regime of seasonal flooding and drawdown, peak productivity is supposed to occur (Fredericksson 1985). As wetland waters fluctuate, ions of nutrients may concentrate or become dilute. Shortly after flooding levels of nutrients are high because of a rapid release of soluble nutrients from the substrate and the pre-flood terrestrial vegetation. Subsequent declines result as the nutrients are absorbed by developing flora and fauna or become trapped by the colloidal contents of the substrate. Temperature and oxygen levels are supposed to have the most pronounced effects. But in extended periods of flooding nutrients may become unavailable in marshes as organic matter accumulates and holds nutrients that can be released only by decomposition when these areas are dewatered.

With the flooding the soil-water regime becomes the most significant environmental factor determining what plant species will occupy a particular site. Early development stages of a wetland are characterized by soils which are composed largely of mineral material and have a low organic content and by plant species which are opportunistic, early colonizers, capable of being established from seeds and growing in a variety of different types of saturated soils. The adaptations of species that utilize wetlands are shaped by the availability and distribution of energy within wetland systems. The availability of energy in wetlands is ultimately related to the supply and internal cycling of nitrogen and phosphorus in the system (Frederickson & Taylor 1982).

Disturbances such as fire, changes in hydro-period or incursions of herbivores and agriculture can alter the pattern of development and cause the wetland to revert to an earlier stage of development.

Above a redox potential of 0.2 volts a thin, brown, oxidized layer exists at the surface of bottom muds. When the redox potential falls below 0.2 volts, the surface mud becomes reduced, the brown layer turns black and nutrients dissolve readily into water. Much of the nutrient fluctuations in impoundments is the result of organic matter interactions with either bacteria or changes in the redox potential of the environment (Moss B. 1980).

The fertilizers commonly used in agriculture reach wetland eco-systems in run-off and greatly accelerate the processes of eutrophication. There is frequently an oxygen deficit and hydrogen sulphide appears in the sediment. At the same time large amounts of organic matter are deposited on the bottom. This causes a shallowing of the water which is then rapidly invaded by emergent macrophytes. (Kusler 1987)

The first year in the life of a man-made, shallow lake is characterized by open water with few rooted plants. Within a few years the surviving plants from former vegetation are replaced by seed germinated submergent, floating and emergent hydrophytes. In artificially flooded lakes the great quantity of accumulated plant material before flooding supports a detritus-based eco-system. The dominant group utilizing this substrate is the Chironimidae. The litter from the pre-flooding period is gradually broken down and the autochthonous production of organic matter becomes more and more important. The detritus-based biomass is thus substantially reduced after 3 to 7 years. (Cairns Jr. 1992)

What are the effects of fluctuating water levels on plants? Mudflat emergents are prolific seed-bearers, but the seeds apparently lose their viability if flooded continuously for several years. Their seeds provide valuable wildlife food and when dead they offer an ideal environment for many invertebrates that feed on micro-organisms that are active on decaying tissue.

Marsh emerents have difficulty in surviving through several years given fluctuating wet-dry conditions that prevail in impoundments with inadequate water. Floating leaved and submergent vegetation will be restricted to areas where pools persist. Stable water levels are required to increase this form. (Knighton 1985)

Basins with a uniform soil surface will develop monotonous vegetation despite planned drawdowns because the soil-water regime will be essentially the same over extensive contiguous areas. Interspersion can be substantially enhanced by extensive scraping and piling of soil to form small islands. (Knighton 1985)

Cattail invasion (Typha sp.) by seed will occur on mineral soil that remains poorly drained and that already has very little sedge or grass to compete.

The Drawdown

When the bottom of an impoundment is exposed after a drawdown, the organic matter deteriorates quickly and nutrients are then available for new plant growth. The drawdown process provides constantly changing conditions that concentrate prey, create habitat conditions that can be exploited by a variety of wildlife and provide soil and water conditions that promote the germination and growth of a wide variety of plants.

As the drawdown of seasonally flooded impoundments begins, the exposed mudflats start producing foods that attract waterfowl. The seeds of plants associated with wetlands can survive flooding for several months. They therefore, germinate as water recedes and moisture is at or slightly below field capacity.

Early in the season a slow draw down (2 weeks or more) produces a more diverse vegetation than a fast one. The latter produces excellent and extensive stands of similar vegetation. Late in the season a slow draw down may produce vegetation of greater diversity than a fast one. Total seed production on impoundments is higher after early drawdowns (slow or fast) but late drawdowns result in higher stem density and greater species diversity.

Two important factors that determine plant responses to moist soil manipulations are: 1. The timing of annual drawdown and 2. The stage of succession (number of years since the area was disturbed); e.g. on early successional site, if, the drawdown is early in the season, germination of *Polygonum* is stimulated. Late season drawdowns stimulate *Bidens*, *Panicum*, and *Digitaria*.

But the composition of germinating species will vary from year to year even when the drawdown dates are similar. This is due to yearly changes in seed availability, plant succession and weather. Also the composition depends on how quickly water is drained. If it takes several weeks, resulting vegetation will be different from the one following a quick drawdown.

Vegetation response is affected by the degree of soil drying (Frederickson & Taylor 1982).

Adverse weather has a lesser effect on production of naturally occurring plants because different species or groups of plants are adapted to different climatic conditions and site characteristics (water depth and degree of soil saturation); e.g. *Polygonum, Echinochloa* and *Eleocharis* are productive during wet years; *Bidens* are productive on drier sites while *Digitaria* & *Panicum* do well under more intermediate conditions.

Important seed bearing plants are *Potamogeton, Polygonum, Oryza, Sagittaria, Eleocharis, Scirpus* & *Carex.* Vegetative parts like leaves and stems also provide food. Wigeons (Anas penelope) and Gadwall (A. strepera) feed on leaves and stems of aquatic plants. *Ceratophyllum* is not a good source of food but supports quantities of invertebrates; so do *Lemna* and *Utricularia.* In some instances areas of *Xanthium strumarium* are heavily used by Shovellers (Anas clypeata). Possibly the leaf litter from such plants provides an ideal substrate for invertebrates. (Rakstad & Probst 1985)

Plants that provide habitat, energy or nutritive requirements for wildlife are considered desirable and plants that interfere with such production are considered undesirable. It appears that the latter tend to become dominant in later successional stages. Some of them however, provide excellent cover though not food.

Deeper water (>25 cm) supply grebes, coots and diving ducks with suitable habitat. Holding water levels between 5 and 25 cms provides foraging areas for herons. Reducing water levels provides habitat for shovellers, garganey and pintail. An irregular topography within an impoundment results in ideal water-depth for a variety of species.

Foods are closely associated with aquatic plant communities. For example, ducks eat soft seeds of *Digitaria, Panicum* and *Bidens.*

Diverse populations of invertebrates, reptiles and amphibians regularly occur in flooded impoundments. Due to availability of invertebrates herons, rails, even upland game birds are attracted to moist-soil sites. The largest standing biomass of invertebrates seems to occur in association with Ceratophylum. Chironomids or freshwater worms are usually the most numerous in shallowly flooded emergent wetlands or typical littoral regions of eutrophic lakes. Dipterans are the most numerous of emerging insects while mayflies and odonates are somewhat less numerous. Snails, Corixids and Amphipods may form the next aquatic group. After a draw down the abundance of invertebrates decreases and may show a rapid increase on reflooding (Reid 1985).

Birds that concentrate on sites with plants lacking food value in seasonally flooded impoundments are probably exploiting invertebrates. Basic invertebrate adaptations for temporary wetlands include rapid development, marked seasonality in life cycles and egg or pupal stages that can tolerate drought periods. Behavioral adaptations to drying conditions may include burrowing in sediments, moving towards deeper water or emigrating from the basin. Populations of molluscs are not large in impoundments if calcium and magnesium needed for shell development are low. (Reid 1985)

Hydrophyte leaf shape, structure and surface areas are related to invertebrate abundance. Higher densities of insects are associated with aquatic plants containing highly dissected leaves and many branched systems. Cattails (Typha sp.) are therefore, poor in invertebrates.

Perennial species tend to increase once an area is under moist-soil management for 4 or more years. Perennials like *Polygonum* not only produce seeds but also provide good habitat for invertebrates.

Ideal cover conditions that support rich bird fauna with maximum numbers of individuals occur when vegetation is patchy and the ratio of cover and water is about 50:50 (Weller and Frederickson 1974). Similarly a mixture of cattails, bulrushes (*Scirpus*) and wild rice (*Oryza sativa*) is seen to provide both excellent cover and food.

Reflooding

If plants have attained a height of 10 to 15 cms, reflooding does less harm. In fact *Echinochloa, Carex* & *Polygonum* respond well to shallow flooding (2-5 cms) but *Panicum, Digitaria* and *Bidens* are less tolerant. Polygonum and grasses are intolerant of complete submergence for longer than 2-3 days.

Xanthium strumarium are easily controlled by shallow floodlng. *Andropogon* can also be controlled. But flooding may stimulate growth of woody species. If the accumulation of plant litter in an impoundment becomes excessive, germination and growth of desirable plants may be reduced because of shading.

Initially waterfowl respond to areas of open water or areas with short or sparse vegetation. After several days of use they start using areas of rank or dense vegetation. Teals and pintails usually arrive first.

An irregular topography within an impoundment results in ideal depths for a variety of species. Coots dive for food and are numerous where water is about

3 cms deep. Shovellers also strain invertebrate food in waters deeper than that used by most dabbling ducks. In deeper waters pintails tip up. Wading birds use water 7-12 cms deep. Dense emergent vegetation is attractive to rails, common snipes and marsh passerines. Shorebirds require water upto 5 cms deep or mudflats. Herons prefer open water with an abundance of submerged and floating vegetation but only sparse emergent vegetation (Frederickson & Taylor 1982).

Habitat Diversity

For greatest diversity of wildlife, an interspersion of the following habitat types should be targetted: open water, emergent vegetation, wetland shrubs, flooded dead timber and adjacent edges of upland openings, shrubs and live timber (Rakstad & Probst 1985).

In areas poor in natural wetlands the creation of artificial waterbodies really means the introduction of a new type of a habitat. Fertile ground and eutrophic water will support a richer vegetation, higher production of invertebrates and generally more birds.

Dabbling ducks utilize largely the early detritus-based eco-systems, while diving ducks and grebes are more dependent on those invertebrates which colonize later and are more permanent inhabitants of the lake systems.

The predators among the invertebrates e.g. beetles Dysticidae, dragonflies Anisoptera and leaches Hirudinae are late colonizers. They and the fish species compete with waterfowl for invertebrate food.

Observations on the Ecology of the Ujni Wetland

On the basis of the theoretical framework described above, what observations can be made about the ecology of the Ujni wetland? The analysis of soil samples indicates that the soil continues to be mineral; the organic carbon contents of the soil are low. The redox potential of the soil as revealed by soil analysis is negative. The oxygen deficit has led to the appearance of hydrogen sulphide in the sediments turning the brown layer of the mud into black and dissolving the nutrients into water.

Visual observations especially during storms have shown that the reservoir receives large quantities of sediment from the surrounding agricultural fields as streams and rivulets from the catchment area drain into the reservoir. As such large amounts of organic matter must also be deposited in the lake bottom. Yet the organic content of the soil continues to be low. This probably must be due to disturbances such as grazing, agricultural operations in the submergence area and changes in hydroperiod due to inadequacy of water especially during the period.

The wetland is now in existence for over 12 years yet the detritus-based eco-system continues and autochthonous production of organic matter has probably yet to become important. This may again be due to disturbances and the harsh annual regime of flooding and drawdown. The eco-system therefore, continues to be in its initial stages when only opportunistic plant species who can tolerate the harsh regime and inadequacy of water seem to be flourishing. A varied aquatic flora has not as yet been established. Experiments in Bharatpur's famous wetland have shown that the highest number of invertebarates is associated with *Nymphoides cristata* and *Lemna sp.* and lowest with *Paspalum distichum* and *Ipomoea aquatica*, which are dominant in the Ujni wetland (Vijayan 1991).

Every year large quantities of fingerlings of carp species are released into the reservoir by the State Fisheries Department. Carp is a bottom feeding fish, and in the process disturbs the sediments leading to turbidity and low light penetration. This affects growth of plants. Carps are also accused of accelerating nutrient cycling by stirring up sediments and of destroying spawning areas of other fish (Cairns Jr. 1992). The existence of carps in the reservoir in good strength may be an additional reason for the lack of a varied flora. Soil however, must be well drained and has not given any opportunity for the spread of *Typha*.

Large areas of the basin of the reservoir partake of a uniform character which is another reason for the lack of floristic variety.

The rainfall at Bhigwan near the project site was below average during the period. 1991 was a drought year when the rainfall was only about 40% of the average rainfall. The drought affected the timetable of drawdown. The reservoir is usually flooded in August. The level of water rises by 2 metres in August over the level in July. In 1991 however, it rose by less than a metre. Between August and October 1990 the level rose by over a metre; while in 1992 during the same period the level rose by more than 2 metres. In 1991 the level in the same period rose by just about a metre. This shows that the pattern of reflooding changes but a little and is not affected by local rainfall. The drawdown period however, has varied during the 3 years of the study period. In all the 3 years the high flood level was attained in October; in 1990 the drawdown was extremely gradual, the level remaining more or less the same till February 1991 and then falling very gradually till June 1991. The drawdown was more rapid in 1991, the level falling by about a metre between October and December and then falling rapidly by about a metre every month. The pattern was similar in 1992 when again the project site witnessed a rapid draw down. In addition in June 1991 the reservoir experienced a minor flood due to heavy rainfall in the catchment area. The flood lasted for about a week before draining into the downstream area. These fluctuations in the hydro-period affected the growth and diversity of vegetation as will be seen below.

