Assessment of Ecological Settings and Biodiversity Values of Papikonda National Park and Indira Sagar (Polavaram) Multipurpose Project Impact Zone in Andhra Pradesh for Development of Mitigatory Measures

FINAL REPORT

September 2014

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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SUMMARY

The Indira Sagar (Polavaram Project) Multipurpose Project envisages the construction of a zoned earth-cum-rock fill dam with an impervious core across the Godavari River in Polavaram. This project also includes the construction of two canals, viz. the Right Main Canal, extending over a distance of 174 km, and the Left Canal, extending over a distance of 181.5 km. The Right Canal will connect the water-surplus Godavari River with the water-deficient Krishna River in Vijayawada and supply 80 tmcft (226 MCM) of water to Budameru in Vijayawada. The Left Canal is designed to provide water to 12 lakh acres in the northern coastal districts besides meeting the drinking water needs of the urban and rural areas around these. It will connect with the Yeleru canal to bring water for industries (Vizag steel plant) and a drinking water supply. It will also supply the northern coastal districts of Visakhapatnam, Vizianagaram and Srikakulam with irrigation water. Apart from boosting irrigation in the region, this project will also provide drinking water to 28 lakh people in 540 villages along the canals and generate around 960 MW of hydro-electricity. Despite these benefits, the project has come under scrutiny from various quarters, especially its adverse impacts on various ecosystems that are closely linked with the Godavari River. Further, an area of 3267 ha of land in Bhadrachalam (S), Bhadrachalam (N), Paloncha, Krishna, Eluru, Kakinada and Visakhapatnam forest divisions also needs to be diverted for submergence, construction of a power house, digging of canals, etc. In this context, as per the direction of the Ministry of Environment & Forests, Government of India, vide their letter no. 8-123/2005-FC dated 26/29th December 2008, Point No. 7(ii), the Wildlife Institute of India (WII) intiated a short-term (18-month) study to assess the impact of the project on the wild flora and fauna and the habitat and subsequently suggest mitigatory measures for the same.

The status and distribution of certain taxa such as mammals, birds, herpertofauna and fishes were assessed using various census techniques. These included the use of line transects and camera traps and sign surveys for mammals, point counts for birds, quadrat methods for herpetofauna, CPUE (Catch Per Unit Effort) and market surveys for fishes and circular plots for vegetation assessment. Further, GIS and remote sensing tools were used to assess the land cover and land use pattern and potential impact of the project at the landscape level.

Of the 89 species of fish recorded from the impact zone of the Godavari River, it is believed that 59 species will be affected during the construction phase as these species are reported from the close proximity of the dam site. Of these 59 species, one species is Endangered, three species are Vulnerable and three more species

are Near Threatened as per the IUCN Red List criteria. Further, were four exotic species (*Cyprinus carpio, Clarias gariepinus, Oreochromis mossambicus* and *Pygocentrus nattereri*) have already been recorded close to the dam site. These species may gain an advantage over native species due to man-made changes in the river during the construction phase. Soil erosion and sediment runoff in the river will be the major impacts due to clearing and excavation activities during the construction phase. This will not only lead to changes in the water quality but may also lead to acute or sub-lethal toxicity in aquatic organisms such as fishes (Bernacsek, 2001). Increased silt runoff might also lead to blocking of key fish breeding, nursery or overwintering habitats in the river. Dredging of the river banks as well as clearing of riparian vegetation during the construction phase also might lead to loss of key habitats for aquatic organisms. Several water bodies such as ponds and small streams have been recorded very close to the construction sites. These are used by the local communities for aquaculture, and they also serve as good feeding grounds for a number of aquatic bird species. Such water bodies will be directly impacted by the various construction activities and the associated traffic flow. If proper steps are not taken, such water bodies as well as the river might also be subjected to increased water pollution due to defaecation by the labourers and effluent runoff.

However, the construction phase may not have a very adverse impact on the terrestrial fauna of the region because the abundance of wild animals in the immediate vicinity of the dam construction site as well as along the two main canals is low. But there will be significant damage to their habitats due to blasting, excavation and other civil activities. Blasting may cause physical damage to the terrestrial birds, reptiles and other smaller animals and might cause considerable damage to their habitats and nests/nesting grounds. Construction activities will mainly affect the flora of the area as huge tracts of forests and vegetation have to be cleared for construction and associated activities.

Habitat Loss

The construction activities will also lead to huge amounts of silt and fine particles becoming suspended in the air, which might settle down and damage agricultural crops and other vegetation. This has already been observed near the dam construction site where the leaves of the trees and shrubs have turned red due to deposition of silt. The high levels of noise and sound during the various stages of construction will also disturb the wild animals in the nearby forests and hills. Moreover, human disturbance during the construction and operational phases of the hydro project will keep away several shy wild animals from the vicinity.

It is expected that there will be severe effects on the aquatic biodiversity during the operational phase of the dam. Dams tend to fragment a riverine ecosystem and change the flowing river into a stagnant reservoir. Both these factors will bring about drastic changes in the physico-chemical properties of the Godavari River, which in turn will lead to a change in its biotic community. The reservoir of

Polavaram Hydro Project may positively affect certain reservoir fish species (and fisheries) or generalist fish species, but the net impact of this project on the fish diversity will eventually be negative (McCully, 1996).

The ecology of a downstream stretch of length about 118 km of the Godavari River, starting from the dam site, is expected to be affected due to regulated or low or nil flow from the dam. Of these 118 km, a 40 km stretch of the river between the dam and the Rajmundry Barrage will be better compared with other parts downstream, i.e. the 78 km long stretch of river between Rajmundry and the Godavari estuary. Similarly, the river flow over an upstream stretch of the Godavari River of length about 80 km from the dam site will be affected by the reservoir, which would change the lotic ecosystem to a lentic ecosystem. This will also affect the species composition of fish and other aquatic species in the river. It is also expected that a few species existing in the river, including exotics, will be benefited due to changes in the hydrology of the river because of the reservoir. Therefore, a significant area of the fish habitat will either be modified or lost due to this project.

Barrier Effect

The Polavaram dam is expected to serve as a physical barrier to the movement of certain migratory species, notably fishes. This prevents the brood-stock from reaching its spawning grounds during the breeding season, resulting in massive failure of recruitment and eventual extinction of the stock above the dam. Most profoundly impacted will be species such as the mahseer, eels and the Indian shad (locally known as *polasa* or *hilsa*) because the dam blocks upriver fish migrations, and downriver passage through turbines or over spillways is often unsuccessful. The *hilsa* was caught in larger number in the downstream and estarine parts of the Godavari River, but the catch has been reduced significantly nowadays, probably due to the existing barrage near Rajmundry. However, the few specimens of *hilsa* that have been collected during the study period near Polavaram and upstream of Rajmundry reveal that this species still makes an attempt to migrate upstream for spawning. This will be adversely affected after the construction of the dam.

At least 17 estuarine/marine fish species have been recorded upstream of Rajmundry barrage. This shows that these species are migratory in nature. The dam at Polavaram will disrupt their normal migratory behaviour, which will ultimately affect the breeding cycle. Therefore, there will be a decline in the population. A decline has already been observed due to the Rajmundry Barrage, which seems to be preventing the migration of *hilsa* and eels upstream significantly.

Sedimentation Flow

The other important environmental impact of this project is changes it will produce in the sediment transport and water quality. The dam will tend to trap sediments and nutrients, starving the downstream stretches of the river. Because of this, the water flowing below the dam will tend to erode the banks, which might render them weak and susceptible to subsidence. A reduction in sediment transport in the rivers downstream of the dam will also influence the channels, floodplain and coastal delta morphology, altering habitats for fish and other groups of animals and plants in the Godavari estuary and Coringa mangroves. Rao et al (2010) studied shoreline recession in the Godavari and Krishna deltas and found that the suspended sediment load decreased by a factor of three in the Godavari delta, from 150.2 million tons during 1970–1979 to 57.2. million tons by 2000–2006, which they attributed to increased sediment retention in the reservoirs of dams on the river. In a similar study (Gupta et al, 2012), it was estimated that after the construction of dams on the Godavari, there was a 74% decline in the sediment load from the historic value. In this context, the Polavaram dam will further reduce the sediments flow downstream, and that will adversely affect the Coringa mangrove and Godvari estuarine ecosystems.

The sediment flow in the 118 km long stretch of the Godavari River downstream from the dam site is expected to be reduced by trapping by the dam. Similarly, the sediment flow will be trapped in the reservoir area that spreads about 80 km long stretch of upstream of Godavari River from the dam site. These changes in the sediment both upstream and downstream of the dam may not be good for several biota, especially the benthic and pelagic animals and plants of the Godvari River.

Environmental Flows

It is increasingly recognized that the distribution and abundance of riverine species are limited by the effects of flow regulation. Research on the distributional ecology of fishes suggests that fish assemblages form in response to the physio-chemical factors of the environment. Changes in the assemblage structure of stream fishes or species composition are imposed by temporal variations in the stream flow, which ultimately affect the entire biodiversity of the river ecosystem. Three kinds of adverse impacts on the aquatic biodiversity are expected because of changes in the natural flow due to the Polavaram dam on the Godavari River: (a) Water will stagnate in the submersible zones, which may not be conducive for certain stream/river fishes such as the mahseer. (b) There will be less or no water flow in the dry zones of the project area, which is also expected to adversely affect the biodiversity of the mangrove and estuarine ecosystems, but it may be mitigated by maintaining minimum environment flows. (c) There will be changes in the natural flow may, as a result of which natural environmental cues may not be provided to the aquatic biodiversity (such as the *hilsa* and eels) to breed or maintain annual life histories, but this can again be mitigated by maintaining minimum environmental flows even though it would help partially to maintain the current status of the aquatic ecosystem and its biodiversity.

Riparian Vegetation

Riparian vegetation is also an important component of an aquatic ecosystem. The riparian vegetation in the project area is very important for providing shelter and cover for the fish. It also provides shade and regulates the temperature and helps regulate floods. The expected changes in the river flow and its level will affect the riparian vegetation of the downstream section of the Godavari River. It was observed that the riparian vegetation downstream of the Dowlaiswaram Barrage was adversely affected compared with upstream due to significant changes in the water flow between these sections. Therefore, it is expected that the Polavaram project will further affect the riparian vegetation, which is a critical habitat for many aquatic plants and animals.

Changes in Nutrient Flow

The Indira Sagar Hydro Project at Polavaram is also expected to stop or regulate the nutrient flow downstream. A stretch of the river stretch of at least 40 km length will be submerged after the construction of the dam. This submerged section will act as a nutrient trap. Changes in the nutrient flow will adversely affect the downstream fishes and other aquatic biodiversity, especially in the mangrove and estuarine ecosystems. Moreover, a few species may benefit from the reservoir, which which again affect the fish composition in the region. Nutrient availability is the major environmental factor that determines the fish species composition in rivers (Sivakumar, 2008). Therefore, any changes in the nutrient flow will affect the overall composition of the fish community.

Further, the local communities who live in the floodplains, i.e. around the Godavari Estuarine Region, might have to face several effects on their ways of life because of the above-mentioned biological changes due to physical changes downstream of the dam.: (a) a reduction in the river flow, (b) saline intrusion close to the coast, which may also affect livelihoods, (c) loss of deposition of nutrients in flooding valleys as as a result of there being no more flooding, which may affect agricultural activities, (d) problems related to fluctuations in the underground water levels, such as dry wells, and (e) the introduction of a risk due to the existence of a dam upstream that might fail and cause a disastrous flood.

Terrestrial Biodiversity

Filling of the Indira Sagar Dam/Reservoir will result in permanent flooding of riverine and terrestrial habitats upstream. The effects of inundation are expected to be severe on agriculture where the river valleys are usually the most productive landscape elements. Due to impoundment, all terrestrial animals disappear from the submerged areas and populations decrease within a few years in proportion to the habitat area that is lost. Flooding can result in both local and global extinctions of animal and plant species. Particularly hard hit are the species dependent upon riverine forests and other riparian ecosystems and those adapted to the fast-flowing conditions of the main river course. From a biodiversity conservation standpoint, the terrestrial natural habitats lost to flooding are usually much more valuable than the aquatic habitats created by the reservoir.

An area of 3267 ha of forest land in Bhadrachalam (S), Bhadrachalam (N), Paloncha, Krishna, Eluru, Kakinada and Visakhapatnam forest divisions will be affected by submergence, construction of a power house, digging of canals, etc. Of this, an area of 187.29 ha falls inside Papikonda Wildlife Sanctuary (WLS) in Bhadrachalam (S), Paloncha, Kakinada and Eluru divisions. Transect walks were carried out along a distance of 89.92 km in the forest land, and a total of 47 common langur and 1 wild boar were directly sighted; there was no sighting of other major mammalian species during the transect walks. However, a sambar and a palm civet were sighted outside the transects. Carnivore sign surveys were carried out along a total length of 37 km of trials. Only indirect evidence of the presence of jungle cat *Felis chaus* and sloth bear *Melursus ursinus*, and that in small numbers, was obtained, indicating that the submergence zone is comparatively poorly used by wild mammals. Further, the camera trap census technique was employed, which confirmed that the presence of mammals in this area is poor. From discussions with locals and through our observations, we found that most of the wild animals, especially the larger mammals, are mainly restricted to the upper reaches of the hills and deep forests of Papikonda National Park (PNP). Due to intense human activity and habitat modification due to farming, wild animals tend to avoid the submergence zone. However, the submergence zone has a high diversity of avifauna, with 101 species reported during the study period, several of which are threatened. Further, opportunistic sightings of threatened mammals such as the sambar and wild dog were made from the submergence area. According to the forest department, the area is also home to one or two tigers. Naik et al (2012) carried out extensive faunal surveys in the submergence region of Polavaram Dam and concluded that the populations of the 9 mammal, 22 reptile and 70 bird species that are present in the submergence region will be affected.