The Hydroperiod

In the man-made Ujni wetland variations in the demand for water from the downstream or command areas have resulted in varying water conditions. Indeed the degree of such fluctuations differentiates wetlands from more permanent water-bodies such as lakes. The hydroperiod thus denotes the seasonal availability of water in the wetland. As the level of water fluctuated on the project site so was the availability of water. This seasonal availability of water or hydroperiod for each sector of the project site is shown below. The table

Table 11
The Percentage Wet Area in each Month in each Sector of the Project Site

Year 1990							
Month	**Sector I**	**Sector II**	**Sector III**	**Sector IV**	**Sector V**	**Sector VI**	**Sector VII**
January	NA	NA	NA	NA	NA	NA	NA
February	NA	NA	NA	NA	NA	NA	NA
March	NA	NA	NA	NA	NA	NA	NA
April	NA	NA	NA	NA	NA	NA	NA
May	Dry	Dry	Dry	Dry	20	Dry	50
June	Dry	Dry	Dry	Dry	Dry	Dry	50
July	Dry	Dry	5	15	40	20	70
August	Dry	Dry	60	35	100	90	100
September	20	40	95	100	100	100	100
October	80	95	100	100	100	100	100
November	80	95	100	100	100	100	100
December	80	95	100	100	100	100	100
Year 1991							
January	80	95	100	100	100	100	100
February	60	80	95	95	100	100	100
March	30	60	80	70	100	90	100
April	Dry	20	50	30	70	60	100
May	Dry	Dry	20	10	50	30	80
June	Dry	Dry	10	10	30	10	70
July	Dry	Dry	10	10	40	30	80
August	Dry	Dry	60	40	100	90	100
September	20	40	90	90	100	100	100
October	80	90	100	100	100	100	100
November	70	80	90	90	100	100	100
December	Dry	Dry	80	80	100	90	100

Year 1992							
January	Dry	Dry	60	40	90	80	100
February	Dry	Dry	20	10	80	60	80
March	Dry	Dry	5	Dry	60	40	70
April	Dry	Dry	Dry	Dry	20	10	60
May	Dry	Dry	Dry	Dry	Dry	Dry	30
June	Dry	Dry	Dry	Dry	Dry	Dry	10
July	Dry	Dry	Dry	Dry	Dry	Dry	Dry
August	Dry	Dry	Dry	5	40	20	60
September	40	60	90	90	100	100	100
October	80	90	100	100	100	100	100
November	70	80	90	90	100	100	100
December	Dry	10	80	80	100	90	100
Year 1993							
January	Dry	Dry	60	40	90	80	90
February	Dry	Dry	40	20	80	60	80
March	Dry	Dry	Dry	Dry	20	10	70

shows the percentage of area of each sector that was under water during each month of the period.

For sector I the hydroperiod extends to just 3 months from September to November. Only in 1991 it had extended to February. But the availability of water has declined in February to just 25% of what it was in October.

For sector II the hydroperiod is similar to sector I though the availability of water is somewhat higher in this sector.

For sector III the hydroperiod is 7 months, the period March to July being dry or without any availability of water.

For sector IV the hydroperiod is similar to sector III.

For sector V the hydroperiod may cover the whole year with average rainfall but may come down to 8 months in years of drought such as 1991.

For sector VI the conditions are similar to sector V.

For sector VII the hydroperiod covers the whole year; in years of drought it may come down to 11 months.

Once the hydro-periods for each sector were known, major plant community boundaries were identified on the basis of the location of the "community edge", the line beyond which the species representing the major structural components of the community were no longer dominant. This community edge approach allowed a more accurate assessment of how the species were interacting with their environment than would the use of one or several scattered individuals that could exist outside their normal habitat as a result of rare or unusual circumstances. (Duever et al 1987).

The dominant plant communities and their habitats during the period were as follows:

Dominant Plant Communities 1990

Dryland

Xanthium strumarium, Digitaria sp. Chloris barbata, Tribulus terrestris, Indigofera cordifolia, Tephrosia purpurea, Solanum xanthocarpum, Amaranthus racemosus, Setaria glauca, Eragrostis pilosa.

Wet Meadow

Ammania baccifera, Eclipta alba, Bidens spilosa, Bacopa monnieri, Digera arvensis, Sida cordifolia, Oldenlandia corymbosa, Cyanotis tuberosa, Cyperus rotundus, Cynodon dactylon, Alternanthera sessilis.

Mudflat emergents

Paspalum scrobiculatum, Polygonum glabrum, Jussiaea suffruticosa, Ipomoea carnea.

Marsh Emergents

Cyperus triceps, Cyperus pumilus, Scirpus argenteus, Asteracantha longifolia.

Floating Vegetation

Ipomoea aquatica, Najas minor, Spirodella polyrrhiza, Nitella, Chara, Hydrodictyon.

Submerged vegitation

Hydrilla verticillata, Potamogeton crispus.

Dominant Plant Communities 1991

Dryland

Solanum xanthocarpum, Tephrosia purpurea, Amaranthus spinosa, Digitaria sp., Phyllanthus simplex, Physallis minima, Indigofera cordifolia, Tribulus terrestris, Xanthium strumarium

Wet Meadow

Eclipta alba, Digera arvensis, Corchorus sp, Sida acuta, Bacopa monnieri, Cynodon dactylon, Alternanthera sessilis, Cyanotis tuberosa, Bidens spilosa.

Mudflat Emergents

Paspalum scrobiculatum, Rotalla densiflora, Polygonum glabrum, Ipomoea carnea.

Marsh Emergents

Cyperus iria, Psapalum scrobiculatum, Echinochloa colonum, Eriocaulon breviscapum, Asteracantha longifolia.

Floating Vegetation

Ipomoea aquatica, Limnophila aquatica, Potamogeton crispus, Najas minor, Chara.

Submerged Vegetation

Hydrilla verticillata, Potamogeton perfoliatus, Ceratophyllum demersum, Vallisneria spiralis.

Dominant Plant Communities 1992

Dryland

Indigofera cordifolia, Chrysopogon fulvus, Solanum nigrum, Digera murricata, Alternanthera triandra, Euphorbia parviflora, Tribulus terrestris, Xanthium strumarium, Vinca pusilla, Vicova indica.

Wet Meadow

Eclipta alba, Ammania baccifera, Cynodon dactylon, Alternanthera sessilis, Cyanotis tuberosa, Bidens spilosa, Eclipta prostrata.

Mudflat Emergents

Paspalum scrobiculatum, Ipomoea carnea, Polygonum glabrum, Jussiaea suffruticosa.

Marsh Emergents

Cyathocline purpurea, Cyperus triceps, Cyperus pumilus, Scirpus argenteus, Asteracantha longifolia.

Floating Vegetation

Ipomoea aquatica, Najas minor, Chara, Potamogeton crispus.

Submerged Vegetation

Hydrilla verticillata, Vallisneria spiralis, Potamogeton perfoliatus.

Plant Community Boundaries

The highest water level reached during the period was 496.5 m. This condition prevailed for 2 months in 1990 and only 1 month in 1991 & 1992. During this period dryland communities remained on the periphery of the project site; mudflat emergents covered about 20% of sector 1 and 10% of sector 2; marsh emergents covered the rest of the area of sectors 1, 2 & 4 and about 50% of sector 3; floating vegetation extended over the rest of sector 3 and about 30% of sector 5 and all of sector 6; the submerged vegetation extended over the rest of the project area in sectors 5 and 7.

When the level dropped to 496 m, most of sectors 1 and 2 was covered with wet meadow community, mudflat emergents were concentrated at the edges of sectors 1 and 2 and covered about 20% of sector 4 and 10% of sector 3, the rest of sector 4 and 60% of sector 3 and 50% of sector 6 were covered by marsh emergents; floating vegetation covered the rest of sectors 3 and 6 and about 50% of sector 5; the rest of the project area in sectors 5 and 7 was under submerged plants. This condition prevailed for 2 months in 1990 and 4 and 2 months respectively in 1991 and 1992.

When the level dropped to 495m., dryland communities covered most of sectors 1 and 2 and about 20% of sector 4; wet meadow plants occupied the edges of sector 1 and 2 and the rest of sector 4; they also occupied edges of sectors 3 and 6; mudflat community extended over 30% of sector 3, 20% of sector 6 and the edges of sector 5; marsh emergents covered the rest of sectors 3 and 6 and about 20% of sector 5; floating vegetation covered the rest of sector 5, the edges of sector 6 and about 30% of sector 7; the rest of the project area was under submerged plants. This condition prevailed for 1 month in 1990 and 3 months in both 1991 and 1992.

When the water level dropped to 494m., dryland communities extended over sectors 1 and 2 and most of sector 4; wet meadow plants occupied the edges of sector 4, and 50% of both sectors 3 and 6; mudflat emergents covered another 30% from each of sectors 3 and 6, and 20% of sector 5; marsh emergents could be seen in the rest of sectors 3 and 6 and another 30% of sector 5; floating vegetation was to be seen in the rest of sector 5 and 50% of sector 7; and the rest of the project site came under submerged plants. These conditions prevailed for 1 month in 1990, 4 months in 1991 and 5 in 1992.

When the level dropped below 494m., dryland communities extended over sectors 1, 2 and 4 and occupied 30% of sector 3, 20% of sector 5 and 30% of sector 6; wet meadow plants extended over the rest of sectors 5 and 6 and another 30% of sector 3; mudflat emergents occupied the edges of sectors 5 and 6 and about 10% of sector 7; marsh emergents covered about 60% of sector 7, the rest of this sector coming under floating vegetation. As the level went down further, dryland communities came to occupy most of the project area, the wet meadow communities, especially Alternanthera sessilis covering most of sector 7. These conditions prevailed for 2 months in 1990 and 4 months in 1992.

Below the water level of 493m, there was no hydro-period on the project site. Only plants that cannot stand flooding were present. In 1990 such conditions did not prevail on the project site. But at the height of summer, i.e. in June 1990, floating and submerged vegetation was absent. The hydro-period for these 2 groups was therefore, 11 months and for the rest the whole year. Dryland communities were excluded from the project site when high flood level was reached and was retained for 2 months. The hydro-period for dryland communities may be taken to be 10 months in 1990.

In 1991 the water level never fell below 493. All communities except the dryland communities were present throughout the year on the project site, having a 12-month hydro- period for them. The highest flood level was retained for 1 month in 1991 when dryland communities were absent from the PS. Therefore, their hydroperiod in 1991 was 11 months.

In 1992 dry conditions extended to 4 months (April to July) when dryland communities covered almost the whole of the PS. In April and early May wet meadow communities covered some portions of sectors 5 and 7. The hydroperiod for all the other communities was reduced to 8 months while for wet meadow communities it was 10 months. The high flood level was retained for 1 month in 1992 giving a hydroperiod of 11 months for dryland communities.

During the period only in 1991 such conditions prevailed in the area as to display maximum diversity of plant communities. In 1992 this diversity was at a minimum while 1990 was an intermediate year for plant diversity on the project site.

While submerged, floating and emergent communities can tolerate indefinitely the water-logged conditions, fen, bog and marsh communities can survive in water-logged conditions for upto 6 weeks and their tolerance of drought conditions is also low. Wet meadow plants such as *Bidens*, *Polygonum*, *Echinochloa*, *Panicum*, *Cyperus* can tolerate waterlogged conditions for 3 to 6 weeks and their tolerance of drought conditions is also good. River flood plain flora like riverside trees, willows, sedges etc. can tolerate waterlogged conditions for 6-7 hours only. (Zimmermann 1987)

The hydroperiods for different communities will be modified to a certain extent by these limits to tolerance of waterlogging and drought.

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Chapter Six

Indicators of Habitat Suitability

Ecological Conditions at Project Site during 1990-91

Normally the contact of land with water results in high biological productivity. The percentage wet area in each sector during May 1990 and March 1991 has already been noted (see Table11). It was estimated on the basis of contour lines showing water-levels at the beginning and end of each month. The driest sector during the period considered here is sector 1, which may be called the dry meadow. Sector 2 appears to be wetter than sector 1 and is therefore, called wet meadow. Sectors 3 to 7 remained under water upto 10 months and may therefore, be called wetlands. A part of the Tern Island always remained above water level when sectors 3 to 7 remained wet.

The project site was selected primarily on the basis of the observed densities of waterfowl. Even earlier observers had, recorded good densities of waterfowl near Kumbhargaon (Bharucha & Gogte 1990). When in May 1990 the site was finally decided upon impressive densities of waterfowl were witnessed throughout the month. In May only small parts of sectors 5 and 7 were wet, but these areas where water-depth was between 10 and 25 cms attracted Greater Flamingo (100 to 250), Little and Intermediate egrets (100 to 300), Glossy ibis (50 to 150), Spotbill duck (90 to 100), Blackwinged stilts (50 to 80), Pheasant-tailed jacana (50 to 70), Blacktailed godwit (50+) and Dabchik (100+) in about 6 hectares.

Obviously receding water levels had exposed the bottom areas leading to a quick deterioration of organic matter. Nutrients then became available for new plant growth which in turn stimulated growth of invertebrates in wet areas. The high densities of waterfowl indicated that the shallow water was probably replete with chironomous larvae, copepods and small fish on which flamingos feed; snails, slugs, insect larvae and worms on which blacktailed godwits and blackwinged stilts feed; fish, frogs, crustaceans on which egrets feed; shrimps & water bugs on which glossy ibis feed; insects, molluscs, and for spotbills and jacanas to congregate in some numbers, shoots and seeds of aquatic plants should also be present. At that time in areas where water-depth varied between 15 and 30 cms we had noted extensive algal mats interspersed with floating rafts of *Hydrilla*, *Chara* and *Najas*.

Towards end-May feeding densities were the highest with 400 greater flamingos, 300 glossy ibis, 150 blackwinged stilts, 70 spoonbills, 20 openbilled storks, and about 50 each of pheasant-tailed jacanas & dabchiks. But when water level was reduced further, the densities declined towards the end of June when only 85 flamingos, a few egrets and some jacanas and spotbills were present. As more and more area became dry, glossy ibis and blackwinged stilts had left and were replaced by Purple moorhens.

There must be a decline in the availability of invertebrates and small fish though not of plant seeds, especially the newly emerged Paspalum, whose seeds and shoots attracted the moorhen.

From July 1990 onwards we began keeping daily counts of certain bird species commonly occurring on the PS with the hope that they probably are the best indicators of the conditions prevailing on the PS. Also a monthly record of plants was kept and from time to time sample counts made of the crop of invertebrates.

The monthly count of birds varied between 660 (July 1990) and 7700 (January 1991) and the number of species counted from 12 to 32. The total number of plant species recorded was 128 (both terrestrial and aquatic) out of which 86 flourished between July and October 1990. There was a sudden drop in November 1990 as only 43 plants were then recorded. Obviously seasonals and annuals lay dormant. In spring there was a partial recovery when 50 species were in evidence on the site.

The reflooding began gradually in July 1990 leading to a great crop of pond-skaters (Gerris sp.) which thronged the surface and edges of newly flooded areas. The emergence of these carnivores indicated the earlier flowering of zooplanktons when the first flood waves began inundating land. The lingering numbers of egrets, the newly-arrived broods of red-wattled lapwing, and the renewed strength of dabchik probably indicated the abundance of certain types of invertebrates, frog-spawn, tadpoles and dragonfly nymphs on which these birds fed. A great crop of dragonflies towards the end of July confirmed the earlier emergence of their larvae. The water continued to be mildly alkaline with pH slightly higher than 7.

There was a sudden eruption of Cyperus species (*Cyperus iria, Cyperus pumilus* and *Cyperus rotundus*) in sector 3 as water to a depth of 15 to 30 cms inundated it. Ipomoea aquatica began invading sector 2 and Paspalum scrobiculatum which were to grow to pest proportion in 1991 started making its presence felt in sectors 4 and 5.

The dry and semi-dry areas of sectors 1 and 2 should be treated as parts of the wetland areas. Dominated by grass and sedge species, they may be important in storing nutrients and filtering out suspended materials when flows are strong (Linde 1985). They extend the edge of the wetland eco-system and should be considered a normal part of it. In September when most of sector 2 and 50% of sector 1 were inundated to a depth of 15 cms. of water, a great revival of grasses and sedges was witnessed (24 species). A corresponding crop of invertebrates could be deduced as newly arrived yellow wagtails and sandpipers began frequenting these two sectors. Common Mormon butterflies in good numbers flitted through the new growth of vegetation and numbers and variety of dragonflies had not yet diminished.

The monsoon flood revitalized fish communities and fishermen began to display huge hauls of catfish and carps whose size had not yet reached record proportions. The water level continued to rise through October when 3/4 of sector 1 was inundated at the beginning of the month. Sedges and aquatic plants such as *Setaria glauca, Eclipta alba, Ammania baccifera* and *Bacopa monnieri* grew well and attracted common and painted snipe wherever the water depth was between 10 and 15 cms. To slightly deeper waters came grey heron and woolly-necked stork that were seen to catch fish of 15 to 20 cm size in shallow waters.

As the grass and sedge communities revived around sectors 1 and 2 a great crop of grasshoppers and flying insects erupted and offered a feast to cattle egrets, swallows and drongos. In drying areas hoopoes hunted for earthworms and beetles. By the time it was November, sectors 3 to 7 were under water for more than 2 months with the depth varying from 1 to 3 metres. Where depth of water was more than 2 metres, dense aquatic communities consisting of *Hydrilla, Potamogeton, Najas* and *Chara* had formed harbouring a variety of insects such as larvae of mayfly, backswimmers, water boatmen, water strider and marsh treader. Where water was less than 1 metre deep, communities of flat worms, tube worms, shrimps, water fleas and mayflies emerged, most of the species having drought resistant eggs lying dormant during the dry season. The newly arrived migrant birds such as coots, wigeons, shovellers and shore birds such as sandpipers, greenshanks and stints throve on the invertebrates and tender shoots of aquatic plants. Coots and wigeons especially concentrated in areas colonized by the new aquatic growth. At the edges of marshy areas pond herons, and in drier areas cattle and intermediate egrets fed on grasshoppers and flying insects. In waters where depth exceeded 2 metres little cormorants hunted for fish. Towards the end of the month the numbers of spotbill duck and purple moorhen registered an increase as *Paspalum, Cyperus* and other sedges began to seed.

December saw a slight decrease in water level with a consequent decrease in densities of birds. Moderately deep waters were still dominated by rafts of coot and lesser gatherings of wigeons and shovellers. Common pochard and tufted duck began to appear in still deeper waters. The number of black headed and brownheaded gulls also registered an increase. Ruddy shelducks were to be seen at the edge of sector 3; some of them even venturing into shallower waters of sector 2. Common teals rested in sector 2 during noon while pheasant-tailed jacanas collected delicate shoots of *Ipomoea aquatica* and *Paspalum* together with invertebrates. In wet meadows and dry grass cattle egrets still outnumbered others as blackheaded munias fed on ripening sorghum in adjacent fields and throngs of rosy pastors invaded upland agriculture. The stands of *Ipomoea carnea* & *Typha angustata* reverberated with calls of great reed warblers and telegraph cables were festooned with numbers of eastern common and red-rumped swallows.

There was little change as the New Year (1991) began. We realized that Ipomoea carnea had reached pest proportions essentially in sectors 4 and 7 where large areas of Tern Island were occupied by this weed. Though it provided cover to purple herons, perching points to Marsh harrier and Great spotted eagle, we decided to remove it manually from certain places as soon as the water level began to recede.

There was a slight fall in the water level in February 1991 and a pH of 8+ was recorded in soils of sectors 1 and 2. The proportion of soil salts also recorded an increase in shallowly flooded areas. As portions began drying up in these sectors the proportion of salts declined. The pH in drying soils was between 7 and 7.5. A variety of aquatic plants was recorded in the distributory that ran along the edges of sectors 1 and 2. North-south bunds have been built in this distributory to create little pools. As water began to recede we found that these pools had harboured great numbers of bottom dwelling fish which were caught with great gusto by the local people. As the level lowered further, common snipes were attracted to the vegetation in the distributory.

As water drained out from sectors 1 and 2 a great crop of *Ammania baccifera* and *Eclipta alba* occupied the drying soil and in the distributory along with *Scirpus* we discovered Najas, *Ceratophyllum demersum*, *Spirogyra* and *Bacopa monnieri*. As grasses ripened on the edges, flocks of red munias began feeding on their seeds. In March *Acorus calamus* was planted in sector 2 and the area was reflooded with water pumped from the reservoir. The intention was to keep one area under stable water level to monitor changes in it. As water was let in flocks of yellow wagtail followed by cattle egrets invaded the field and drongos began catching flying insects. *Paspalum*, which had invaded this area when it was under water did not however, revive.

Deeper waters in sectors 6 and 7 were now occupied by tufted ducks and coots. In shallower waters of sectors 5 and 6 garganey, spotbill and a few pintail upended for food. But with open water areas shrinking due to the invasion of Paspalum, wigeon, shoveller and cotton teal had to move to deeper waters where they probably fed on invertebrates. Only purple moorhens used the Paspalum stands. In one of the clumps of *Ipomoea carnea* on the edge of sector 4 a pair of spotbill duck began nesting. When a mudflat appeared in sector 4 at the end of March, blacktailed godwits, little pratincoles, glossy ibis and sandpipers came to feed on insect larvae, worms and snails. River terns had arrived in some numbers hunting fish in deeper waters, though their breeding grounds on Tern Island were still submerged.

In April the water level continued to fall gadually freeing still more areas from water. Dragonfly nymphs were then still waiting to emerge. By mid-April there was another explosion of dragonflies. Their presence in water (as nymphs) probably made some migratory birds such as yellow wagtails, coots and sandpipers stay on. A few garganeys and gulls could also be seen in marshy and deep-water areas respectively.

But what struck one most was the increasing strength of glossy ibis and blacktailed godwit who searched for insect larvae, shrimp and water beetles and bugs in mudflats. As April ended the river terns had not yet began nesting on Tern Island and Greater flamingos had not yet arrived as there was still too much water around Tern Island where they usually fed. Among resident birds egrets and jacanas came into breeding plumage. A few moths and butterflies like Lime had emerged also.

The Lessons of 1990-91

As May dawned and the reservoir water went back to the level when the project began, a whole cycle of seasonal flooding and subsequent draw down came to an end. The study of the conditions the fluctuating water levels produced indicated that the project site lacked a varied topography. A more undulating landscape would probably offer greater variety of habitat conditions. This would break the monotony of a flat landscape and bring in patchiness of habitat as increases in avian variety were found to be related to dispersion and patchiness of habitat (Rakstad & Probst 1985). Though seasonal flooding and drawdown had increased the edge of the habitat, its effectiveness was reduced due to absence of suitable vegetation at the edge. Waterside plants, amphibious plants, surface-floating plants and emergents were absent to attract a greater variety of invertebrates and fish. The invasion of Paspalum had reduced the open water areas and the 50:50 ratio of open water to cover was not there. There was also very little vegetation like Typha and Scirpus stands that would have offered shelter to birds. Birds lacked suitable perches and areas to rest. Trees along the edge of the wet areas were also not in evidence. These would have provided not only perches but also cover and nesting sites for colonial birds. Ipomoea carnea had spread everywhere reducing the areas of the island for nesting terns and pratincoles. Though it offered shelter to a few species, it was found to be wanting in invertebrates and offered no food for terrestrial and aquatic birds.

It was therefore, decided as the project entered its second year, to try to fill up some of the lacunae perceived so far. To provide waterside vegetation, *Salix tetrasperma, Acorus calamus* and *Pandanus sp.* were planted on the boundary of sectors 2 and 3. Saplings of Salix were planted on the ground as well as in steel barrels to give them a lift if seasonal flooding began before they attained a certain height. To provide cover and rest points at the water's edge, earthen mounds were also built and Acacia nilotica saplings were planted on them. Acacia trees are ideal for colonially nesting birds, as they are thorny thereby deterring predators and produce a lot of dead twigs which birds can use for nest building.

In sectors 3 and 4 islands were built in areas normally under water to a depth of around 2 metres, as resting points for birds and small animals. Acacia nilotica saplings were planted on them as an aid to nesting. With these modifications the study of the effects of seasonal fluctuations of water level was continued.

Ecological Conditions on the PS during 1991-92

From May onwards we began keeping counts of birds occurring in each sector. Together with the recording of plants occurring on the PS, properties of soil and water in different months were analyzed by collecting samples from dry land as well as lands that were seasonally flooded. Let us now briefly describe the ecological conditions as observed during May 1991 to April 1992.

In May 1991 substantial areas of sectors 5, 6 and 7 were still under water (see table 11). There was still enough water around Tern Island to induce river terns and little pratincoles to nest. More than 50 nests of each species were counted towards May end. In rapidly drying areas in sector 3 and 5 little ringed plovers and redwattled lapwings nested while purple moorhens were nesting in stands of *Ipomoea carnea*.

Towards May end flamingos arrived too. Surprisingly the proportion of juveniles among them was as high as 40. Two adults were acting as matrons with 8 to 12 juveniles in toe with each. To the west where falling water level had helped an island to emerge, had collected another flock of flamingo and another nesting colony of terns and pratincoles had materialized.

Heavy rains at the end of the first week of June brought about a sudden flooding with most of the areas of sectors 3 to 7 inundated to a depth of 10 to 40 cms. Nests of terns and pratincoles were washed away in this outburst and the sudden rise in water level drove away flamingos, purple moorhens, ibises, storks and jacanas. The sudden flood started receding in mid-June accelerating the growth of Paspalum. Puddles left by the receding water attracted jacanas and godwits. Many insects including common species of butterflies like Plains tiger & crow emerged also. July saw the water-level lingering around 494. Though about 50% of the total area was wet, over much of this water was shallow and mud exposed at many places. The habitat was ideal for flamingos, spoonbills, ibises and jacanas to return. In Paspalum purple moorhens were numerous and spotbill ducks searched for fresh shoots of aquatic vegetation and invertebrates in water 15 to 20 cm deep. Stilts and godwits were still lingering in areas where water was about 10 cm deep.