Impact on Overall Landscape

Construction of the dam will cause submergence of the low-lying areas in the catchment area. Of the total area of the PNP, which is 1042 km^2, about 117 km^2 is at risk of submergence. The land cover type that will be impacted the most comprises of dense vegetation cover, which was observed during the field surveys to be a mixed deciduous teak-and-bamboo forest. The land use type that will undergo immense loss is cultivated land since most of the cultivation in the area is carried out in low-lying regions in close proximity to the river bank. This impact will be felt within the designated boundary of PNP. However, the area lying downstream of the dam will also see certain adverse impacts because of the changed flow of the river. To make an assessment of the landscape in the downstream region coming under threat, the following map was generated.

Land cover pattern in the land around the river downstream of the dam

Assuming that about 50 km^2 of land in the buffer area around the river basin is directly and solely dependent on the river water, the downstream areas may be directly affected during the dry season, during which the water flow from the dam will be restricted. About 1566 km^2 of agricultural land can be expected to come under the direct threat of having no water during the dry season. This area may also be affected by way of reduced productivity as the river will not carry the full silt load after the construction of the dam. Eventually, since there will be continued erosion with the siltation halted, the slope of the land in the downstream region may also change, making the region more prone to cyclonic floods.

Apart from agriculture, the basin supports human habitations with an extent of about 800 km^2 that are most probably directly dependent on the river for water for domestic use. Close to 1000 km^2 of riparian vegetation will also be affected in view of the declining water flow.

Impact on Coastal Landscape

All parts of a river ecosystem are inter-connected. Therefore, a disturbance in one part will produce a greater or lesser response over much of the system. The Polavaram Dam can stop the migration of certain fish to their spawning grounds in the headwaters, impacting the estuarine fishery at the other end of the system. Further, this dam is expected to produce a wide range of environmental effects, including severe alteration of deltas and estuaries; increased coastal erosion; reduced biodiversity and productivity of fisheries; and changes in the dynamics of the coastal phytoplankton. Moreover, reducing the flow of freshwater into estuaries can reduce their naturally high productivity and species diversity. This will happen via declines in essential nutrient input, alterations to the salinity regime and increases in the concentrations of toxic chemicals entering the system. The alteration of flood cycles and runoff patterns also may affects those biological processes attuned to seasonal flow dynamics. A decreased variability in saltwater intrusion affects the distribution of most estuarine organisms because their distributions are determined primarily by their salinity tolerance levels. Changes in the salinity might have allowed range extensions or altered the distributions of many species because areas that were formerly subjected to seasonally intolerable salinity levels for those species would now be habitable throughout the year. The tradtional ecological knowledge (TEK) of the fishermen of the region confirms that there are drastic declines in the catches of many brackish water species from the Godavari estuary, which might be due to an alteration in the flow caused by the Rajmundry Barrage. Mangroves are best developed in areas that receive freshwater runoff and are subjected to tidal water flushing. The diversion of water for irrigation upstream of the Rajmundry Barrage has already resulted in the flow of freshwater into the Godavari mangrove swamps becoming poor. The poor flows of tidal and freshwater have resulted in high salinity in the mangrove swamps and thus the growth of mangroves has been reduced. Further, the mangroves of the Godavari delta are already threatened due to climate change-related impacts such as a rising sea level, increased atmospheric CO_2 concentrations, fluctuations in the annual precipitation, fluctuations in the temperature, high-water events such as storms and floods, etc. These adverse impacts can be minimized through careful management of the release of water, and in this regard variability is very important. Therefore, the objective in optimizing water release from the dam will be to closely mimic the natural flooding regime.

Recommendations

Integrated Management Plan for PNP: The Environment, Forest, Science and Technology Department, Government of Andhra Pradesh has notified a 1012.8588 km^2 area in and around Papikonda WLS as PNP as a part of mitigatory measures to minimize/compensate the adverse impacts of the Indira Sagar Hydro Project.

Most of the submergence area of the project has been included in the national park so that it will be available for both terrestrial and aquatic wildlife. Further, this area, which is comparatively free from human pressures, is expected to become a better habitat for the wildlife of the Pappi Hills. However, an integrated management plan is required to manage the new PNP, which should be prepared in consultation with all the line departments, including the Indira Sagar Project Authority and local communities. The vision of the 'Integrated Management Plan of Papikonda National Park' should be long-term landscape-level conservation of the biodiversity of the region and sustaining the normal ecological services of the Pappi Hills and their biodiversity. More emphasis needs to be given to the riverine ecosystem and its biodiversity. During the operational stage of the dam, the reservoir may attract several species of migratory bird, and the riverine habitats will attract the terrestrial animals of the Papi Hills, especially during summer. Therefore, an intensive monitoring and management protocol is required in the management plan to conserve these migratory birds and other animals that may move towards the reservoir area in summer. Since the river will be continously used for navigation by the local people and pilgrims, there should be an adequate boat traffic management plan in the management plan of the PNP. Further, if required, the entire submergence zone of the PNP may be divided into different zones. A boat nagivation zone, tourist zone and 'no-use zone' need to be clearly demarked and managed. The entire submergence zone may be considered a separate range, and an exclusive ACF-level officer with adequate staff and logistic facilities may be appointedat Polavaram to assist the DFO of PNP. Only eco-friendly tourism should be allowed inside PNP, with adequate tourism management planning, which should be a part of the management plan of PNP. Soil conservation activities along the reservoir could serve to limit erosion of the terrestrial parts of PNP and sedimentation in the reservoir. Therefore, implementation of a well-planned long-term soil conservation programme along the reservoir is important, and it should be a part of the management plan of PNP. The Indira Sagar Project Authority should financially support the implementation of this management plan.

Fish Passes (Ladders)

The Indira Sagar Dam will pose a barrier to fish that move from one part of the river to another as part of their life cycle processes. This dam will always be detrimental to the survival of certain fishes, especially migrants that use different habitats for different life history requirements. Fish passes are often believed to be an engineering mitigation measure for reducing impacts on fish, especially migrants. In general, the efficiency of fish passes is considered low, and fish migrations are severely affected, possibly due to poor engineering. Even where fish passes have been installed successfully, migrations can be delayed by the absence of better navigational cues, such as strong currents. Therefore, a fish pass with better navigational cues should be planned, and that should help the most profoundly impacted species such as the mahseer, eels and the Indian shad move upward. The compositions of the fish communities of the Godavari River and estuary are different from those of other rivers in India. Therefore, it is recommended that the help of the Central Inland Fisheries Research Institute

(CIFRI), Kolkota be sought to design a better fish pass to cater to the specific behavioural propensities and physical capabilities of fish species inhabiting this river. The fish pass should have a sufficient number of baffles of sufficient width and depth so that even larger fish can pass through it. The length and slope of the fish pass should be selected on the basis of the requirements of the 17 migratory species identified in the river. Most importantly, adequate protection should be provided for the fish pass, even during the non-migratory period. Further, the fish pass should not be used as a fish trap.

Fish Hatcheries

Any kind of ex-situ conservation programme (as an alternate conservation strategy) to artificially restock (through ranching) the fish populations of species that would be threatened due to dams or any other kinds of barrier construction across rivers or streams may not fully compensate for the natural breeding phenomenon of migration. Moreover, species that are non-migratory and less significant to fisheries are largely ignored in ex-situ (fish ranching) conservation programmes. Migratory fishes in the region will therefore be affected adversely by hydro-electric projects. Therefore, the state fisheries department should, in consultation with the forest department, design a fish hatchery to enhance the stock of native fish species that are already threatened in the river. It is strictly advised that there should not be any introduction of exotic fish species in the region. Further, it is also suggested that a brackish water fish hatchery be established in the estuarine region to enhance the stock of brackish water fishes that will be affected due to changes in the freshwater flow.

Promoting Traditional Methods of Fishing

Fisheries in the Godavary River and estuary used to target species depending upon the season. Traditional fishing practices were gradually replaced with modern fishing gear and craft, and larger fishing operations that capture all kinds of fishes as well as non-targeted aquatic fauna, fry and fingerlings. Therefore, there was a decline in the overall fish diversity in the region. In this context, it is suggested that the traditional fishing knowledge of the region be documented and its practice be promoted.

Estuarine/Mangrove Conservation Plan

The problems caused by the reduction of the amount of sediment transported to the coast can only be solved with expensive engineering work, namely beach nourishment and ultimately shoreline protection. The stopping of floods results in marine sedimentary deposition in the river mouth, which can be solved only by dredging. Therefore, the management plan of the Coringa WLS or the management plan of the Godavari Estuarine Area should clearly list out all action plans required to nourish the shoreline and remove marine sediments regularly from the mouth so that the marine flow into the estuary is maintained. Further, the existing or proposed management plans of Coringa WLS and Godavari estuary should contain a disaster-preparedness plan with respect to the Indira Sagar Project as well as one with respect to climate change. In the Godavari estuary, where the river flow is greatly controlled by the dam, there is a time lag between the maximum rainfall and maximum discharge in the river. This delay can sometimes compromise the recruitment of estuarine fish species—this will cause some negative impacts on fish populations and shifts in the natural patterns of other biological communities. This is why a minimum flow from the dam should be allowed. Sometimes, it is difficult to make a compromise between effective nature conservation and the economical improvement of an area. Positive impacts in the local economy should be achieved through sustainable and rational growth of human activities in the area, including tourism. Tourism is regarded as one of the solutions for achieving economic development in the Godavari Estuarine Region. Therefore, the scope of eco-tourism in Coringa WLS may be extended to the estuarine region. But development of economically viable tourism in this region has to be ecologically sensitive and culturally appropriate. Therefore, protection of nature and understanding the worth of the natural patrimony that characterizes the Godavarine estuary/mangroves should not be neglected or forgotten.

Mangrove forests are the major coastal ecosystem of the Godavari estuary and are among the richest and most productive ecosystems. A number of commercial and traditional products are provided by mangrove ecosystems. These include the nutrient enrichment for aquatic and terrestrial flora and fauna. Mangrove vegetation plays an indirect but very important role in coastal protection. Mangrove forests provide unique ecological niches and habitats for a variety of marine and terrestrial animals. Similarly, estuarine and sandy beaches are known to be the nesting areas of sea turtles. Therefore, an integrated coastal zone management plan is required in the estuarine region of the Godavari River to address the entire gamut of issues related to conservation and sustainable use of the biodiversity of the region.

The functioning of the Godavari mangrove ecosystem is closely linked to terrestrial land use practices. In particular, changes in water-flow regimes affect mangroves, and overdrawing of ground water may increase the danger of aquifer salinization and contamination. Consequently, the coastal zone should be considered an integral component of overall regional land use planning and development so that appropriate land use policies and action programmes may be formulated. Priority should be given not only to rehabilitation of degraded coastal lands but also rational use of land on a sustainable basis, including planned development of sustainable forest/marine products. Many of the uses and services of mangroves are compatiblewith each other, such as honey collection, coastal protection and small-scale capture fisheries. Others are less so, and hence a zonation of the area according to primary land-use objectives is necessary. This underscores the need for a holistic approach within the framework of integrated coastal zone management planning.

Integrated management planning should also ensure that all goods, services and values are catered to. Management planning should therefore include periodic environmental impact assessment, and the actual management must be monitored periodically by environmental auditing. Good environmental management promotes conservation of biodiversity. However, there is limited information on the biodiversity value of the Godavari estuary—hence there is a need for research.

Public Awareness and Education

The mangrove/estuarine management action plan cannot succeed without considering the requirements and aspirations of all the people. Success depends, inter alia, on being able to match management objectives with the interest of local populations and, through extension, securing their support and commitment. Therefore, a degree of "self management" should be encouraged among the various users of the mangrove environment so that they can be involved in protecting their own environment. In the recent past, there were a number of incidental captures of whale sharks off the mouth of the Godavari. The whale shark is one of most highly threatened sharks in the world, and it is protected under the Wildife (Protection) Act, 1972. The Gujarat government initiated an innovative compensation programme for fishermen who release incidentially captured whale sharks. Similar models may be adopted in the region to prevent killings of this species.