Between beginning of July and end of August the water level rose by more than a metre and over 60% of the PS was submerged. As water level increased birds started using islands built for them in sectors 3 and 4. The emergence of flying insects continued and birds like drongo, common green bee-eater and wire-tailed and red-rumped swallows began using perches that were provided for them for hawking insects. The seasonal flooding of large areas now accelerated growth of vegetation and probably invertebrates. This was reflected in large catches of fish, especially the large shrimp or prawn (Macrobrachium rosenbergii) that were harvested by fishermen. *Paspalum scrobiculatum* began to cover water between 1 and 2 metres deep. September also saw the arrival of migrants like yellow wagtail, shoveller and osprey who fed on abundant insects, zooplankton and fish.

The highest water level was reached in October when almost the whole of sectors 1 and 2 were submerged. Terrestrial insects like ants had to take shelter on tall stems of *Paspalum* and *Cyperus* having been stranded in water. Moths, spiders, flies and grasshoppers were abundant and were predated by bluecheeked bee-eaters, egrets, lapwings and drongos. Brown field rats bred too. Dabbling ducks like garganey and pintail arrived in the shallows while wigeon, shoveller and a few common pochard resorted to deeper waters. Large submerged beds of *Hydrilla, Najas, Chara* and *Vallisneria spiralis* developed in water 2 metres deep. Shallow water in sectors 1 and 2 was so replete with invertebrates and small fish that not only little cormorant and purple and Grey heron were attracted but we even witnessed a golden oriole attempting to catch insects in water from an erected perch. Spirals of *Ipomoea aquatica* spread throughout the shallows.

There was a slight fall in water level in November and parts of sectors 1 and 2 began drying up. *Cyanotis tuberosa* and *Commelina sp.* emerged on these drying lands. In deeper water coots settled in great numbers as they arrived. A few blackheaded gulls also came. While Paspalum continued to reduce the open water area, in shallow pools of open water egrets, sandpipers and jacanas began to concentrate. In beds of *Hydrilla verticillata* we collected water beetles, shrimps, fishfry and molluscs (Hydrometra, Gerris and Lethocerus sp.). In upland areas rosy pastors began to feed on ripening grain. By December Paspalum stands had overrun sectors 3, 4 and 5. Only purple moorhens and a few passerines such as weaverbirds could use those areas. All other birds resorted to more open waters.

Huge flocks of rosy pastors found an ideal refuge in the dense growth of Ipomoea carnea on Tern island. As the habitat of dabbling ducks was reduced, so was their number. Deeper waters attracted diving ducks and a few wigeons. A small strip of mud was exposed in sector 4 immediately attracting sandpipers, little stints, blackwinged stilts, glossy ibises, river terns and pratincoles.

As water level went down further in February 1992 and land surface began drying up, Paspalum wilted and a new growth of *Cynodon dactylon* began showing up. Cattle were immediately attracted to it. Now birds concentrated near the water's edge, especially waders and dabbling ducks; while tufted duck, pochard and coot occupied open stretches of deep water. Spiders and flying insects continued to be numerous in grasslands and on the edge of upland agriculture.

In March as more and more areas began to be exposed ruddy shelducks, egrets and waders occupied shallows and mudflats and soon waves of greater flamingo arrived to join them. This year juveniles constituted only 10 p.c. of the flock. They were surrounded by blackwinged stilt, blacktailed godwit, and little ringed plovers. As the flat areas of Tern island were freed from water river terns and pratincoles flocked to them and were soon laying their eggs in fast drying up masses of algal mats. Great stretches of these mats floated on water no deeper than 30 cms. Birds avoided these stretches and were forced to open areas.

This year also the nesting of terns was unsuccessful as most of the eggs were eaten by stray dogs who crossed over to the island wading through shallow water. As April set in most of the ducks and coots left for their northern home and so were the ospreys and eagles. By the end of the month even the shallow waters that attracted flamingo, glossy ibis, blacktailed godwit, blackwinged stilt and egret had dried up. The whole project site now presented a desolate picture with all vegetation fast drying, all invertebrates shifting to deeper waters or burying themselves deep into the mud or migrating. The deep river basin did not offer areas suitable for feeding and birds had to resort to newly emerged island edges or bays and inlets of the reservoir.

As May dawned and the last year of the project began, scarcity of water emerged as the biggest problem and vegetation that was introduced on the PS had to be saved by hauling water over great distances.

Indicators of Habitat Suitability

The number of birds occurring on the PS was continued to be monitored in 1991-92. But a refinement was introduced. Birds were counted according to their daily occurrence in different sectors. The number of birds of different species seen between 8 and 9 a.m. was recorded every day in each sector. For analysis birds occurring on the project site were grouped under the following 10 headings based on their known feeding habits:

Group No.	Name of the Group	Birds included in the Group
1	Birds of Prey	Marsh Harrier, Osprey, Great Spotted Eagle
2	Upland feeders	Common myna, White-throated munia, Yellow-wattled lapwing
3	Grassland feeders	Red munia, Weaver bird, Black ibis, Blackheaded munia
4	Wetmeadow feeders	Redwattled lapwing, Cattle & Intermediate egrets, Yellow wagtail.
5	Marsh feeders	Pond heron, Purple heron, Glossy ibis, Spoonbill.
6	Mudflat feeders	Greater flamingo, Ruddy shelduck, Sandpipers and Blacktailed godwit.
7	Lily-trotters	Purple moorhen, Pheasant- tailed jacana.
8	Surface feeders	Spotbill, Cotton Teal, Pintail & Wigeon, Shoveller, Coot and Gulls.
9	Fish-eaters	Grey heron, White-necked Stork, Painted stork & River tern.
10	Divers	Dabchik, Little cormorant, Tufted duck, Common pochard.

Let us now consider how these birds occurred in different sectors during 1991-92. The percent occurrence of the groups of birds in sectors 1 to 7 will now be considered. This information is given in Table 12.

If the proportion of birds occurring in different sectors is examined, it appears to bear a close relation to the proportion of wet area in different months in different sectors. No birds could be recorded in sectors I and II in March and April 1992 when these sectors were fully dry. In February when the process of drying had already begun, only grassland feeders were attracted to this area. In Sectors III to VII which are wetter than sectors I and II and can be called wetlands, the numbers of birds were seen to fluctuate with the water level. When large portions of these sectors became dry, birds concentrated in wet areas or on the edges of wet and dry areas. Obviously different groups of birds were using the PS in different ways and might find the conditions on the PS attractive at different times. But is there a time when most groups of birds found the conditions on the PS attractive? We may then probably be justified in assuming that the situation on the PS at that particular time be called optimal condition for the groups of birds considered here.

Let us be very clear what assumptions we are making. These are: 1. that wildlife habitat can be expressed as a numerical index that reflects biotic and

Table 12
Percent Occurrence of Groups of Birds in Different Sectors during 1991-92

Sector I: Dry Meadow (Area 0.49 ha.)										
Month	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**	**Group 10**
May 1991	0	59.0	2.2	38.6	0	0	0	0	0	0
June	0	12.6	61.5	14.7	0	11.0	0	0	0	0
July	0	10.2	56.2	33.5	0	0	0	0	0	0
August	0	6.4	0	93.5	0	0	0	0	0	0
September	0	0	35.0	32.1	3.6	0	13.1	1.5	0	14.4
October	2.6	0	19.1	27.4	7.6	22.2	13.47	7.7	0	0
November	4.0	0	19.7	7.3	8.6	15.3	34.2	7.4	1.0	8.6
December	0	38.3	7.4	47.0	6.3	0	0	0.7	0	0
January 92	5.4	0	81.1	13.4	0	0	0	0	0	0
February	0	0	99.9	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0
Sector II: Wet Meadow (Area 0.19 ha.)										
Month	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**	**Group 10**
May 1991	0	26.6	45.2	28.0	0	0	0	0	0	0
June	0	17.3	77.8	0	0	0	0	0	4.8	0
July	0	0	80.9	14.4	0	0	0	0	4.5	0
August	0	7.6	20.5	71.7	0	0	0	0	0	0
September	0	0	54.4	18.3	0	5.4	0	19.1	2.5	0
October	4.4	0	34.9	8.8	10.4	0	12.5	13.9	14.8	0
November	3.5	0	28.6	9.2	24.4	12.0	4.8	15.5	9.7	1.9
December	0	0	51.5	46.4	0	0	0	0	2.0	0
January 92	0	0	99.9	0	0	0	0	0	0	0
February	0	0	99.9	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0

Sector III: Wetland (Area 6 ha.)										
Month	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10
May 1991	0	0	2.2	40.7	27.5	5.9	18.6	3.2	1.4	0
June	0	0	2.8	43.6	9.9	5.4	34.3	3.1	0.6	0
July	0	0.1	8.4	27.7	4.3	16.1	39.9	0	3.1	0
August	0	0.3	3.1	25.1	5.7	7.7	41.1	10.3	6.2	0
September	1.2	0	3.8	5.7	1.2	3.3	33.2	40.4	10.8	0
October	2.5	0	0	0	5.6	0	13.9	65.6	0	12.1
November	0.7	0	0	0	15.0	0	16.7	65.8	0	1.5
December	0	0	0.3	5.2	16.1	0	20.1	56.1	1.8	0.2
January 92	0	0	1.1	5.4	32.3	4.5	27.7	25.2	1.6	0.6
February	1.4	0	1.3	14.0	8.6	37.6	19.0	15.3	2.4	0
March	0.9	0	0.7	14.5	26.9	22.4	14.1	15.2	1.5	3.3
April	2.3	0	18.6	12.7	19.1	16.8	20.1	3.9	6.1	0

Sector IV: Wet Meadow (Area 3 ha.)										
Month	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10
May 1991	0	11.0	53.6	27.0	0	8.3	0	0	0	0
June	0	0	9.0	52.3	11.1	4.1	19.1	4.1	0	0
July	0	0.3	13.1	44.5	0	3.6	33.5	0	4.7	0
August	0	0	5.1	24.0	2.7	6.0	40.0	18.4	2.8	0
September	0	0	0	0	0	0	0	82.7	0	17.2
October	0	0	0	0	6.1	0	0	73.7	5.7	14.3
November	1	0	0	0	14.1	0	14.2	67.7	0	2.7
December	0	0	0	0	20.9	0	20.3	55.3	1.7	0.9
January 92	1.3	0	1.6	7.7	30.1	7.7	19.2	26.7	5.4	0
February	1.7	0	0	96.4	0	0	0	0	1.7	0
March	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0

Sector V: Wetland (Area 4.5 ha.)										
Month	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10
May 1991	0	0	1.9	12.5	27.1	8.1	37.6	10.4	2.0	0
June	0	0	1.8	21.5	12.6	17.1	39.3	6.3	1.1	0
July	0	0	2.8	12.7	6.5	9.2	49.0	10.3	9.0	0
August	0	0	2.7	16.4	7.3	0	27.3	39.8	2.4	3.8
September	0	0	0	0	0	0	0	76.9	0	23.3
October	0.8	0	0	0	8.2	0	3.6	80.5	0	6.6
November	0.8	0	0	0	9.7	0	10.5	76.2	0	2.5
December	0	0	0	0	10.6	0	12.3	75.0	1.3	0
January 92	0	0	0	3.1	15.6	28.5	0	51.2	1.4	0
February	0	0	0	10.1	15.3	8.0	32.0	31.0	3.3	0
March	0	0	0.8	8.5	29.5	18.1	16.6	21.9	1.6	2.5
April	1.4	0	15.7	11.2	24.8	19.8	24.3	0	2.5	0

Sector VI: Wetland (Area 4 ha.)										
Month	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**	**Group 10**
May 1991	0	0	0	0	20.0	0	52.3	23.1	4.3	0
June	0	0	0	26.9	11.7	18.0	30.4	4.3	0.2	8.1
July	0	0	0	0	11.0	10.1	2.2	40.6	7.7	28.1
August	0	0	0	0	0	0	1.0	82.8	0	16.0
September	0	0	0	0	0	5.3	0	76.0	0	18.5
October	1.2	0	0	0	8.6	0	2.1	81.3	0.7	5.8
November	0.8	0	0	0	8.5	0	0	89.1	0	1.5
December	0.5	0	0	0	9.1	0	1.5	88.3	0.6	0
January 92	0.3	0	0	0.1	1.5	0	0	96.6	0.1	1.5
February	0	0	0	0.7	4.3	0.2	0.5	91.4	0.1	2.7
March	0	0	0	2.5	21.5	22.2	11.0	38.0	1.0	3.6
April	0	0	0	9.0	26.5	36.9	27.4	0	0	0
Sector VII: Wetland (Area 2.5 ha.)										
Month	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**	**Group 10**
May 1991	0	0	0	16.8	24.3	10.9	40.2	5.4	2.9	0
June	0	0	1.2	26.6	17.2	21.9	24.5	0	0.7	7.6
July	0	0	0.7	2.3	9.9	22.7	37.7	7.8	6.3	12.3
August	0	0	0	20.0	8.1	0	0	71.8	0	0
September	0	0	0	0	0	20.9	0	72.9	4.1	1.9
October	1.4	0	0	0	7.3	0	0	87.3	1.4	1.7
November	1.0	0	0	0	12.9	0.9	1.2	84.0	0	0
December	0.4	0	0	0	7.3	0	1.3	87.8	0.7	0
January 92	0	0	0	0	0.9	0	0	97.5	0	1.6
February	0	0	0	1.2	3.5	0.6	0.4	89.8	2.0	2.7
March	0.3	0	0.4	0.3	20.3	8.5	6.5	31.0	18.8	2.1
April	0	0	1.5	5.4	14.2	22.4	14.2	8.4	33.3	0

abiotic conditions associated with a given wetland; 2. that habitat numerical scores give a general indication of habitat carrying capacity and 3. populations of birds indicate generally the habitat quality. Habitat suitability indices then are generally thought to express the relation:

$$\text{Habitat Quality Index} = \frac{\text{Populations associated with current habitat conditions}}{\text{Populations associated with optimal habitat conditions (Williams 1985)}}$$

Let us now find out when the optimal habitat conditions prevailed on the project site, i.e. when the highest densities of groups of birds considered here occurred on the project site. This information is given in Table 13.