A lack of understanding of the importance of mangroves is an important cause of mangrove depletion and degradation. The state forest department should justify its mangrove management programme to the general public and other line departments. The authority should ensure that awareness and education programmes that inform the public about mangroves, their uses and services and how to maintain them, as well as government plans in relation to management of these resources, are developed and implemented. These programmes should be aimed primarily at the people who live near the mangroves/estuary and depend on them for various needs. These programmes should also be developed for planners, decision-makers and agricultural and public works sectors since their actions can have serious impacts on mangroves. Relevant audio-visual and visual aids, seminars, talks, workshops and exhibitions on mangrove products and services targeted at various audiences should be conducted to create public awareness. All the management actions suggested in the foregoing should be supported financially by the Indira Sagar Multipurpose Hydro Project Authority through the EGREE Foundation (Kakinada) and the Forest and Fisheries departments of the Government of Andhra Pradesh.

Expansion of Ecosenstive Zone Around Coringa WLS

This is important in the context of the Indira Sagar Project. All the degraded mangroves around the Coringa WLS may be declared either the eco-sensitive zone of Coringa WLS or a conservation reserve so that the necessary management interventions can be made to restore these mangroves habitats. The state forest department should strengthen its ongoing mangrove restoration activities and the sea turtle conservation programmes in the region with financial support from the Indira Sagar Polavaram Project.

Riverine Landscape Management Plan

The Polavaram dam will cause submergence of the low-lying areas in the catchment area. Of the total area of the newly notified PNP, which is 1042 km^2, about 117 km^2 is at risk of submergence. The land cover type that will be impacted the most is dense vegetation cover, which was observed to be a mixed deciduous teak and bamboo forest during the field surveys. Similarly, the area lying in the downstream region of the dam will also experience certain adverse impacts because of the changed flow of the river. Therefore, an intensive plantation programme needs to be intiated to compensate for this loss along both banks of the river as well as along the Left and Right canals of the project. It is important to note that no exotic species should be encouraged in this plantation programme. Further, plant species that are compatible with the local riverine ecosystem should be planted.

At present, the Left bank riverine habitat of downstream (from Dam) of Godavari is in a relatively better condition than right bank. The human disturbance recorded in left bank was relatively less. On the other hand, the degree of human interference was higher on right bank with numerous plantations and agricultural fields right at the bank. A higher degree of cattle grazing and exotic species were also observed on the right bank.

The RVI survey shows that there is a very high degree of degradation of the riparian zone along the river. Even it is highly unlikely that the riparian zone will recover to its natural pristine condition, there is scope for improving conditions. The importance of a healthy riparian zone has already been highlighted, not only from the ecological point of view but also for other purposes such as bank stabilization, protection from floods, groundwater recharge and maintaining the fishery resources, which are the major source of income of the local people. Therefore, it is proposed that both the banks be strengthened by plantation of natural vegetation and not using any exotic species.

In this context, it is suggested that an area of width 50 m along either bank of the river, from the dam site to the Godavari estuary, be declared an econsenstive zone. A green belt needs to be developed in this ecosensitive zone using only native plants without disturbing the natural landscape, with the financial support of the Indira Sagar Multipurpose Hydro Project.

Otters and fishing cats in the Godavari mangroves need special attention in the integrated management plan of Coringa WLS or the Godavari Estuarine Ecosystem. These two species are umbrella or flagship species of this ecosystem.

Any adverse impact due to the dam or climate change on the mangroves will ultimately affect the populations of these two species. Therefore, the integrated management plan of Coringa WLS should consider these two species as flagship species and try to restore their populations and their habitats. Interestingly, otters were observed close to human habitations but on the fringes of the mangroves. It was also observed that there were some conflict between otters, fishing cats and aquaculture farmers. These wild animals are known to hunt fishes in the aquaculture farms nearby. In this context, it is important to get the support of farmers for conserving otters and fishing cats in the region as these species are already highly threatened in India.

Environmental Flows: Environmental flows are flows that are essential for maintaining the normal ecological services of a river. Their purpose could be as general as maintenance of a “healthy” riverine ecosystem or as specific as enhancing the chances of survival of a threatened species and associated animals. The flow regime is one of the important components of the river ecosystem that can reflect its health, its geographic location and the geological and topographic features of the area, including whether the socio-economic status of the region has been fulfilled. The environmental flow has been defined in the context of maintaining the health of river stretches downstream of Polavaram, the estuary and the mangroves of the mouth of the Godavari River.

The Godavari River has a catchment area of 3,14,685 km^2 and a long-term average annual surface flow of 110 km^3. The discharge of the river is highest during the south-west monsoons (June—September), when the region receives almost 80% of the average annual rainfall.

There are more than 200 methodologies to suggest better environmental flows if the normal flow of the river is disturbed. However, there is no single method for flow assessment that can be used universally without any modification(s). This is largely due to variations in the topography, climate and other environmental settings across the globe. Moreover, the flow requirement varies with different needs of the region. Further, environmental flows should also provide the required environmental cues for the various life history traits of a species because important activities such as breeding, growth, metamorphosis and migration are mainly dependent on seasonal variations in the natural flow. Moreover, the requirements of the life history stages of many fishes are dependent on the seasonal flow. Taking this into account, the environmental flow required for different sectors of the river was calculated from the mean monthly flow (MMF), appreciating the requirement of seasonal variations. We used a method that is a hybrid of the building block, habitat rating and hydrologic modelling methods. Moreover, we have also suggested alternate flows based on the Environmental Management Class of the Godavari River (Smakhtin et al, 2007

The region experiences four main seasons. These are the following.

(a) *Season I:* This is considered the high-flow season, influenced by summer and the monsoon. This extends over the months from July to September. (b) *Season II:* This season is considered an average-flow period and falls in the month of October. (c) *Season III:* This season is considered the low- or lean- or dry-flow season and extends from November to May. (d) *Season IV:* This season is considered an average-flow period, and the flow is the same as that of Season II. This season falls in the month of June. Based on this classification of the seasons, the MMF that is expected to provide the required environmental cues to the biota of the region to complete their normal life cycles was estimated. Two methods used for estimating the required minimum environmental flow yielded more or less same for the lean season. Therefore, this study suggests the release of 26% cumecs from November to May, 30% cumecs during June and October and 35% cumecs from July to September. These suggested flows, which are the minimum required flow, are expected to provide the required environmental cues to the biota of the region as well as sustain the ecosystems and allow their biodiversity to perform the normal ecological services. It is important to note here that this is the minimum required flow for the functioning of the downstream ecosystems and for the normal life cycles of the fauna and flora. Therefore, it should not be concluded that the animals and plants will survive forever with this minimum requirement. It was also observed that the Dolaishwaram Irrigation Canal may also supply water directly to the Coringa mangroves provided enough water is released through this canal after the requirements of the farmers in the region are satisfied. However, this canal should not be considered an alternate route for the main river with respect to the minimum water flow releases.

Table 1.1 Mean monthly flow (MMF) (% in cumecs) that needs to be released from Dowlaiswaram (Rajmundry) Barrage, Andhra Pradesh. The MMF should be calculated from the last 30 years' flow data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
% of MMF	26	26	26	26	26	30	35	35	35	30	26	26

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Chapter 2

INTRODUCTION

2.1 Background of the Indira Sagar Multipurpose Project

The Indira Sagar Multipurpose Project (Polavaram Project) was first mooted by Mr. L. Venkata Krishna Iyengar in early 1941, when he developed definite proposals for a storage reservoir near Polavaram. Since then the project has undergone several changes, and its feasibility has been the subject of numerous debates. Finally, the current project proposal was finalized based on revised reports produced in 1978, 1982, 1987 and 1990; further investigations and studies; and the comments of the Central Water Commission on previous proposals.

The current project proposal envisages the construction of a zoned earth-cum-rock fill dam with an impervious core across the Godavari River in Polavaram. The spillway is located in the right flank saddle and the power dam on the left flank saddle. The proposed FRLof the reservoir is +150 feet, and the spillway has been designed for a maximum flood of 36 lakh cusecs at an elevation of +140 feet for maintaining a lower level of submersion in the neighbouring states during floods (AFCL, 2005a, 2005b). The current project also involves the construction of two canals, viz. Right Main Canal, extending over a distance of 174 km, and the Left Canal, extending over a distance of 181.5 km. The Right Canal will connect the water-surplus Godavari River with the water-deficient Krishna River in Vijayawada and supply 80 tmcft (226 MCM) of water to Budameru in Vijayawada. The Left Canal is designed to provide water to 12 lakh acres in the northern coastal districts besides meeting the drinking water needs of urban and rural areas around it. It will connect with the Yeleru canal to bring water for industries (Vizag steel plant) and the drinking water supply. It will also supply the northern coastal districts of Visakhapatnam, Vizianagaram and Srikakulam with water for irrigation.

Apart from boosting irrigation in the region, this project will also provide drinking water to 28 lakh people in 540 villages along the canals and generate around 960 MW of hydro-electricity. Despite these benefits, the project has come under scrutiny from various quarters. An area of 3267 ha of forest land in Bhadrachalam (S), Bhadrachalam (N), Paloncha, Krishna, Eluru, Kakinada and Visakhapatnam forest divisions is required to be diverted for submergence, construction of a power house, digging of canals, etc. And of this 3267 ha of forest land, an area of 187.29 ha falls inside Papikonda WLS in Bhadrachalam (S), Paloncha, Kakinada and Eluru divisions. The submergence zone will stretch along the Sabari River, a tributary of the Godavari, up to the borders of Orissa and Chhattisgarh.

2.2 Background of the current study

Because of the above-mentioned reasons, the proposal to construct a multipurpose project across the Godavari River required a comprehensive environmental impact assessment, the wildlife being one of the main aspects of such a study. In this connection, according to the direction of the Ministry of Environment & Forests (MoEF), Government of India (vide their letter no. 8-123/2005-FC dated 26/29 December 2008), Point No. 7(ii), the Wildlife Institute of India (WII) was requested by the Government of Andhra Pradesh to assess the impact of the project on the wild flora and fauna and the habitat and subsequently suggest mitigatory measures for the same.

In response to the directions from MoEF, a rapid reconnaissance survey of the project site by WII was conducted with the support of the Government of Andhra Pradesh in November 2009. This was followed by a second reconnaissance survey (Assessment of Floral and Faunal Values in the Submergence Areas and Left and Right Canal Alignment of the Indira Sagar (Polavaram) Project) in the summer months of June and July 2010. Though the second survey identified few impacts on the movements of animals along the right and main canals, one of the main recommendations of the second survey was to conduct a detailed seasonal assessment of the terrestrial and aquatic components of the submergence zone in PNP as well as examine the possible impacts of the proposed dam on the downstream river ecology. Based on this, a detailed study (Assessment of Ecological Settings and Biodiversity Values of Papikonda National Park and Indira Sagar (Polavaram) Multipurpose Project Areas Impact Zone in Andhra Pradesh for Development of Mitigatory Measures) is being conducted by the WII since December 2012. The objectives of this study are listed in the following.

2.3 Review of impact of dams on biodiversity

Conflicts over dams have heightened in the last two decades largely due to the social, ecological and environmental impacts of dams that were either ignored in the planning process or were not adequately evaluated (WCD, 2000): first-order impacts that involve the physical, chemical and geomorphologic consequences of blocking a river and altering the natural distribution and timing of streamflow; second-order impacts that involve changes in the primary biological productivity of ecosystems, including effects on riverine and riparianplant life and on downstream habitats such as wetlands; or third-order impacts that involve alterations to the fauna (such as fish) caused by a first-order effect (such as blocking migration) or a second-order effect (such as a decrease in the availability of plankton). Modifying the ecosystem changes the biochemical cycle in the natural riverine system. Reservoirs interrupt the downstream flow of organic carbon, leading to emissions of greenhouse gases such as methane and carbon dioxide that contribute to climate change.

2.4 Terrestrial biodiversity

Terrestrial biodiversity plays an important role in ecosystems. Filling of a dam/reservoir results in permanent flooding of riverine and terrestrial habitats, and depending upon the topography and habitats of the river valley upstream of the dam, these impacts can vary greatly in extent and severity. The effects of inundation are especially severe when the reservoirs are situated close to mountains, in dry areas or at higher latitudes, where river valleys are usually the most productive landscape elements. Impoundment causes all terrestrial animals to disappear from the submerged areas, and populations decrease within a few years in proportion to the habitat area that is lost (Dynesius and Nilsson, 1994). Flooding can result in both local and global extinctions of animal and plant species. Particularly hard hit are the species dependent upon riverine forests, and other riparian ecosystems, and those adapted to the fast-flowing conditions of the main river course. From a biodiversity conservation standpoint, the terrestrial natural habitats lost to flooding are usually much more valuable than the aquatic habitats created by the reservoir (McAllister et al, 1999).