The numbers in the table refer to the groups in which the birds occurring on the PS have been divided. A look at the table shows that during October 1991 such conditions prevailed on the PS as to attract the highest densities of as many as 11 groups of birds in different sectors. It may therefore, be assumed that conditions in October 1991 were optimal for the groups of birds being considered here. If we assign an index value of 10 to conditions prevailing in October, a habitat quality index can be calculated for conditions obtaining in other months of the year. This information is given in Table 14.

The lowest index value of 0.9 for March 1992 perhaps shows the minimum conditions required for the survival of groups of birds on the project site. It appears that the conditions prevailing on the PS during May 1991, October 1991 and April 1992 were optimum or nearer to optimum. Let us now see what these conditions were: In October 1991 the highest water level was reached and the sectors 2 to 7 were fully wet. Only a small part of sector 1 was dry. We do not

Table 13
The Highest Densities of Groups of Birds occurring in Different Sectors during 1991-92.

Month	Sector I	Sector II	Sector III	Sector IV	Sector V	Sector VI	Sector VII
May 91	2	2	0	2,3,6	0	7,5	7
June	0	0	4	0	4	4	4
July	0	0	0	0	7,9	9,10	6,10
August	4	0	2,7	7	0	0	0
September	6	8	9	8,10	10	0	0
October	7,9	1,7,9	1,10	9	8	1	1
November	10,5,8	5,6,10	8	0	0	0	0
December	1	4	0	0	0	0	0
January 92	1	3	5	5	0	8	8
February	3	0	6	1,4	0	0	0
March	0	0	0	0	5	0	0
April	0	0	3	0	1,3,6	5,6	3,9

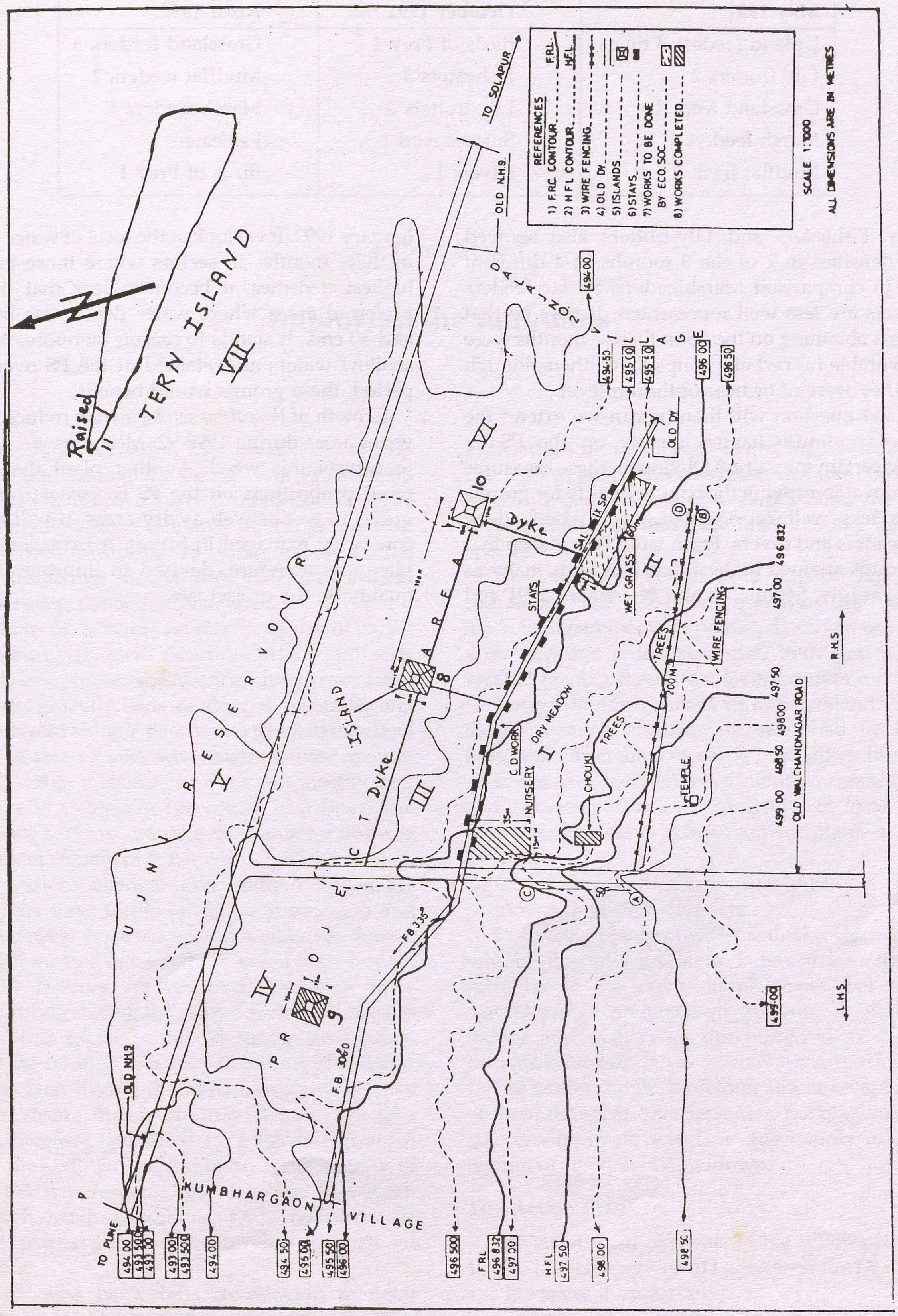
have accurate data about the proportion of open water area to covered water area for each month. But as Paspalum had not attained pest proportions in October, we may say that the open to covered water area ratio was nearer 50:50 than in any other month. The index of habitat quality went down steeply in November and December when Paspalum began to reach pest proportions. The index began to rise again when water level declined, Paspalum wilted and mud was exposed.

Let us now look at the habitat quality index of May, October and April a little more closely. In these months the following groups of birds recorded the highest density:

In each month only 5 of the 10 groups had attained highest densities. When only 17% of the total area was wet, as in May '91 and April '92, it is no wonder that upland, grassland and mudflat feeders showed highest

Table 14
The Densities of Groups of Birds and the Habitat Quality Index in Different Months

Month	No. of Groups with Highest Density	Habitat Quality Index
May 91	8	7.2
June	4	3.6
July	6	5.4
August	4	3.6
September	6	5.4
October	11	10.0
November	7	6.3
December	2	1.8
January 92	6	5.4
February	4	3.6
March	1	0.9
April	8	7.2


TERN ISLAND
VII
Raised
UJNI RESERVOIR
V
IV
PROJECT AREA
III
VI
C T Dyke
ISLAND
8
9
10
Dyke
I
II
DRY MEADOW
WET GRASS
NURSERY
C D WORK
STAYS
CHOUKI
TREES
TEMPLE
WIRE FENCING
200 M
OLD NH 9
OLD N.H.9.
TO PUNE
TO SOLAPUR
KUMBHARGAON VILLAGE
DALAJ NO 2 VILLAGE
OLD DY
OLD WALCHANDNAGAR ROAD
F.B 30
F.B 335°
F.R.L
H.F.L
494.00
493.500
493.00
494.50
495.00
495.50
496.00
496.500
496.832
497.00
497.50
498.00
498.50
499.00
498.00
494.50
495.10
496.50
LHS
RHS
REFERENCES
1) F.R.C. CONTOUR
2) H F L CONTOUR
3) WIRE FENCING
4) OLD DY
5) ISLANDS
6) STAYS
7) WORKS TO BE DONE BY ECO. SOC.
8) WORKS COMPLETED
SCALE 1:1000
ALL DIMENSIONS ARE IN METRES

May 1991	October 1991	April 1992
Upland feeders 3 times	Birds of Prey 4	Grassland feeders 3
Lily trotters 2	Fisheaters 3	Mudflat feeders 2
Grassland feed. 1	Lily-trotters 2	Marsh feeders 1
Marsh feeders 1	Surface feed 1	Fisheaters 1
Mudflat feed. 1	Divers 1	Birds of Prey 1

densities. Fisheaters and Lily-trotters also showed highest densities in 2 of the 3 months in 4 different sectors. In comparison Marshfeeders, Surfacefeeders and Divers are less well represented. It may be that conditions obtaining on the PS in these 3 months were more favorable for certain groups than others, though overall they were at or near optimum level.

The next question will then be can we extend the period of optimum habitat quality on the PS by adopting certain measures? Obviously these measures should aim at improving the habitat quality for groups that are less well represented, i.e. marshfeeders, surfacefeeders and divers. From table 14 it is seen that these groups attained highest densities in as many as 2 sectors in July, September and November 1991 and January 1992. If we look at the level of water prevailing in these months, in sectors where those groups had highest densities, it becomes clear that these birds preferred areas where water depth was between 10 and 30 cms. It stands to reason therefore, that if such shallow waters are retained at the PS over a longer period, these groups would benefit.

Growth of *Paspalum scrobiculatum* reduced the open water areas during 1990-92. Measures were necessary to control this weed. Another plant that grows to weed proportions on the PS is *Ipomoea carnea*. As it grows in wet as well as dry areas, it will have to be constantly managed in future. A management action plan was therefore, devised to improve the habitat quality on the project site.

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Chapter Seven

Improving the Indicators

The preceding discussion has already thrown up the reasons underlining the necessity of drawing up an action plan to improve the conditions prevailing on the PS. The constituent elements of the action plan have also been indicated to some extent in the preceding discussion. Let us now recapitulate these before describing the action plan itself.

The course of a river usually presents a varied habitat pattern, viz. swift flowing current and calm bays and inlets; ripples and rapids; midstream rocks and barriers; gravelly beds & alluvial substrate; and sandy banks and shingle beaches. A great diversity of life forms is able to take advantage of these various habitats. There is a change in the basin morphology when a lake is created in the course of a river. The topographical features are drowned under a more or less permanent column of water with a uniform surface. The flow pattern changes and sudden floods are absorbed. The most fertile lands are submerged and uplands that never experienced floods and drawdowns, are either submerged or form the edges of the reservoir.

The flow regimes are reversed. Formerly flows used to be strong during the rainy season; and used to be reduced to a trickle as the dry season progressed. Now with the creation of a lake, floods are stored and flows minimized during the rainy season; while they tend to be strong during the dry season. The lake region is therefore, subjected to a harsh regime of flood and draw down leading to an acute scarcity of water in the dry season. Very few life forms can tolerate such harsh conditions. Only opportunistic species of plants are able to survive in such an environment.

A varied seed bank fails to develop in such conditions in the lake region. Moreover, human induced disturbances such as grazing, agriculture and fire tend to keep the eco-system in early successional stages. In the absence of a varied flora, the crop of invertebrates also becomes devoid of late colonizing species.

The lake often serves as a trap or sink for the sediments. The release of nutrients from sediment leads to algal blooms depleting dissolved oxygen and with negative redox potential, hydrogen sulfide is created turning the brown layer on the mud black.

The riverine fish decline in numbers and variety as their spawning grounds are swamped by loads of sediments. Fish such as carps brought in from exotic river-systems, recycle the sediments, increase turbidity and adversely affect the spawning of local fish. As penetration of light declines, aquatic plants are unable to survive.

A monotonous, uniform substrate of a lake also precludes biological diversity.

By making plenty of water available during the dry season, the lake tends to intensify certain human activities to the exclusion of others. For example, agriculture is preferred to growing of timber and fodder and cash crops are preferred to crops that provide biomass.

The action should therefore, aim at reversing some of these trends and/or lessening the harshness of the lake environment, which is due mainly to a severe regime of flood and drawdown.

The Action Plan

The constituent elements of the action plan are:

1. To launch a mosaic of habitats on the PS to replace the present uniformity;
2. To lessen the severity of conditions created by the

annual flood and drawdown;

3. To attempt to increase usable biomass by encouraging production of fodder, timber and other useful biological produce;
4. To provide conditions in which riverine fish will be able to spawn and waterfowl to breed;
5. To provide conditions in which birds that use marshes, mudflats and shallow water will be able to sustain themselves.

The Details of the Plan

A mosaic of following habitats was initiated on the PS: Trees & shrubs; Grassland; Wet meadow; Waterside vegetation; Marsh vegetation; Pools of calm water; Islands and Open water.

A series of dykes connecting islands and the edges of the reservoir were planned. These dykes would help to hold water in pools lengthening the hydroperiod on the PS.

The dykes would break the monotony of the landscape and together with islands provide perches and resting places for invertebrates and birds and a refuge for waterside aquatic and amphibious vegetation.

Trees were to be planted on islands to provide future nesting places for waterfowl.

Salix tetrasperma were to be planted on the borders of sectors 2 and 3 to provide waterside trees as shelter for birds; their floating and submerged roots expected to provide refuge and anchoring places for fish and invertebrates; their leaf fall to add organic matter to the water and food for fish; their wood to be available for a variety of uses. By planting them in steel barrels they were given a lift to save them from complete submergence during high floods.

1 metre x 1/2 m. x 1/2 m. earthen mounds to be set up along the banks of the distributory. They were to be planted with trees, grasses and sedges to lessen the impact of flood waves and wind generated waves; control bank erosion and provide shelter & refuge for invertebrates, fish and birds.

Useful marsh plants like *Nymphea* and *Nelumbo* species to be introduced in the distributory for future spread on the PS.

A part of the sector 2 to be planted with useful grasses and aquatic plants like *Pennisetum* and *Acorus calamus*; with water pumped in from the reservoir, this part to be maintained as a wet meadow to further lessen the scarcity of water on the PS and help broaden the biological base.

A part of sector 1 to be planted with good fodder grasses such as *Cynodon dactylon* and *Senchrus celearis*.

The remaining part of sector 1 to be planted with such useful shrubs as *Aloe sp.*, *Agave sissalana*, *Psoralea orylifolia*. Trees to be planted in this part to include *Azadirachta indica, Tamarindus indicus, Ficus inornata, Cassia fistula, Cassia siamea, Parkea biglandulosa, Casurina equisetifolia, Lucaena leucocephala* and *Pongamia pinnata*. *Dendrocalamus strictus* was to be planted on the edge of the high flood level.

Perches for birds to be erected at suitable places.

The more or less even surface of the submergence area was to be broken by scraping and piling.

The area covered by *Paspalum scrobiculatum* was to be ploughed by tractor and roots etc. of the plant to be removed to control the spread of this weed. Clumps of *Ipomoea carnea* to be uprooted, physically removed and burnt to check its spread. Useful species of grasses and sedges to be planted in its place. The accompanying figure illustrates the various measures taken on the PS.

Implementation

The implementation really began when an experiment of creating small pools by placing dykes at intervals in the old distributory was tried. In the spring of 1991 when the water began to recede these pools produced a record catch of riverine bottom-dwelling fish.

In the summer of 1991 mounds along the banks of the distributory were raised and planted with *Pennisetum sp.* and *Acacia nilotica* saplings. Islands in sectors 3 and 4 were raised at the beginning of the 1991 monsoon and trees and grasses planted on them. From August to December these islands were surrounded by water & were used by purple moorhens, black ibis, spotbill, redwattled lapwing, whitenecked stork and marsh harrier for resting, perching and feeding.

Due to a rapid drawdown through winter and spring of 1991 and 1992 respectively, water scarcity was felt on the PS early in the season and planted trees, bushes and grasses had to be irrigated by pumping water from the reservoir. The harsh conditions favoured opportunistic species like *Paspalum*, which spread like wildfire through sectors 3, 4 and 6 at the end of 1991.

When water level receded further and submerged areas became dry in the summer of 1992, portions covered by Paspalum were ploughed and burnt. The rootstalks of the grass were hand collected and destroyed.

Dykes connecting islands in sectors 3, 4 and 6 were constructed in May & June 1992 creating pools over a total area of 1.2 ha. The substrates of the pools were made uneven by scraping and piling.

A portion of the Tern Island where *Ipomoea carnea* thickets had grown was cleared of this weed and its height raised by 2.5 metres to create a broad mound.

Just before the break of the monsoon in 1992 and before the waves of the first flood hit the PS, all elements of the action plan were in place on the project site.

The remaining part of the project period (September 1992 to March 1993) was spent in observing and monitoring the effects of the changes the action plan had brought about on the PS.

Monitoring the Action Plan

The period May to July 1992 was exceptionally dry on the PS. The water level continued to be between 491 m. and 492 m., much below the level prevailing during the same period in 1990 and 1991. Even dryland communities of plants found it difficult to survive in sectors 1 and 2 which were seldom visited by any bird. Sectors 3 and 4 had been ploughed to control Paspalum. A part of sector 6 was also ploughed. The rest of the project area was dry too with extensive growth of *Alternanthera sessilis* which the cattle did not eat. Thousands of shells of molluscs of all sizes littered this area. Birds had retreated to the original river channel on whose banks a number of spoonbills, painted storks and a few greater flamingos had gathered.

The prolonged drought had affected the vegetation introduced on the PS. The vegetation could survive because it was irrigated by bringing water from a great distance at considerable expense.

Though there was some rain in July and August (see Table 6), the water level remained more or less the same till the middle of August. It rose by almost 3 metres between the middle of August and August end. Sectors 5,6 and 7 were then inundated. Then a curious thing happened.

A Government Resolution of the Revenue and Forest Departments of Govt. of Maharashtra issued in 1990 suddenly became a point of dispute. The GR demarcated the area of the proposed bird sanctuary on the Ujni reservoir. As the GR listed definite areas from each village to be included in the sanctuary, the villagers assumed that the Govt. will eventually acquire these areas for the sanctuary and they would again lose their lands as they did when the reservoir came into being. A great public agitation took shape against the idea of a bird sanctuary. This Project which also dealt with birds also came under attack and the demonstrators damaged trees and saplings and prevented the project staff from carrying out their duties.

The monitoring therefore had to be restricted to recording daily bird counts and some desultory collection of plants. The project staff could get no protection from the Government. We organized village meetings and tried to explain the aims and working of the project. We clarified our view that no land needed to be acquired for the proposed bird sanctuary. The villagers however, refused to be convinced. The Govt. then struck down the GR and the Chief Minister announced the abrogation of the decision to create a bird sanctuary on the reservoir. Even then the villagers continued their opposition to the project and would not allow the project staff to continue the work. The situation continued till the end of March 1993 when the project period came to an end and all equipment from the project site was withdrawn except the watchman's shed.

The dominant plant communities during the period had already been alluded to. Let us now analyze the occurrence of groups of birds during the period April 1992 to March 1993. This information is given in Table 15.

As the table shows the absence of any wet area during May-July 1992 precluded most of the bird groups from sector 1 and 2.

In April wet meadow conditions still prevailed in sector III which was later divided into 3 sub-sectors: - 3A opposite sector 1; 3B between 3A and the old Solapur road (see map); and 3C opposite sector 2. The birds concentrated mainly in sector 3A while 3B and 3C failed to attract any birds till August.

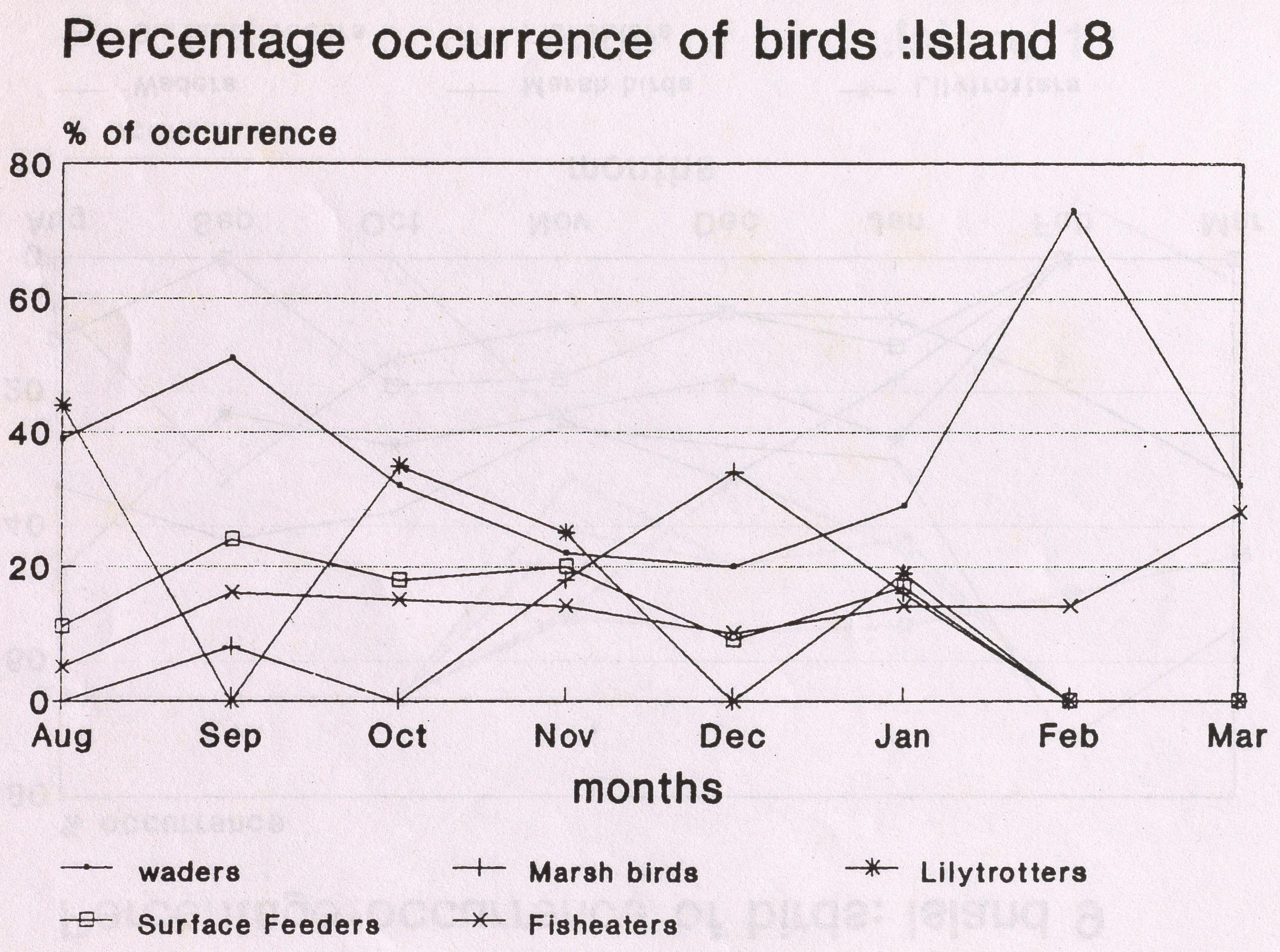
Showers in July and August and a sudden rise in the water level towards August-end, terminated the drought on the PS. The fresh growth of grass in sector 1 and 2 and rainwater puddles in the distributory attracted grassland and wet meadow birds and even a few fish-eaters. Similar conditions prevailed almost all over the project area with grassland and wet meadow birds predominating all over the PS.

Near full reservoir level conditions prevailed on the PS in September 1992. As portions of sector 1 and 2 were under shallow water, they witnessed a fresh growth of *Ipomoea aquatica* and grasses and sedges that attracted lily-trotters, wet meadow and grassland birds. Similar conditions prevailed in sector 4. The dyked portions of sectors 3 A and C gave rise to shallow pools which were immediately taken over by surface feeders like spotbills. These pools also attracted fisheaters. Shallow waters in sectors 5, 6 and 7 also attracted these two groups. As aquatic vegetation was not yet developed, these two groups must be feeding on invertebrates brought in with the new flood and fish.