2.4.1 National level

India has a high level of biodiversity. Geological events in the landmass of India have provided conditions for high levels of biological diversity. A split in the single giant continent that existed around 70 million years ago, led to the formation of northern and southern continents, with India a part of Gondwanaland—the southern landmass—together with Africa, Australia and the Antarctic. Later tectonic movements shifted India northward across the equator to join the northern Eurasian continent. As the intervening, shallow Tethys Sea disappeared, plants and animals that had evolved both in Europe and in the Far East migrated into India before the Himalaya formed. A final influx came from Africa with Ethiopian species, which were adapted to savannas and semi-arid regions. Thus India's special geographical position between three distinctive centres of biological evolution and radiation of species is responsible for our rich and varied biodiversity. Among the biologically rich nations, India stands among the top 10 or 15 for its great variety of plants and animals, many of which are not found elsewhere. India has 350 different mammals (rated eight highest in the world), 1200 species of bird (eighth in the world), 453 species of reptile (fifth in the world) and 45,000 plant species, of which most are angiosperms (15th in the world). This flora includes an especially high species diversity of ferns (1022 species) and orchids (1082 species). India has 50,000 known species of insect, including 13,000 butterflies and moths. It is estimated that the number of unknown species is several times higher. It is estimated that 18% of Indian plants are endemic to the country and found nowhere else in the world. Among the plant species, the flowering plants have a much higher degree of endemism, and a third of these are not found elsewhere in the world. Among the amphibians found in India, 62% are unique to this country. Among lizards, of the 153 species recorded, 50% are endemic. High levels of endemism have also been recorded among various groups of insects, marine worms, centipedes, mayflies and freshwater sponges.

2.4.2 International

There are at present 1.8 million species known and documented by scientists in the world. However, scientists have estimated that the number of species of plants and animals on earth could vary from 1.5 to 20 billion. Thus the majority of species are yet to be discovered. Some large dam projects have tried to mitigate terrestrial impacts on biodiversity by physically rescuing animals from the area to be flooded or have anticipated that mobile species will simply move to neighbouring areas. Operation Noah and Operação Curupira are two examples undertaken at the Kariba and Tucurui dams. The respective World Commission of Dam Case Studies show that neither programme yielded tangible benefits for the wildlife involved. This may be a result of the implicit and probably incorrect assumption that the recipient habitat was not already at carrying capacity for the species concerned. An alternative to mitigation is the compensatory project approach, involving environmental 'offsets'. For example, in India there is a legal requirement that forests flooded by reservoirs must be replanted elsewhere. However, the India Case Study found that only half of the required forest is typically planted—and even this is poorly managed, yielding little in the way of comparable benefits or services. Additional compensatory measures may include either trust funds established through grants from developers (for example Harvey Basin Restoration Trust, Australia) or trust funds that manage parts of the revenue stream and use it for environmental purposes. This latter model is proposed for the planned Nam Theun II dam, in Laos, with the intention of creating and managing a national park in the catchment. The plan has the potential to benefit both forest ecosystems and the lifespan of the dam through reduced sedimentation (WCD, 2000).

2.5 Aquatic biodiversity

Aquatic biodiversity is the rich and wonderful variety of plants and animals from crayfish to catfish, from mussels to mayflies, from tadpoles to mahserr, that live in watery habitats (Helfrich et al, 2009). Aquatic ecosystems (habitats and organisms) include our rivers and streams, ponds and lakes, oceans and bays, and swamps and marshes and their associated animals. These species have evolved and adapted to watery habitats over millions of years. Aquatic habitats provide the food, water, shelter and space essential for the survival of aquatic animals and plants. The greater the diversity of habitats is, whether in water or on land, the greater the biodiversity will be. Coastal estuaries and mangrove swamps, for example, are 'edge' ecosystems that link saltwater and freshwater and trap nutrients that allow them to support a rich diversity of aquatic plants and animals. Generally, the more complex or larger the ecosystem is, the greater its biodiversity. The biodiversity in a limited area such as a drop of water is less than that in the ocean. Species diversity also tends to increase from the poles toward the equator and with increasing rainfall and decreasing elevation. Islands generally have lower species diversity compared with the nearby mainland.

2.5.1 International

Freshwater ecosystems may well be the most endangered ecosystems in the world. Declines in biodiversity are far greater in freshwaters than in the most affected terrestrial ecosystems (Sala et al, 2000). Over 10,000 fish species live in freshwater (Lundburget al, 2000)—approximately 40% of global fish diversity and one quarter of global vertebrate diversity. When amphibians, aquatic reptiles (crocodiles, turtles) and mammals (otters, river dolphins and platypus) are added to this freshwater-fish total, it becomes clear that as much as one third of all vertebrate species are confined to freshwater. Yet surface freshwater habitats contain only around 0.01% of the world's water and cover only about 0.8% of the Earth's surface (Gleick, 1996). Another way of looking at this is to ask, How many of the species described by scientists live in freshwater? The answer is, around 1,00,000 out of approximately 1.75 million (Hawksworth and Kalin-Arroyo, 1995) (almost 6%), and an additional 50,000 to 1,00,000 species may live in ground water

(Gibert and Deharveng, 2002). Given the rate at which humans are degrading freshwaters, it is literally true that we would loose many freshwater species soon.

2.5.2 National

In India, forests and grasslands are continuously being changed to agricultural land. Encroachments have been legalized repeatedly. Similarly, natural wetland systems have been drained to establish croplands, resulting in loss of aquatic species. The River Gangesis the largest river in India and the fifth longest in the world.

The Godavari River is the second largest river in India, with a catchment area of 312,812 km^2 and a long-term average annual surface flow of 110 km^3, of which 76 km^3 is estimated as utilizable (Amarasinghe et al, 2005). The cultivable area in the basin is about 18.9 million ha. The existing Arthur Cotton Barrage, located downstream of the future Polavaram Reservoir site, provides irrigation water to about 1,70,000 ha in the lower Godavari basin. As in other parts of India, the use of groundwater to meet irrigation water demands is also a common practice.

Mangroves are important among biological diversity in aquatic systems. Mangrove forests are considered to be highly productive tropical ecosystems (Clough, 1992).

Chapter 3

OBJECTIVES OF THE STUDY

i. To determine the current status of the wildlife habitat and distribution pattern of mammals, birds, herpetofauna and fishes within PNP and the submergence zone of the Polavaram Project area;

ii. To study the distribution pattern and status of aquatic vertebrates in the project area, including the national park;

iii. To identify corridors and migratory paths of important wildlife species, keystone habitats within the conservation area and the impact of the project on these values; and

iv. To develop mitigatory measures as part of the biodiversity management plan of the extended PNP and the environmental management plan of the Indira Sagar (Polavaram) Multipurpose Project.

Figure 3.1 Dam construction area

Chapter 4

GEOGRAPHICAL SCOPE OF THE STUDY

i. The submergence zone of the proposed Indira Sagar Multipurpose Project, extending into PNP; and
ii. the Godavari River basin from PNP to Godavari estuary (the distributary Gowthami) in Yanam, Pondicherry.

The landscape along the Right and Left canals was not included in the scope of tje current study as it was predicted after the second reconnaissance survey that there would be very little or no impact on the forests or wildlife along the two canals. The focus of this study was on the submergence zone and the aquatic ecology of the river.

4.1 Papikonda WLS and PNP

An area of over 591 km^2 extending across Khammam, East Godavari and West Godavari districts was declared a wildlife sanctuary by the Government of Andhra Pradesh (vide its gazette notification beats). In view of the proposed Polavaram Project, Papikonda WLS was renotified a national park (vide G.O.Ms. No. 144, dt. 4 November 2008), with the inclusion of an additional 421 km^2. The areas included were Rampachodavaram, of Kakinada Division, in East Godavari District, and Chintoor, of Bhadrachalam Division, in Khammam District.

Figure 4.1 Fishermen in Karuturu village, PNP, with the Papi Hills in the background

The Papikonda Hill Range is an unbroken chain of rugged hills and plateaus that form one end of the Eastern Ghats. PNP has the typical southern tropical dry deciduous forest and southern tropical moist deciduous forest types intermingled with scrub vegetation (Champion and Seth, 1968). The importance of this landscape has been recognized internationally, with the eastern Deccan Plateau moist forests of the northern Eastern Ghats being designated a Global 200 Ecoregion (WWF, 2007). The floral wealth is dominated by *Cleistanthus collinus, Chloroxylon swietenia, Tectona grandis, Terminalia tomentosa, Adina cordifolia, Hardwicki abinata, Anogeissus latifolia, Ficus* sp., *Dalbergia sissoo* and *Butea monosperma*. and the undergrowth is composed of *Helicteres isora* and *Grewia hirsuta*. The faunal wealth includes *Panthera tigris, P. pardus, Bos gaurus, Tetracerus quadricornis* and *Anthracoceros coronatus*. The submergence zone may also harbour the golden gecko *Calodactylodes aureus* (Beddome, 1870; Javed et al, 2007), which is endemic to the Eastern Ghats. The WII conducted a country-wide survey during 2006 to determine the status of tigers, co-predators and prey. The results of this report has revealed the occurrence of tigers in the four beat areas of the submergence zones, viz. Valamuru (Maredumilli Range, Kakinada Division), Maredupudi (V.R. Puram Range, Bhadrachalam South Division), Pochavaram (V.R. Puram Range, Bhadrachalam South Division) and Kakeshnoor (Kukunoor Range, Paloncha Division) (Jhala et al, 2008).

4.2 Coringa WLS

Coringa WLS, a part of the Godavari mangrove, was declared a sanctuary in July 1978 to conserve the mangrove vegetation of the estuary, which extends over an area of about 236 km^2. It has three reserve forests, namely Coringa RF, Coringa Extn RF and Bhairavapalem RF. Most of the stretches of mangroves in the sanctuary are not directly connected with the Bay of Bengal. The Gaderu and Coringa rivers are distributaries of the Godavari River. The mangroves of Coringa WLS receive tidal flushing through the Matlapalem canal, Coringa River and Gaderu River. The other six reserve forests, namely Rathikalava RF, Masanitipa RF, Balusutippa RF, Kothapalem RF and Kandikuppa RF, are situated on the southern side of the Nilarevu River and fall in the non-sanctuary area. The sanctuary has the unique distinction of having an 18 km long sand spit in the north-eastern side (Hope Island), where sea turtles such as olive ridley turtle nest during January–March every year. The sand spit of Hope Island has changed with time and has grown nearly 2.6 km between 1937 and 2001 (Ramasubramaniyan et al, 2006).

Figure 4.2. Coringa WLS

4.3 Godavari estuary

The Godavari is the largest of the rivers of the Indian peninsula. Upon reaching the eastern coastal plain, downstream of the dam at Dowlaiswaram (near Rajahmundry), the river divides into two main distributaries, the Gautami and the Vasishta, which give rise to a sprawling estuarine deltaic system fringed with tidal creeks and dense mangrove forests before they reach the Bay of Bengal. Along this arcuate delta, the position and orientation of ancient beach ridges reveal sea level fluctuations and progradation of the delta. The Godavari estuary is the largest mangrove forest in the State of Andhra Pradesh and second in India. It is a region with high biodiversity value and includes the Coringa WLS and numerous coastal and marine features. Since 1971, when the first hydrographic report appeared, the Godavari estuary has received a lot of attention, especially in the wake of recent extensive aquaculture activity. Estuarine is well mixed with the tidal effect dominating in the lean season. The (semi-diurnal) tidal amplitude is 0.5–2 m.

Chapter 5

GENERAL METHODOLOGY

In order to comprehensively assess the impacts of the proposed multipurpose project on the ecology of the region, holistic analyses of both the terrestrial and aquatic flora and fauna of the area are imperative. Keeping this in mind, the current study was divided into two broad components, viz. the terrestrial and aquatic components. The study period was from December 2012 to July 2013.

The terrestrial component focused on seasonal analyses of the flora and fauna of the submergence zone falling within PNP. Line transects, pellet counts and trial walks were conducted to assess the density of ungulates, carnivores and other mammals. Point counts were undertaken for estimating the bird species diversity index in the forested landscape. Quadrate studies and time constraint searches were conducted to encounter the rate of the herpetofauna as well as its diversity in the study area.

In order to study the aquatic ecology of the river, fishes species were chosen for detailed analysis. Sampling was conducted to determine the distribution of various freshwater species in the entire stretch of the river from PNP to Yanam, Pondicherry. The streams and other natural water bodies forming the catchment basin of the river inside PNP were also sampled.

In addition, a novel biomonitoring technique of studying riparian vegetation, involving the use of the Riparian Vegetation Index, was also employed in the study. This technique helps assess the general 'health' of a particular river and may also act as an important biomonitoring tool for such multipurpose projects in the future.

The subsequent sections provide details of the various methodologies used in the study and discuss the results of the terrestrial and aquatic assessment. The current trend of the discharge of the river being seasonal and future flow requirements are discussed in a separate section.

Figure 5.1 Flora and fauna of PNP

For the purposes of the present study, the geographic scope was the forest areas that have been identified for diversion for submergence and construction of the dam and other facilities. Their extent amounts to 3267 ha in PNP in the Badrachalam, Eluru and Kakinada forest divisions of the Khammam and Rajahmundry circles of Andhra Pradesh.

The general forest type in the geographic scope of the study area is dry deciduous teak forest with bamboo, *Pterocarpus*, *Cassia* and other species dominating, conforming to the Eastern Ghats vegetation. The forest types in the Bhadrachalam (S), Polancha and Kakinada forest divisions, in which PNP is located, are described in the following.

a. Badrachalam (South) Forest Division

The total area required for diversion is approximately 2271 ha, of which, 13 ha (of Rekhapalli Hill RF) falls under Papikonda WLS and PNP. There are a total of 5,63,884 trees and 1,25,400 bamboo culms in this region. The main species among the flora are *Cleistanthus collinus, Chloroxylon swietenia, Wrightia tinctoria, Lannea coromandelica, Adina cordifolia, Terminalia tomentosa, Tectona grandis, Hardwickia binata, Pterocarpus marsupium, Strychnos nux-vomica, Tamarindus indica*, *Syzigium cumini* and *Xylia xylocarpa*. The major species reported from the fauna are the tiger, leopard, spotted deer, wild boar, sambar and gaur (Gujja et al, 2006).

b. Polancha Forest Division

About 533.61 ha of forest land is required for diversion, of which 88.81 ha falls within PNP, near Perantapalli. There are a total of 2,07,692 trees and 14,152 bamboo culms. The estimated volume of tree growth is 14,027.12 m^3 of timber, and 21,721 m^3 of fuelwood. The main species among the flora of the region are *Cleistanthus collinus, Chloroxylon swietenia, Wrightia tinctoria, Lannea coromandelica, Terminalia tomentosa, Tectona grandis, Diospyros melanoxylon, Holarrhena antidysenterica, Somyda fabrifuga, Albizia amara, Lagerstroemia parviflora, Anogeissus latifolia* and *Madhuca indica* (Gujja et al, 2006).

c. Kakinada Forest Division

The forest land required for diversion from this division is approximately 149.45 ha, of which 14.13 ha is within PNP. There are a total of 20,022 trees and 34,335 bamboo culms. The volume of fuel and timber from the trees is estimated to be 874 m^3 and 7 m^3, respectively. The main species of the flora of this region are *Cleistanthus collinus, Chloroxylon swietenia, Wrightia tinctoria, Lannea coromandelica, Terminalia parviflora, Tectona grandis, Adina cordifolia, Hardwickia binata, Pallaquium ellipticum, Pterocarpus marsupium, Pterospermum xylocarpum, Semecarpus anacardium, Strychnos potatorum, S. nux-vomica, Tamarindus indica, Syzigium cumini, Xylia xylocarpa, Flacourtia indica, Zizyphus xylopyrus, Anogeissus latifolia,* *Dalbergia paniculata, Bridelia montana, Casearia elliptica* and *Sterculia villosa*. The major species of the fauna are the tiger, leopard, spotted deer, wild boar, sambar, gaur, four-horned antelope, hyaena, sloth bear and peafowl (Gujja et al, 2006).

To conduct the floral and faunal assessment, a total of 13 beats of PNP were selected that lie within the submergence zone of the proposed Indira Sagar Multipurpose Irrigation Project. Sites with forest land and croplands were randomly selected from the submergence maps provided by the Irrigation Department and Forest Department of Andhra Pradesh. Sampling was carried out in these beats from December 2012 to May 2013.

Different methods were adopted for collection of data on different groups of fauna and flora. Each method is explained in the following.

1. ***Trail walks/sign surveys*:** The relative abundance of the carnivores and other mammals occurring in the proposed area was obtained from data on their presence or absence and intensity of use of a beat/unit of forest area by them. Forest roads, footpaths, riverbeds, nallahs and unused metal roads were used for trial walks. A 4–5 km long trial walk was carried out in each beat/sampling unit to search for signs of carnivores and other mammals. The total time spent, a brief description of the topography, the forest type, the weather and human disturbances, if any, were recorded during the trial walk. Carnivore signs were classified as (1) pugmark trails, (2) scats (old—dry with hair and bones visible; fresh—dry but intact with shiny surface; very fresh—soft, moist and smelly), (3) scrapes, (4) scent marks (spray, rolling), (5) rake marks on trunks, (6) actual sightings, (7) roaring (vocalization) or (8) kills (predation on wild prey). Apart from these details, the numbers of other mammals encountered, with their group compositions, were recorded.

2. ***Camera trapping*:** Remotely triggered cameras (camera traps) have been widely used all over the world for surveys of elusive carnivores and for estimating populations. By having a sufficient number of camera traps at

the appropriate places, it is possible to get an estimate of the number, based on the widely used mark–recapture model, with a low coefficient of variation. Other valuable information such as the sex of the animal and whether it has littered can also be obtained. We used Cuddeback camera traps in the submerged area for animal presence at randomly selected locations.

3. ***Line transects*:** Line transects were used to estimate the ecological densities of ungulates and primates and to determine their habitat use in the proposed submergence zone of the protected area. A beat was considered as the unit for sampling. After considering the shape, size, vegetation and terrain type of the beat (Burnham et al, 1980), 1–3 transect lines of a minimum length of 2 km were marked for sampling. For each transect the coordinates (latitude and longitude) of the beginning and end were recorded using a global positioning system device. The broad forest type and terrain type that the transect traversed were also recorded. Each transect was walked during the early morning hours (6:30 AM to 8:30 AM) and was replicated either in evening (4:00 PM to 6:30 PM) or the next morning, depending on the local conditions. The following were recorded for each animal sighting: time of sighting, species name, number of individuals sighted, sighting distance, angular distance, age structure, sex and activities. Human disturbance, habitat quality, invasion of weeds, broad category of vegetation, etc. were also recorded along the transect by laying 15 m radius circular plots at 400 m intervals.

4. ***Pellet counts*:** The relative abundance of ungulates was estimated using pellet counts in the proposed submergence zone in PNP. This exercise was done on the same line transect that had been sampled for estimating ungulate populations. Every 400 m along the transect (line of walk), an area 2 m by 20 m, perpendicular to the transect, was sampled for quantifying ungulate pellets. This was done using a 2 m long stick held

at the centre horizontally in the hand and walking slowly, 20 m right and left of the transect alternately every 400 m. All ungulate pellets encountered were identified to ungulate species, and the number of faecal pellets was counted. Where the pellets occurred in large heaps, they were categorized as A (50–100), B (100–200) or C (>200). In areas where small livestock such as sheep and goats were known to graze, their faecal pellets may be confused with those of wild ungulates, especiallyspotted deer. In such areas, a mention was made of the fact that goats or sheep graze the area.

5. ***Vegetation:*** The status of the vegetation was estimated by laying 10 m radius plots every 200 m on the 2 km long transects. The species, with numbers and GBH, were recorded to estimate their basal area, relative density and dominance. The ground cover was estimated by recording the percent cover of dry and green grass, herbs, shrubs and weeds in a 1 m radius circular plot every 200 m along the transect. Vegetation sampling was conducted only once between December 2012 and March 2013.

6. ***Human disturbance:*** The anthropogenic pressure on the site was estimated by recording the presence of woodcutting, lopping, grass/bamboo cutting, presence of humans/livestock/trails every 200 m along the transect on a scale of 0–4 (0 being nil and 4 being very high).

7. ***Bird distribution:*** Point count method was used for preparing a bird species diversity index in the forested landscape under the submergence zone. The habitat usage as well as habits of each bird species was also recorded to assess the important habitats used by them in the submergence zone. In each beat, at least one bird count was conducted.

8. ***Herpetofauna:*** Quadrat surveys and time constraint searches were conducted to determine the rate of encounter of the herpetofauna as well as the diversity in the study area from December 2012 to December 2013.

Chapter 6

STATUS AND DISTRIBUTION OF FAUNA AND FLORA IN THE SUBMERGENCE ZONE INSIDE PAPIKONDA NATIONAL PARK

6.1 Status and distribution of mammals

6.1.1 Overall

To assess the mammal density in the submergence area, we covered 26 transects, and the effort was 89.92 km, spanning 13 beats, 3 ranges and 3 divisions. We found a total of 47 common langur and 1 wild boar. We did not find any other species during the sampling. We had some opportunistic sightings of sambar and palm civet though.

6.1.2 Season-wise details

Jan–March

To assess the ecological densities of ungulates in the submergence zones, a total of 21 linear transects were walked covering 13 beats in 3 ranges, in 3 forest divisions. A total of 35.11km of transect was walked in the study area. Along the transects, only three sightings of common langur *Semnopithecus entellus* groups (n=18) were made. Opportunistic sightings of wild boar *Sus scrofa* (n=1) and hare (n=3) were also made in the study area. However, not a single ungulate was observed during the entire transect survey effort.

May–July

In May–July, a total of 25 linear transects (around 28.11 km) were walked, covering 13 beats in 3 ranges, in 3 forest divisions, within the study area. Along the transects, only three sightings of common langur *Semnopithecus entellus* groups (n=18) and livestock (n=552) were made. Opportunistic sightings of wild boar *Sus scrofa* (n=1) and hare (n=1) were also made in the study area when the transects were walked. An opportunistic sighting, possibly of a sambar fawn, was made during an RVI survey in the forested river bank of Mallu Konda, near Tekuru village.

August–December

In winter i.e. AugustDecember, a total of 24 transects (around 26.71 km were walked, covering 13 beats in 3 ranges, in 3 forest divisions, within the study area. Along the transects, only three sightings of common langur *Semnopithecus entellus* groups (n=11) and livestock (n=507) were made. We did not have any opportunistic sighting of wild boar or any other ungulates.

6.1.3 Habitat–wise details

January–March

Forest

In winter we covered 5.6 km in the forest. A total of 4 transects covering 3 forest divisions, 3 ranges and 4 beats were walked within the study area. Along the transects, we did not get even one observation due to a high level of disturbance.

Agriculture

A total of 11 transects were laid on agricultural land, covering 12.76 km, 2 forest divisions, 2 ranges and 9 beats. Twelve common langur *Semnopithecus entellus* were recorded. We did not find any animals such as wild boar and other ungulates.

Mixed

We laid 6 transects in mixed habitats with forest and agricultural land. We covered 7.85 km, 3 forest divisions, 3 ranges and 5 beats. A total of 5 common langur *Semnopithecus entellus* were encountered. We did not get sightings of any ungulates.

May–July

Forest

In summer we covered 5.6 km in 4 transects in forest areas, covering 3 forest divisions, 3 ranges and 4 beats within the study area. Five common langur *Semnopithecus entellus* were encountered. We did not find any ungulates during the sampling.

Agriculture

A total of 15 transects were laid on agricultural land, covering 14.55 km, 2 forest divisions, 2 ranges and 9 beats. Five common langur *Semnopithecus entellus* were recorded. We did not find any animals such as wild boar and other ungulates.

Mixed

In mixed forests we laid 6 transects covering forests and agricultural land. We covered 7.85 km, 3 forest divisions, 3 ranges and 5 beats. A total of 5 common langur *Semnopithecus entellus* were encountered. We did not find any ungulates.

August–December

Forest

In winter we covered 6.2 km in the forest. There were a total of 4 transects covering 3 forest divisions, 3 ranges and 4 beats within the study area. Along the transects we did not get even one observation because of a high level of disturbance.

Agriculture

A total of 11 transects were laid on agricultural land, covering 10.96 km, 2 forest divisions, 2 ranges and 8 beats. Four common langur *Semnopithecus entellus* were recorded. We did not find any animals such as wild boar and other ungulates.

Mixed

In mixed forest we laid 6 transects covering forests and agricultural land. We covered 7.85 km, 3 forest divisions, 3 ranges and 5 beats. A total of 7 common langur *Semnopithecus entellus* were encountered. We did not record any other ungulates.

6.1.4 Ungulate pellet density in submergence zone

January–March

A total of 97 pellet count plots with an area of 0.388 ha were sampled during the present investigation. Two hundred and eighteen groups of cattle dung (mean=2.25±4.87) and 17 groups of hare pellets (mean=0.18±1.05) were observed. The densities of the cattle dung groups and hare pellet groups were calculated to be 561.88±1217.3 per hectare and 43.81±262.7 per hectare, respectively. Pellets of wild ungulates such as cheetal *Axis axis*, sambar *Rusa unicolor*, nilgai *Boselaphus tragocamelus* and wild boar *Sus scrofa* were not observed on the plots. There were also a few observations of sloth bear *Melursus ursinus* scats (n=3) during the hill transects.

May–July

Ninety-one pellet count plots were sampled during the present investigation. One hundred and eighteen groups of cattle dung (mean=1.29/ha) and 77 groups of goat pellets (mean=0.84/ha), 2 groups of sambar pellets (mean=0.021/ha), 2 groups of four-horned antelope pellets (mean=0.02/ha) and 48 piles of wild boar *Sus scrofa* pellets (mean=0.52/ha) were observed. Pellets of wild ungulates such as spotted deer *Axis axis* and nilgai *Boselaphus tragocamelus* were not observed on the plots. A few sloth bear *Melursus ursinus* scats (n=3) were also observed during the hill transects.

August–December

Eighty-eight pellet count plots were sampled during the present investigation. One hundred and sixty groups of cattle dung, 54 groups of goat pellets and 12 piles of wild boar pellets were observed. Pellets of ungulates such as spotted deer *Axis axis* and nilgai *Boselaphus tragocamelus* were not observed on the plots.