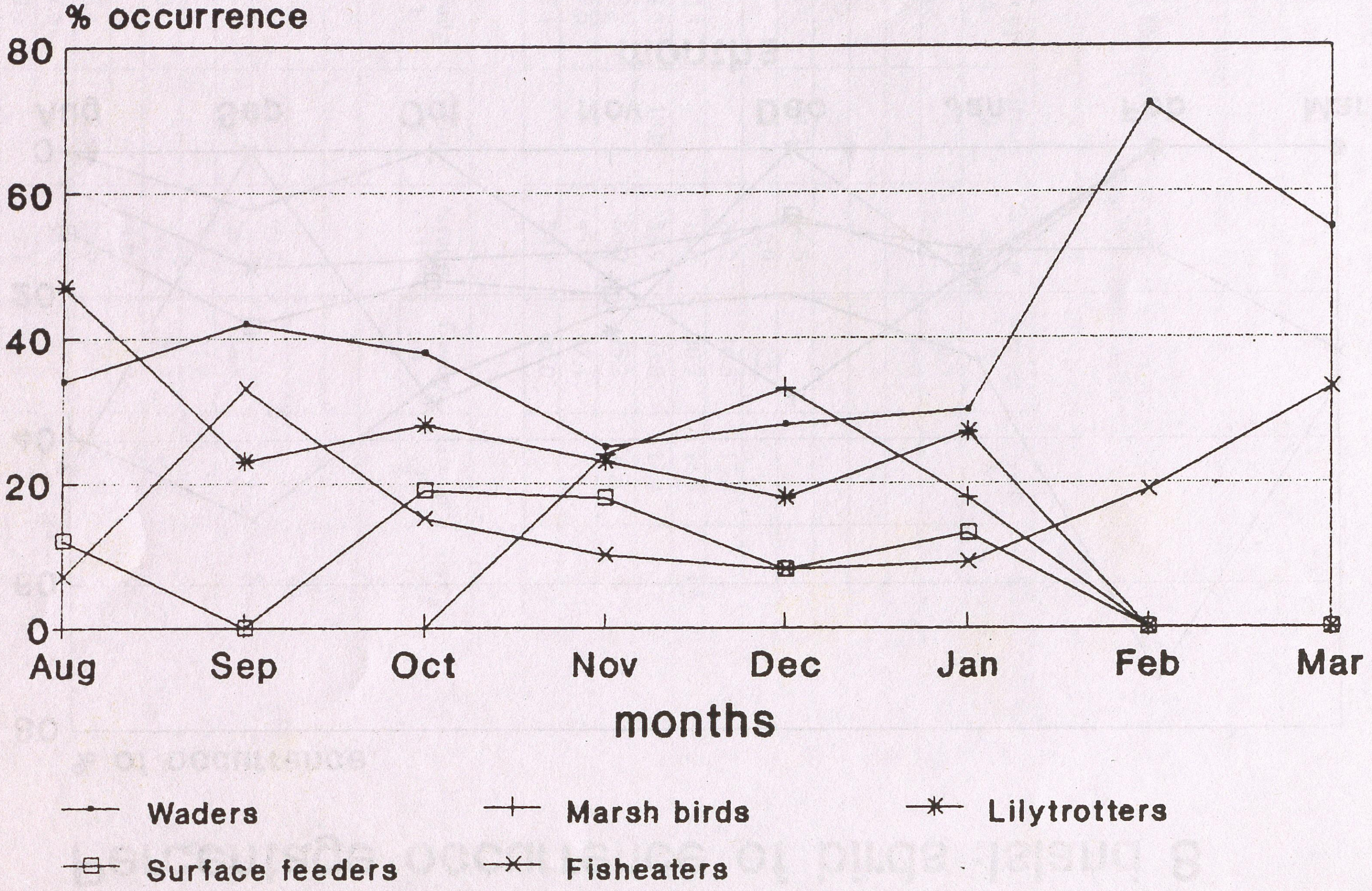
The highest flood level was reached in October 1992, when most of the PS was wet. Even sectors 1 and 2 attracted marshfeeders, lily-trotters and fish-eaters. In the rest of the project area surface feeders dominated almost to the exclusion of other groups. From November onwards the water level recorded a fall similar to the one in 1991. The situation changed but a little in November in sectors 1 and 2. But in other sectors, with the arrival of migrant birds, marshbirds began to compete with surface-feeders. Only in sector 4 lily-trotters were more numerous than marshbirds. A further fall in the water level in December did not change the situation.

Table 15
The Occurrence of Groups of Birds on the Project Site in Different Sectors during the Period April 1992 to March 1993.

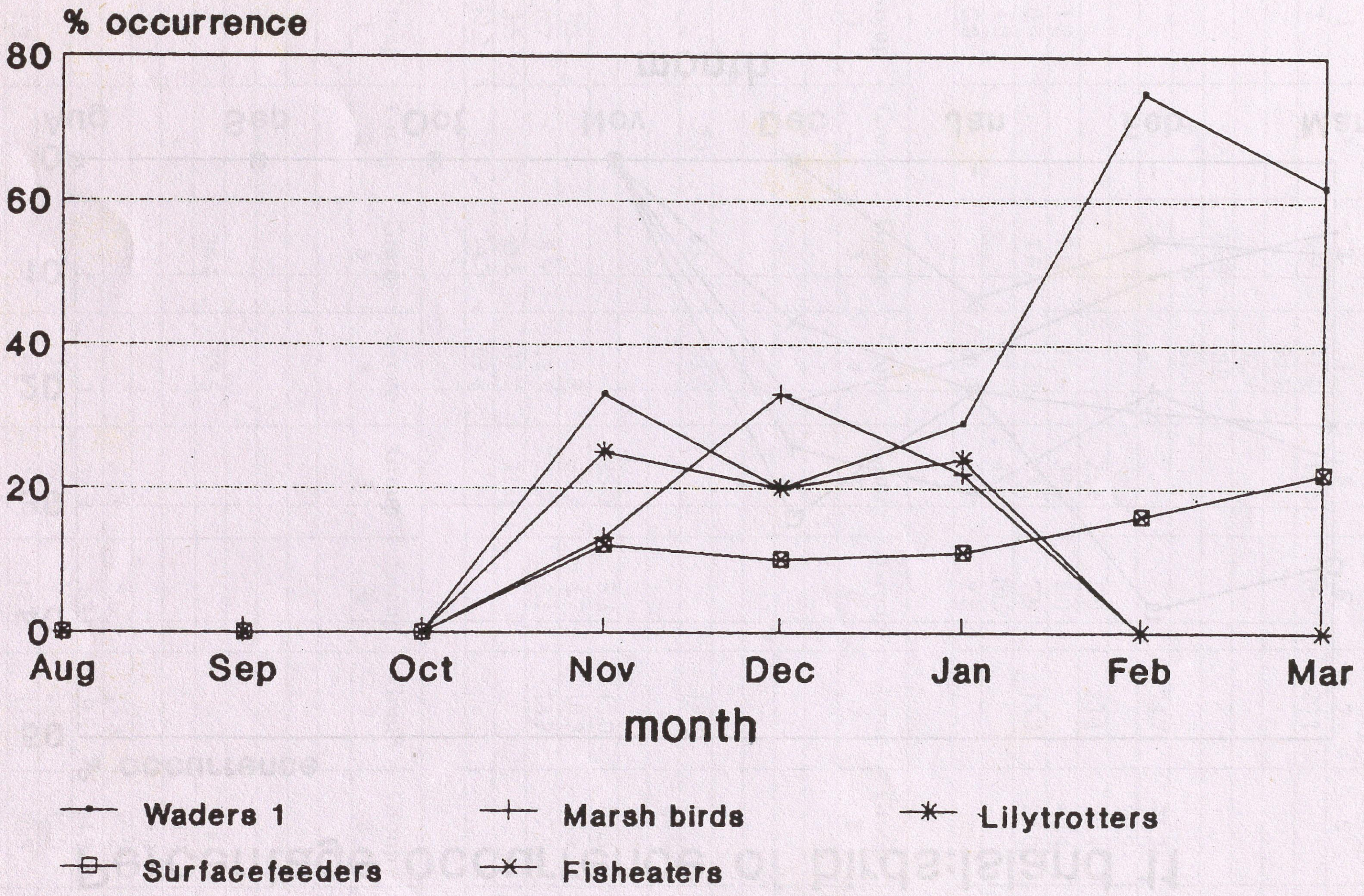
Sector I									
Month	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**
April				99.9					
May				99.9					
June									
July									
August		14.2	66.5						19
September			30.9	6.3			42.6	8.4	11.5
October			24.2	16.5	15.8		21.5		11.3
November	0.3		18.0	30.7	14.9	4.4		5.1	6.0
December	4.2	13.0	33.9	33.8	13.4				1.2
January 93	3.7		60.0	25.2	6.7				
February	7.5		45.0	47.4					
March	8.4		50.9	40.0					
Sector II									
Month	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**
April									
May									
June									
July			99.9						
August		7.1	28.4	56.8					7.5
September			7.2	31.8			34.7	10.0	15.9
October	0.6		5.4	59.2	16.4		17.5	7.2	12.4
November			4.0	32.9	37.7	5.2	6.5		12.9
December	3.8	12.3	26.0	27.0	19.7				10.9
January	7.4		55.0	37.4					
February	9.9		37.1	52.8					
March	8.2		57.5	34.0					


Percentage occurrence of birds :Island 8
% of occurrence
80
60
40
20
0
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
months
waders
Marsh birds
Lilytrotters
Surface Feeders
Fisheaters

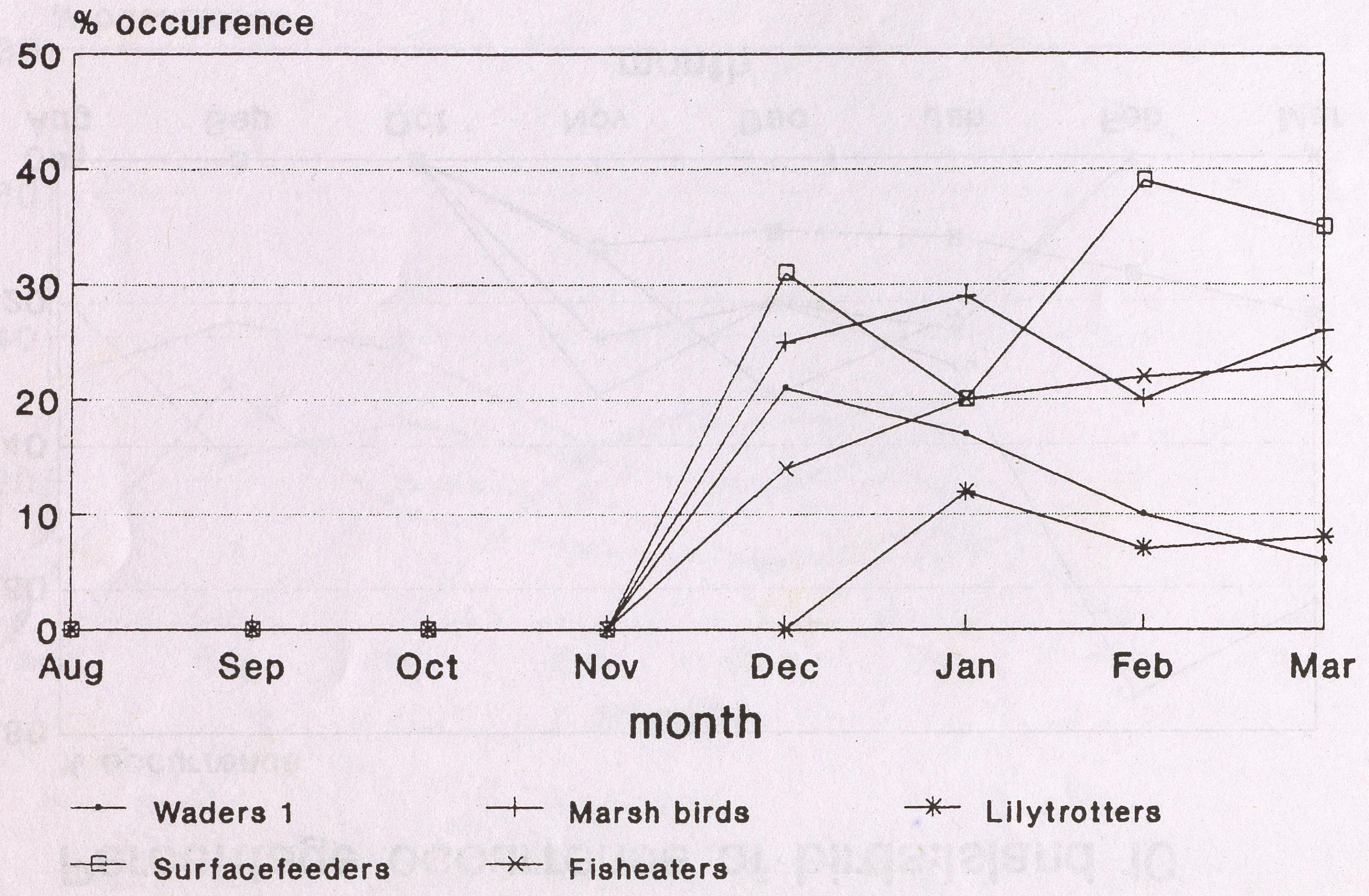
Percentage occurrence of birds: Island 9



Percentage occurrence of birds:Island 10



Percentage occurrence of birds:Island 11



Sector III A

Month	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
April	2.3		4.9	31.2	19.0	16.7	20.1		6.1
May				94.1					5.6
June				82.9					16.9
July		5.7	85.9	8.2					
August		6.2	17.2	61.4					15.0
September							24.7	75.2	
October								99.9	
November					25.6	5.0	23.1	38.4	7.3
December	1.2		2.6	12.8	35.0	2.0		40.4	5.4
January 93	0.9		1.6	12.3	33.1	7.9	15.4	24.0	3.8
February	4.0			37.2	42.4	10.7			5.4
March	0.8			41.0	54.0	2.8			1.1

Sector IIIB

Month	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
April									
May									
June									
July									
August		7.1	33.1	33.6			19.2		6.7
September								99.9	
October								99.9	
November					33.0	5.3	13.0	42.3	5.9
December	1.3			16.8	33.4	4.7	10.3	28.4	4.7
January 93	0.7		5.5	11.1	29.7	7.1	13.7	27.5	4.0
February	3.5		43.8	37.7	11.0				3.6
March	12.2		14.7	69.4	2.4				0.8