6.1.5 Carnivore abundance in the submergence zone

January–March

The sites were surveyed for presence or absence of carnivore species through indirect evidence such as pugmarks, scats, scraps, rakes and vocalization. Fourteen sign surveys covering 36.81 km of the study area yielded 8 carnivore signs, showing a low abundance of carnivores. During the surveys, scats of jungle cat *Felis chaus* (n=3, encounter rate=0.06 per km) and sloth bear *Melursus ursinus* (n=4, encounter rate=0.08 per km) were found in the agricultural and forest areas. A few unidentified scats were also collected and preserved for confirmation.

May–July

Four sign surveys covering 45.34 km of the study area yielded 8 carnivore signs, showing a low abundance of carnivores. During the surveys, scats of jungle cat *Felis chaus* (n=3, encounter rate=0.06 per km) and wild boar *Sus scrofa* were found in the agricultural and forest areas.

August–December

We conducted carnivore sign surveys in the submergence area. We covered 56 km of the submergence area in 14 sign surveys. During the survey we found sloth bear rake marks and scats and jungle cat scats. These were the only signs we found because the level of human disturbance was high.

Camera trapping

We carried out camera trapping in the submergence area to determine what species were present in the study area. We obtained images of only black-naped hare during the study period.

Figure 6.1 Camera trapping and images obtained

6.2 Bird density in submergence zone

Figure 6.2 Asian paradise flycatcher (male), very common in PNP

6.2.1 Season-wise details

January–March (winter)

A total of 101 species of bird belonging to 43 families were recorded by the present study in the study area (Table 6.1). The family Accipitridae dominates the list, with 6 species, followed by the family Motacillidae (5 species). Two species that visit in summer, viz. the pied cuckoo *Clamator jacobinus* and Asian paradise flycatcher *Terpsiphone paradisi*, were recorded along with 12 winter visitor species, viz. the ruddy shelduck *Tadorna ferruginea,* barn swallow *Hirundo rustica,* long-tailed shrike *Lanius schach,* blue-tailed bee-eater *Merops philippinus,* paddyfield pipit *Anthus rufulus,* yellow wagtail *Motacilla flava,* white wagtail *Motacilla alba,* Asian brown flycatcher *Muscicapa dauurica,* Eurasian golden oriole *Oriolus oriolus,* little stint *Calidris minuta,* common greenshank *Tringa nebularia* and black redstart *Phoenicurus ochruros.*

During the study, four Near Threatened species (Birdlife International, 2013), i.e. Indian darter *Anhinga melanogaster,* river lapwing *Vanellus duvaucelii,* white-throated flowerpecker *Dicaeum vincens* and black-headed ibis *Threskiornis melanocephalus*, were also reported.

A total of 312 point count plots were surveyed, with a survey effort of 390, in the study area. A total of 3135 birds were observed in 1088 independent observations. Analysis of point counts carried out using Distance 6.0 produced the following density estimates. A half-normal model with cosine adjustments was fitted to estimate the detection probability.

Table 6.1 Density of birds in the submergence zone of PNP (January–March)

Parameters	**Estimate (per ha)**	**Standard error**	**%CV**
Cluster density	23.55	4.7	20.8
Cluster size	2.16	0.5	2.6
Density	50.96	10.3	20.3

Figure 6.3 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density.

Table 6.2 List of birds (winter)

Sl. no.	Species	Diversity	Density(per ha)
1	Ashy drongo	0.013	0.10
2	Asian paradise flycatcher	0.002	16.5
3	Asian pied starling	0.054	0.51
4	Babbler	0.017	0.18
5	Black drongo	0.155	2.47
6	Black-hooded oriole	0.023	0.21
7	Black-naped oriole	0.002	1.10
8	Blue-tailed bee-eater	0.004	0.66
9	Blue-throated fly catcher	0.002	0.82
10	Bush chat	0.021	0.16
11	Cattle egret	0.307	3.12
12	Chestnut-headed bee-eater	0.01	0.47
13	Citrine wagtail	0.006	2.47
14	Common iora	0.013	0.86
15	Common myna	0.155	3.20
16	Cormorants	0.002	0.41
17	Coppersmith barbet	0.004	0.16
18	Crested serpent eagle	0.008	0.71
19	Cuckoo	0.008	0.14
20	Dove	0.017	0.19
21	Eagle	0.006	0.39
22	Golden-fronted leaf-bird	0.004	0.13
23	Great egret	0.02	1.21
24	Greater coucal	0.004	0.66
25	Green bee–eater	0.035	0.38
26	House crow	0.078	2.83
27	House sparrow	0.023	0.37
28	Indian robin	0.006	0.27
29	Indian roller	0.024	0.14
30	Intermediate egret	0.03	0.49
31	Lapwing	0.004	0.33
32	Large-billed crow	0.131	0.78
33	Legge's flowerpecker	0.002	0.81
34	Little cormorant	0.006	0.99
35	Long-tailed shrike	0.002	0.41
36	Oriental magpie–robin	0.02	0.16
37	Oriole	0.004	0.81
38	Owlet	0.002	0.33
39	Pale-billed flowerpecker	0.01	5.5
40	Parakeet	0.161	5.9
41	Peafowl	0.006	0.10

42	Pied bush chat	0.004	0.66
43	Pipits	0.006	0.39
44	Plain martin	0.32	15.49
45	Plum-headed parakeet	0.058	0.25
46	Pond heron	0.037	0.18
47	Purple-rumped sunbird	0.004	0.41
48	Purple sunbird	0.071	2.45
49	Raptor	0.008	0.4
50	Red-wattled lapwing	0.032	0.66
51	Red junglefowl	0.015	0.12
52	Redstart	0.008	0.14
53	Red-vented bulbul	0.18	4.67
54	Rose-ringed parakeet	0.023	0.47
55	Rufous tree–pie	0.027	0.20
56	Short-toed snake–eagle	0.004	0.13
57	Singing bush larks	0.002	0.41
58	Spangled drongo	0.006	0.80
59	Sparrows	0.013	1.02
60	Spotted dove	0.08	1.71
61	Sunbird	0.004	0.2
62	Swallows	0.234	1.05
63	Swifts	0.01	0.20
64	Tits	0.004	0.16
65	Unidentified birds	0.125	2.26
66	Warbler	0.004	0.86
67	Wagtail	0.013	3.30
68	Weaver birds	0.048	0.10
69	White-bellied drongo	0.013	0.58
70	White-breasted kingfisher	0.027	0.11
71	Yellow-wattled lapwing	0.02	0.41

May–July (summer)

A total of 176 point count plots were surveyed, with an effort of 390, in the study area. A total of 1295 birds were observed in 609 independent observations. Analysis of the point counts carried out using Distance 6.0 produced the following density estimates. A half-normal model with cosine adjustments was fitted to estimate the detection probability.

Table 6.3 Density of birds in the submergence zone of PNP (May–July)

Parameters	**Estimate**	**Standard error**	**%CV**
Cluster density	1083	98.6	9.11
Cluster size	10.2	0.5	3.08
Density	1762	169.4	9.62

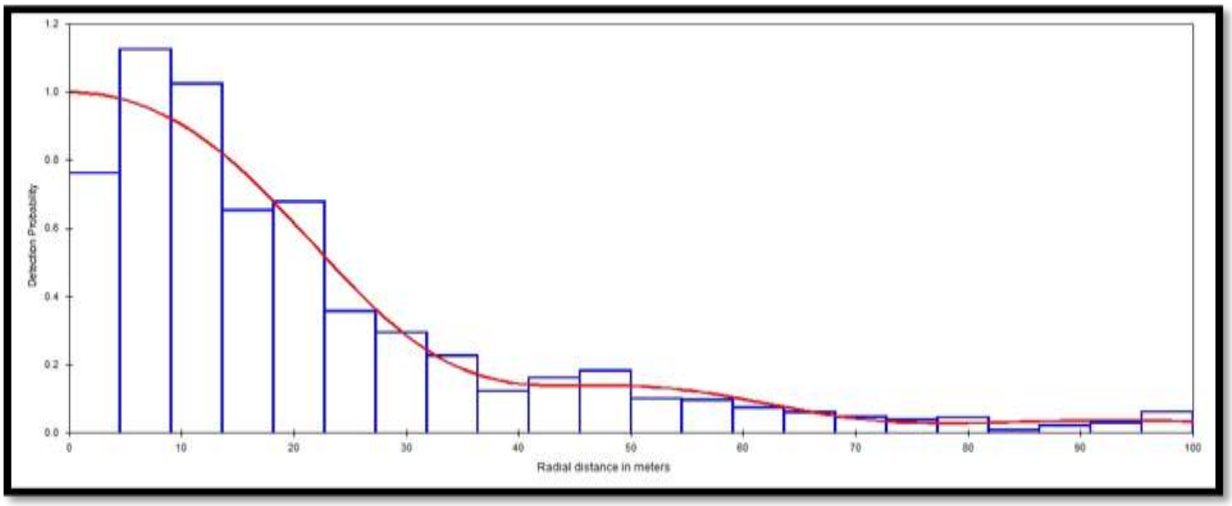


Figure 6.4 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density (May–July)**[Please approve the edits to the figure captions.]**

Table 6.4 List of birds (summer)

Sl. No.	**Species**	**Diversity**	**Density**
1	Asian pied starling	0.010	4.24
2	Ashy drongo	0.010	1.34
3	Ashy prinia	0.006	0.43
4	Ashy wood-swallow	0.022	4.12
5	Asian koel	0.010	2.31
6	Asian palm swift	0.272	17.51
7	Baya weaver	0.061	10.12
8	Black drongo	0.165	13.89
9	Black-hooded oriole	0.036	14.17
10	Black-shouldered kite	0.006	2.10
11	Blue-faced malkoha	0.006	1.0
12	Blue-tailed bee-eater	0.015	2.47

13	Blue-winged leaf-bird	0.015	3.01
15	Cattle egret	0.347	58.9
16	Chestnut-headed bee-eater	0.006	20.0
17	Common crow	0.168	2.89
18	Common iora	0.022	4.69
19	Common myna	0.129	30.94
20	Coppersmith	0.006	15.9
21	Cormorant	0.152	5.7
22	Drongo cuckoo	0.010	0.79
23	Egret	0.006	8.01
24	Eurasian golden oriole	0.006	0.66
25	Golden spectacled warbler	0.018	0.21
26	Great egret	0.010	9.45
27	Greater cormorant	0.010	9.32
28	Greater coucal	0.010	1.40
29	Greater flameback woodpecker	0.010	0.33
30	Green bee-eater	0.045	8.41
31	Grey-headed parakeet	0.010	1.0
32	House sparrow	0.006	0.62
33	Indian bush lark	0.010	11.21
34	Indian pitta	0.026	4.78
35	Indian robin	0.078	34.65
36	Indian roller	0.018	24.03
37	Intermediate egret	0.015	0.5
38	Jungle crow	0.061	9.34
39	Kingfisher	0.015	0.55
40	Lesser coucal	0.006	9.34
41	Little egret	0.022	1.06
42	Loten’s sunbird	0.010	0.47
43	Magpie–robin	0.022	0.38
44	Malabar whistling thrush	0.006	0.68
45	Plain martin	0.029	29.44
46	Oriental turtle dove	0.006	0.62
47	Osprey	0.010	8.93
48	Rose-ringed parakeet	0.110	48.2
49	Pied bush chat	0.018	21.08
50	Pied cuckoo	0.010	0.82
51	Pied starling	0.010	23.3
52	Plain prinia	0.010	2.74
53	Plum-headed parakeet	0.006	1.46
54	Pond heron	0.076	2.93
55	Purple sunbird	0.071	39.27
56	Red junglefowl	0.015	4.49
57	Redstart	0.010	0.96
58	Red-vented bulbul	0.175	5.85

59	Red-wattled lapwing	0.036	0.9
60	Red-whiskered bulbul	0.006	1
61	Rose-ringed parakeet	0.100	48.2
62	Rufous-fronted prinia	0.006	42
63	Rufous tree–pie	0.015	2.1
64	Spangled drongo	0.006	8.76
65	Spotted dove	0.104	17.31
66	Swallows	0.029	0.52
67	Warbler	0.022	2.7
68	White-bellied drongo	0.006	0.52
69	White-breasted kingfisher	0.026	1.11
70	White-breasted waterhen	0.022	0.4
71	White-browed bulbul	0.018	4
72	White-rumped shama	0.015	5.6
73	White-throated fantail	0.006	4.9
74	Yellow-footed green pigeon	0.022	0.53

August-December

Table 6.5 Density of birds in the submergence zone of PNP (August–December)

Parameters	**Estimate**	**Standard error**	**%CV**
Cluster density	23.55	0.34	5.92
Cluster size	2.15	0.5	2.5
Density	12.54	0.80	6.45

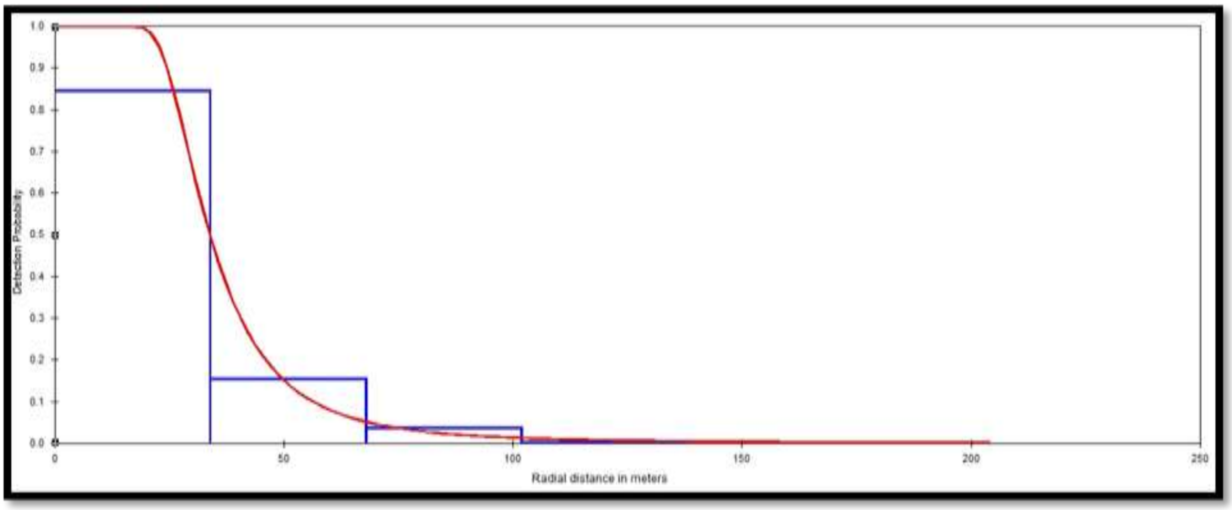


Figure 6.5 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density (August–December)

Table 6.6 List of birds (monsoon)

Sl. no.	Species	Diversity	Density
1	Alexandrine parakeet	0.003	0.33
2	Ashy drongo	0.011	0.1
3	Ashy prinia	0.006	1.6
4	Asian pied starling	0.072	0.51
5	Babbler	0.021	0.2
6	Black drongo	0.163	3.41
7	Black-hooded oriole	0.031	0.21
8	Black-shoulder kite	0.015	0.6
9	Blue-tailed bee-eater	0.006	1.6
10	Bush chat	0.027	1.1
11	Cattle egret	0.301	4.7
12	Chestnut-headed bee-eater	0.017	0.47
13	Common hoopoe	0.009	0.26
14	Common iora	0.015	0.86
15	Common myna	0.185	3.2
16	Coppersmith barbet	0.003	0.33
17	Cormorants	0.003	0.33
18	Coucal	0.006	1.65
19	Crested serpent eagle	0.009	0.81

20	Cuckoo	0.011	0.14
21	Dove	0.017	0.19
22	Eagle	0.006	1.6
23	Gold-fronted leaf-bird	0.006	1.6
24	Golden oriole	0.006	1.6
25	Greater coucal	0.006	0.66
26	Green bee–eater	0.044	0.39
27	House crow	0.094	1.7
28	House sparrow	0.019	0.53
29	Indian robin	0.036	0.27
30	Intermediate egret	0.027	0.49
31	Large-billed crow	0.142	2.62
32	Little cormorant	0.009	0.99
33	Oriental magpie-robin	0.019	0.15
34	Pale-billed flowerpecker	0.013	5.5
35	Pied bush chat	0.006	0.66
36	Pied crested cuckoo	0.003	0.33
37	Pipits	0.003	0.39
38	Plain martin	0.347	34.94
39	Plum-headed parakeet	0.019	0.24
40	Pond heron	0.017	0.37
41	Purple sunbird	0.086	2
42	Red-wattled lapwing	0.011	0.76
43	Red junglefowl	0.019	0.12
44	Redstart	0.011	0.14
45	Red-vented lapwing	0.037	0.82
46	Red-vented bulbul	0.201	4.67
47	Rose-ringed parakeet	0.197	0.91
48	Rufous tree–pie	0.034	0.12
49	Short-toed snake eagle	0.006	0.13
50	Sky lark	0.009	1.32
51	Spangled drongo	0.009	0.8
52	House Sparrow	0.015	0.53
53	Spotted dove	0.095	1.71
54	Sunbird	0.006	0.29
55	Swallows	0.041	1.05
56	Swifts	0.013	0.38
57	Tits	0.006	0.16
58	Wabler	0.050	1.04
59	Wagtail	0.003	3.3
60	Weaver birds	0.060	0.1
61	White-bellied drongo	0.015	0.58
62	White-breasted kingfisher	0.032	1.53
63	White-rumped shama female	0.003	1.1
64	Yellow-wattled lapwing	0.023	0.47

6.2.2 Habitat wise

January–March

Agriculture

Table 6.7. Abundance of birds in the agriculture fields.

Parameters	Estimate	Standard error	%CV
Cluster density	0.88	0.33	7.10
Cluster size	2.27	0.12	5.52
Density	0.20	0.98	9.31

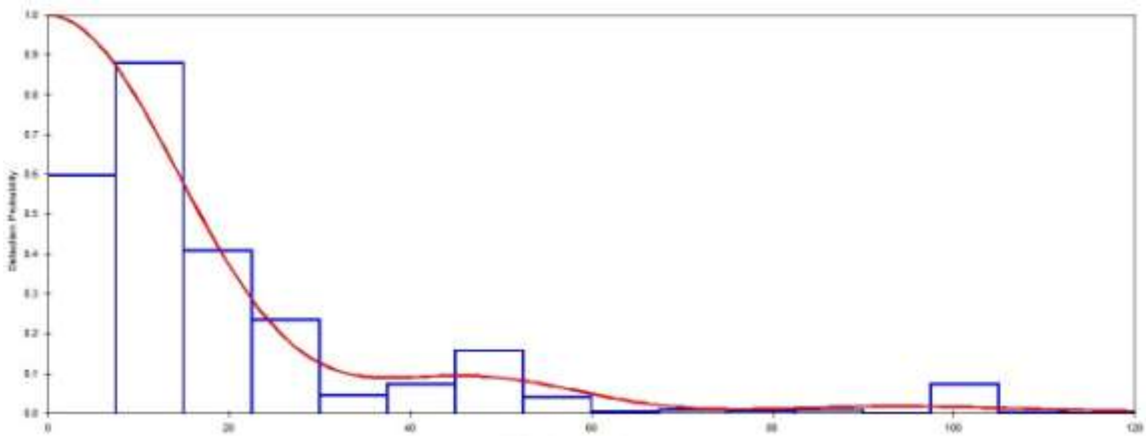


Figure 6.6 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density in agricultural land

Forest

Table 6.8. Abundance of birds in the forested habitats.

Parameters	**Estimate**	**Standard error**	**%CV**
Cluster density	0.52	0.24	7.9
Cluster size	1.83	0.15	7.5
Density	0.96	0.06	1.02

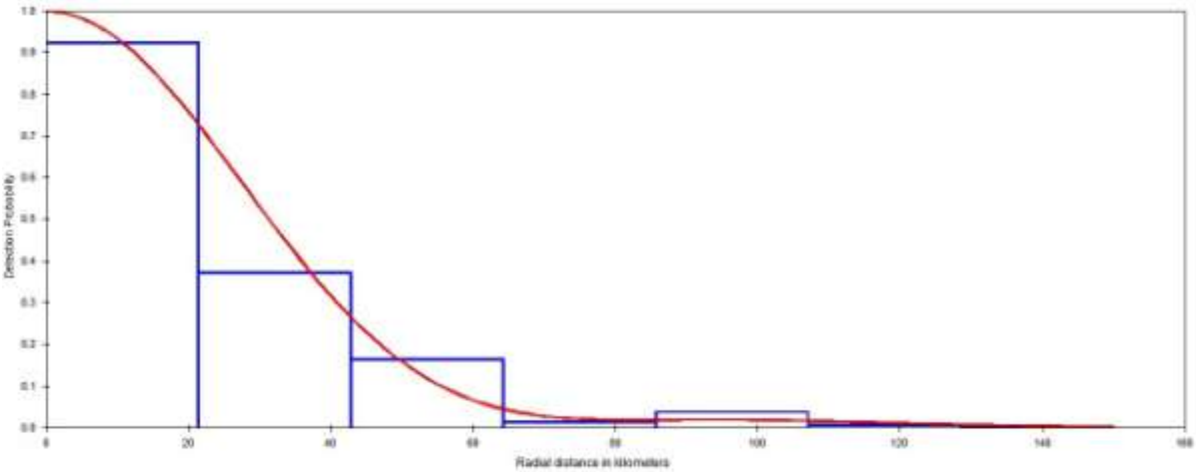


Figure 6.7 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density in forests

Mixed

Table 6.9. Abundance of birds in the mixed or mosaic habitats.

Parameters	**Estimate**	**Standard error**	**%CV**
Cluster density	0.35	0.08	2.9
Cluster size	2.87	0.22	7.9
Density	0.10	0.04	2.4

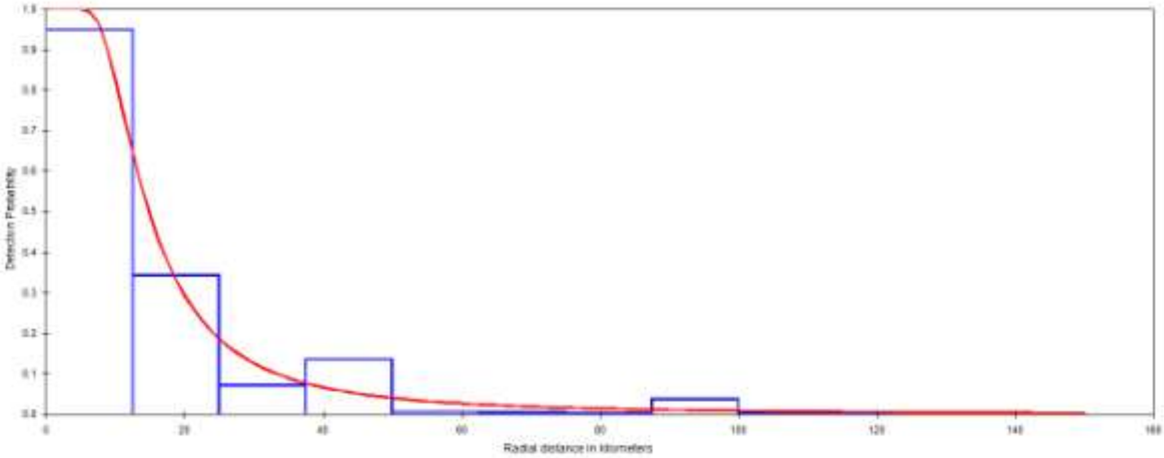


Figure 6.8 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density in mixed-use land**[Edit OK?]**

May–July

Agriculture

Table 6.10**.** Abundance of birds in the agriculture fields.

Parameters	**Estimate**	**Standard error**	**%CV**
Cluster density	3.6	1.2	4.1
Cluster size	1.8	0.10	2.1
Density	6.6	0.4	2.5

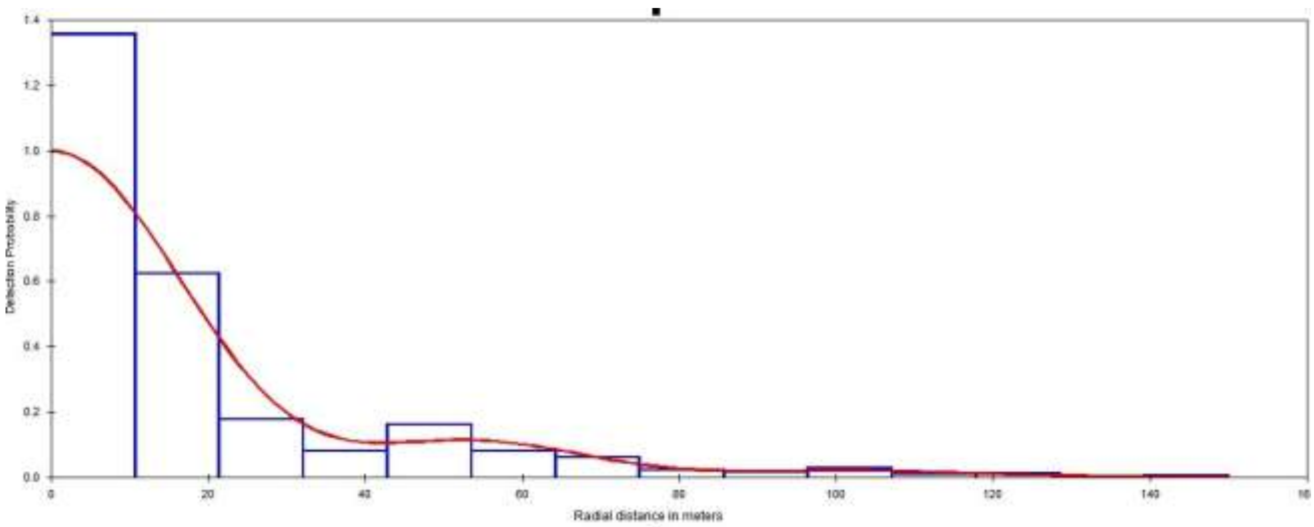


Figure 6.9 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density in agricultural land

Forest

Table 6.11. Abundance of birds in the forested habitats.