Sector IIIC

Month	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
April									
May									
June									
July									
August			38.4	53.5				7.8	
September								99.9	
October								99.9	
November	1.1				34.3	5.6	13.8	39.2	6.6
December					32.5	1.3	9.8	54.9	1.1
January 93				2.9	24.3	7.1	15.5	47.0	2.6
February	1.2			8.2	24.9	17.4	11.0	30.5	6.9
March	1.6		5.4	15.5	25.3	16.3	2.6	27.5	5.7

Sector IV

Month	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
April									
May									
June				99.9					
July									
August		9.3	26.9	33.8	11.1			10.3	3.7
September							68.9	30.9	
October								99.9	
November					24.4	2.9	31.9	40.6	
December	1.4		1.4	2.7	31.2	2.0	18.9	37.2	4.3
January 93			5.2	23.2	34.3	3.0	3.8	24.9	4.2
February	6.3			73.6		7.8			12.0
March	13.5			68.2					17.9

Sector V

Month	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
April	1.4		2.8	24.0	24.7	19.8	24.2		2.7
May				91.4					8.5
June				92.9					7.0
July			45.1	54.8					
August		17.7	35.2	33.6	6.0			5.5	1.5
September								66.6	33.6
October								99.9	
November					31.7	3.1	11.6	52.0	1.0
December					31.9	2.8	9.1	55.8	1.0
January					24.9		5.1	62.5	7.1
February	1.3			1.6	26.5	13.4	11.8	36.2	8.3
March	1.6			2.1	24.7	12.5	20.1	31.2	7.7

Sector VI

Month	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
April				8.9	26.4	36.9	27.4		
May				27.2	8.1	52.9			11.3
June				77.4		5.9		7.1	9.4
July			2.5	40.7	25.7	24.9			5.6
August		14.2	41.6	35.6				5.7	2.5
September								95.9	3.6
October								99.9	
November					24.3	3.2	6.4	56.6	8.0
December	1.7				30.7	2.9	9.3	55.0	
January 93					22.3		7.7	51.7	7.6
February	1.0			4.3	21.3		12.6	43.8	16.0
March	1.1				19.1	6.0	8.8	51.5	13.4

Sector VII									
Month	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**
April				7.2	14.1	22.3	14.4	8.8	33.2
May				26.6		12.0		53.8	7.3
June				35.5		24.4			39.8
July			5.0	69.2		25.5			
August		17.5	33.5	27.8	2.8		7.6	6.7	5.8
September								93.4	6.5
October								99.9	
November	0.2				26.5		6.1	62.8	4.3
December	1.7				26.7		9.2	62.1	
January 93	0.7				24.1		7.0	67.6	
February	0.8				23.6	11.4	44.0	15.2	4.7
March	1.2				10.8	15.8	52.8	17.0	1.7

In January 1993 surface-feeders still dominated sectors 5, 6, 7 and marsh-feeders were more numerous in sectors 3A, 3B and 4. In sectors 1 and 2 grassland and wet meadow birds occurred in strength. The dykes appeared to be successful in enhancing the occurrence of marsh-feeders and surface-feeders on the PS.

With a further fall in the water level in February and March, wet meadow and grassland birds came to dominate sectors 1 to 4 and in the rest of the area surface-feeders and marsh-feeders still outnumbered other groups.

The islands also attracted different groups of birds. The use of islands by different groups of birds is shown in the accompanying graphs.

Let us now find out when most groups of birds found the conditions on the PS attractive. The highest densities of groups of birds in different months could indicate this. This information is given in Table 16.

The occurrence of the highest densities of birds shows that optimal conditions prevailed on the PS in August 1992 when as many as 16 groups showed high densities. Near-optimal conditions prevailed in September 1992, October 1992 and March 1993. If we compare these high densities with those prevailing in 1991-92, it appears that more groups reached highest

Table 16
The highest densities of different groups of birds in different sectors during the Period April 1992 to March 1993

Month	Sector 1	Sector 2	Sector 3A	Sector 3B	Sector 3C	Sector 4	Sector 5	Sector 6	Sector 7
April	4		6			6,7	7		
May	4		4						
June			9		4.5		4	4	9
July			3				3	6	4,6
August	2,3,9		2	2,7,9	3,4	2,3	2	2,3	2,3
September	7,8	7,8,9	7	8	8	7	9		
October	5	4	8	8	8	8	8	8	8
November	6	5,6			5				
December		2	5	5			5	1,5	1,5
January				3,6	7				
February		1	1		6,9	6		9	
March	1	3		1,4	1	1,9	1		7
(The digits in the table show the group number)									

densities in 1992-93 than in 1991-92 (34 and 27 respectively). To that extent the conditions on the PS may seem to have improved.

The habitat quality index in different months during the period under reference can now be calculated by assigning a value of 10 to conditions prevailing in August 1992. This information is given in Table 17.

The conditions prevailing in May 1992 when the lowest habitat quality index was reached, may be the minimum condition necessary for the survival of groups of birds considered here.

The habitat quality index of different months during 1992-93 does not show any improvement over the one in 1991-92 inspite of the improved position of occurrence of certain bird groups. This was probably due to the scarcity of water on the PS during 1992-93. The optimum conditions favored bird groups such as Birds of prey, Upland and Grassland birds. The quality of habitat on the PS was such as to favour these groups throughout the period. In 1991-92 Marshfeeders, Mudflatfeeders and Surfacefeeders were under-represented. In 1992-93 their representation improved but was restricted to certain months only. In this they were helped by improvement measures carried out on the PS (such as dykes, islands etc.). If water had been plentiful, as was the case in 1990-91, habitat quality index could have shown improvement. The crucial role-played by the availability of water on the PS stands therefore, re-emphasized.

Table 17

The Habitat Quality Index on the PS during April 1992 to March 1993

Month	No. of Bird Groups with Highest Density	Habitat Quality Index
April	5	3.1
May	2	1.2
June	6	3.7
July	5	3.1
August	16	10.0
September	10	6.2
October	9	5.6
November	4	2.5
December	8	5.0
January	3	1.8
February	6	3.7
March	9	5.6

The Lessons Learnt

It is possible to put to multiple uses the lake region of the river valley projects. This potential of the reservoirs should be fully utilized.

The lake region, i.e. the area between full reservoir level and maximum draw down level, should be brought under a mosaic of habitats to provide for the needs of human and non-human beings.

The mosaic of habitats should be so developed as to provide usable biomass in the form of fuel, fodder, timber and other wood; and food supplements such as fish.

At present the lake region is mainly used for cultivation. It should continue to be so used on condition that the farmers use part of the land to produce the above-mentioned usable biomass. In fact at least 50% of the lake region should be devoted to create a varied habitat pattern.

As natural wetlands decline and wetland flora suffer, an effort to conserve this flora should be made by utilizing the lake region for this purpose. A suitable wetland habitat should be included in the mosaic of habitat referred to above.

Dams across a river affect the movements of fish and other riverine animals. Fish ladders are difficult to work in Maharashtra because of paucity of water. It is therefore, necessary to help riverine fish fauna by providing them with spawning habitat and places where they can take shelter and refuge.

For this purpose it is necessary to revive riverside and flood plain vegetation (such as groves of *Acacia nilotica* and *Salix tetrasperma*) which was such a characteristic of our rivers. The lake region can be used to revive this.

It is necessary to study in depth the impact of the release of exotic fish (fish from other river systems) on the ecology of the river.

The environmental value of an irrigation, power, indeed any development project can be increased if natural habitats destroyed for the construction of the project are restored or revived. Therefore, restoration of different natural habitats should be made a condition for the environmental clearance of any development project.

The already completed or existing development projects: irrigation, power, industry, settlement etc., should be required to make a provision for the restoration of natural habitats for their continued environmental clearance.

(Note: The term "natural habitat" here means natural according to the topography and climate of a particular region. For example, in a rain shadow area the natural forest will be 'scrub and thorn'. In this area the accent should be on the revival of scrub and thorn and not plantation of trees.)

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Scientific Names of Animals, Birds and Insects Mentioned in the Text

Animals

Canis lupus (Wolf), *Mus booduga* (Indian Field Mouse), *Antilope cervicapra* (Blackbuck).

Birds

Podiceps ruficollis (Dabchik),
Phalacrocorax niger (Little Cormorant)
Ardea cinerea (Grey heron), *Ardea purpurea* (Purple heron), *Ardeola grayii* (Pond heron), *Bubulcus ibis* (Cattle egret), *Egretta alba* (Large egret), *Egretta intermedia* (Intermediate egret), *Egretta garzetta* (Cattle egret), *Ixobrychus sinensis* (Yellow bittern)
Anastomus oscitans (Openbill stork), *Ciconia episcopus* (Whitenecked stork), *Mycteria leucocephala* (Painted stork)
Platalea leucorodia (Spoonbill), *Plegadis falcinellus* (Glossy ibis), *Threskiornis aethiopica* (White ibis), *Pseudibis papillosa* (Black ibis) .
Phoenicopterus ruber (Greater flamingo)
Tadorna ferruginea (Ruddy shelduck), *Anas penelope* (Wigeon), *Anas crecca* (Common teal), *Anas querquedula* (Garganey), *Anas acuta* (Pintail), *Anas clypeata* (Shoveller), *Aythya fuligula* (Tufted duck), *Aythya ferina* (Common pochard), *Aythya nyroca* (Ferruginous duck), *Anas poecilorhyncha* (Spotbill duck), *Nettapus coromandelianus* (Cotton teal)
Pandion haliaetus (Osprey), *Aquila clanga* (Spotted eagle), *Circus aeruginosus* (Marsh harrier), *Circus macrourus* (Pale harrier)
Hydrophasianus chirurgus (Pheasant-tailed jacana)
Larus argentatus (Herring gull), *Larus ichthyaetus* (Great blackheaded gull), *Larus ridibundus* (Blackheaded gull), *Larus brunnicephalus* (Brownheaded gull).
Sterna nilotica (Gullbilled tern), *Sterna aurantia* (River tern)
Fulica atra (Coot), *Gallinula chloropus* (Indian moorhen), *Amaurornis phoenicurus* (White-breasted waterhen), *Porphyrio porphyrio* (Purple moorhen)
Charadrius dubius (Little ringed plover), *Calidris minuta* (Little stint), *Tringa glareola* (Spotted sandpiper), *Tringa ochropus* (Green sandpiper), *Tringa hypoleucos* (Common sandpiper), *Tringa nebularia* (Greenshank), *Limosa limosa* (Blacktailed godwit), *Gallinago sp.* (Snipe)
Himantopus himantopus (Blackwinged stilt)
Esacus magnirostris (Great stone plover), *Glareola lactea* (small Indian pratincole)
Vanellus indicus (Red-wattled lapwing), *Vanellus malabaricus* (Yellow-wattled lapwing)
Pterocles exustus (Indian sandgrouse)
Alcedo atthis (Common kingfisher), *Halcyon smyrnensis* (White-breasted kingfisher)
Merops superciliosus (Bluecheeked bee-eater)
Hirundo rustica (Swallow), *Hirundo daurica* (Red-rumped swallow)
Oriolus oriolus (Golden oriole)
Dicrurus adsimilis (Black drongo)
Sturnus roseus (Rosy pastor), *Acridotheres tristis* (Common myna)
Acrocephalus stentoreus (Indian great reed warbler)
Motacilla flava (Yellow wagtail), *Motacilla maderaspatensis* (Large pied wagtail)
Ploceus philippinus (Baya), *Estrilda amandava* (Red munia), *Lonchura malacca* (Blackheaded munia)

Insects

Pachliopta hector (Common rose), *Papilio demoleus* (Lime butterfly), *Papilio polytes* (Common Mormon), *Catopsilla pomona* (Common emigrant), *Danaus chrysippus* (Plain tiger), *Euploea core* (Common crow)

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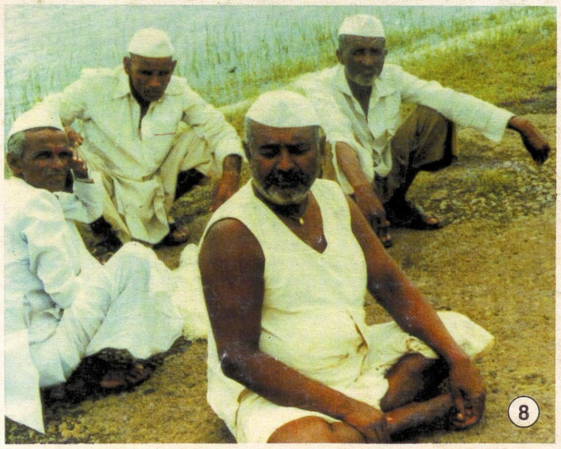

1. Mounds as reservoir bank 2. Ponds as fish-breeding habitat 3. Sadges regenerating after drawdown 4. Mudflats attracting flamingos 5. Island created for bird-use 6. Nest of a River Tern pair 7. Fresh water prawn 8. Group of fishermen 9. Plantation at project site 10. Bank mounds and bird perches 11. Bank-side plantation in barrels