Parameters	**Estimate**	**Standard error**	**%CV**
Cluster density	5.4	1.7	2.6
Cluster size	1.40	0.5	4.1
Density	7.6	2.4	2.5

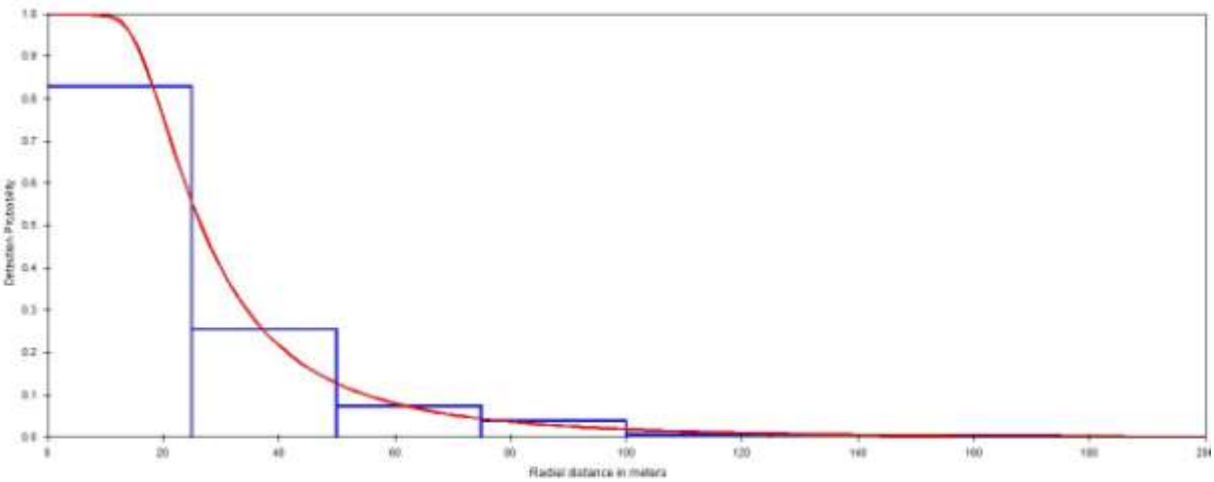


Figure 6.10 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density in forests

Mixed

Table 6.12**.** Abundance of birds in the mixed or mosaic habitats.

Parameters	**Estimate**	**Standard error**	**%CV**
Cluster density	3.28	0.6	9.31
Cluster size	2.08	0.19	9.35

Density	6.87	0.67	1.3

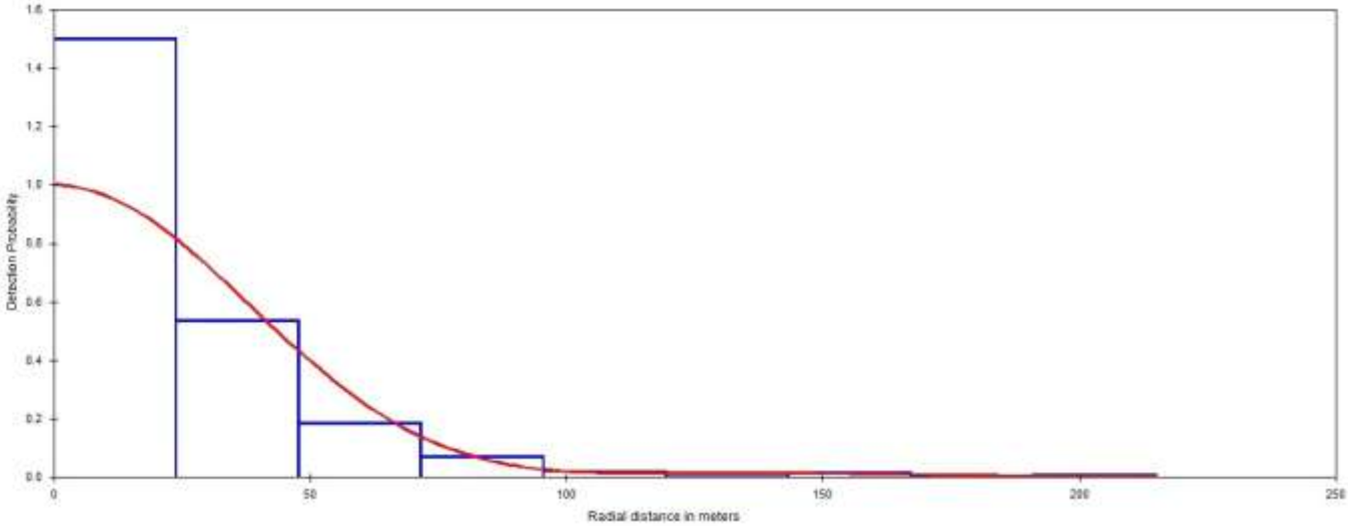


Figure 6.11 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density in mixed-use land**[Edit OK?]**

August–December

Agriculture

Table 6.13**.** Abundance of birds in the agriculture fields.

Parameters	**Estimate**	**Standard error**	**%CV**
Cluster density	5.03	0.3	7.2
Cluster size	2.5	0.1	5.9
Density	13.06	1.2	9.3

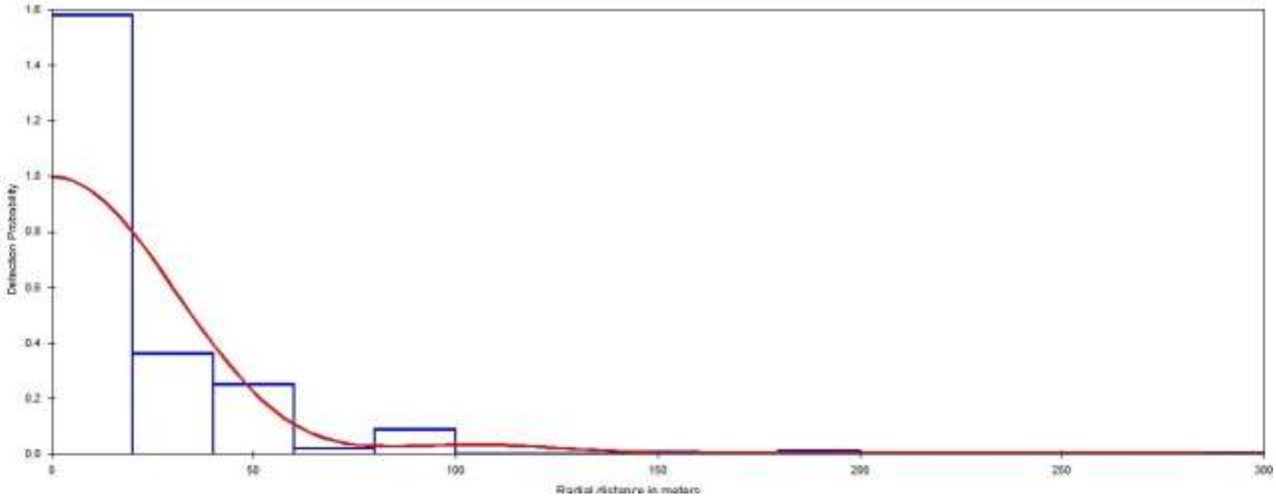


Figure 6.12 Results obtaind by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density in agricultural land

Forest

Table 6.14. Abundance of birds in the forested habitats.

Parameters	**Estimate**	**Standard error**	**%CV**
Cluster density	4.34	4.9	11.3
Cluster size	1.8	0.1	5.8
Density	8.1	12.0	4.6

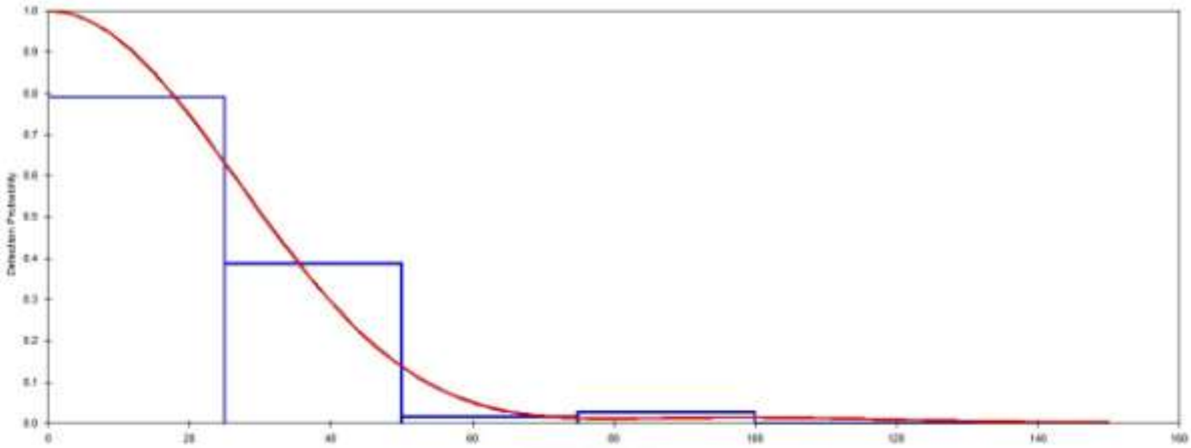


Figure 6.13 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density in forests

Mixed

Table 6.15**.** Abundance of birds in the mixed or mosaic habitats.

Parameters	**Estimate**	**Standard error**	**%CV**
Cluster density	5.72	0.9	12
Cluster size	2.2	0.19	8.6
Density	12.97	1.9	5.09

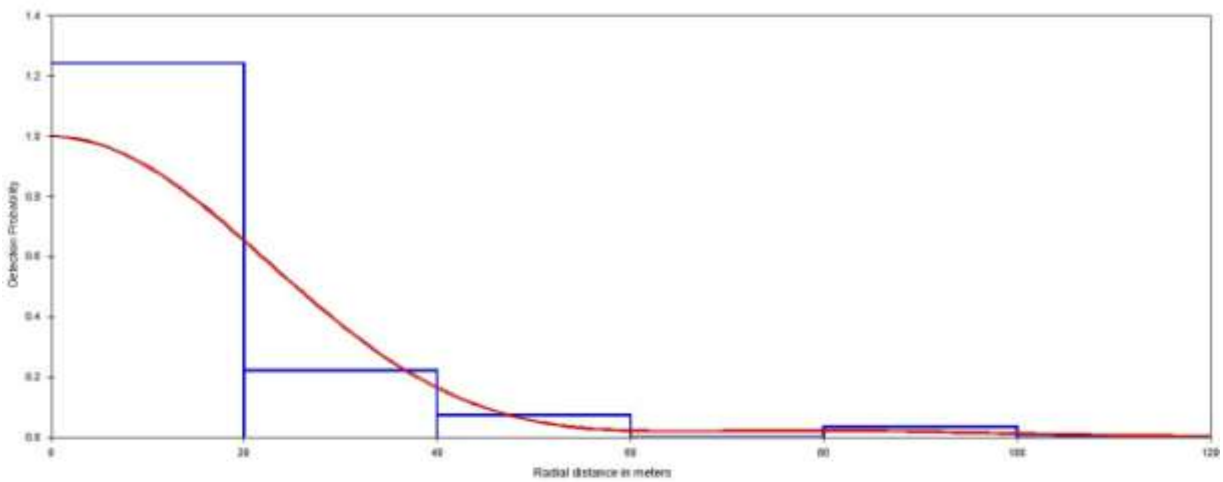


Figure 6.14 Results obtained by fitting half-normal model with cosine adjustments in Distance 6.0 to estimate the bird density in mixed-use land

6.3 Herpetofaunal diversity in submergence zone

Figure 6.15 Golden gecko found in submergence zone in PNP

To estimate the reptile density, 27 plots of area 625 m^2 each were laid along the line transects in the study area. Some random plots were also laid in the submergence zone. Among the reptiles, 2 species of gecko, *Hemidactylus* sp. and *Psammophilus blanfordanus*, belonging to the family Agamidae were recorded. Three species of snake, viz. Duméril's

Figure 6.16 Golden gecko eggs found in PNP**.**

black-headed snake *Sibynophis subpunctatus*, common kukri O*ligodon arnensis* and checkered keel-back *Xenochrophis piscator* (family Colubridae), have been identified till now. Identification of of the other reptile species recorded is in progress.

6.4 Vegetation

Borassus flabellifer, Tectona grandis, Cleistanthus collinus, Anogeissus latifolia, Anacardium occidentale and *Chloroxylon swietenia* were some of the dominant tree species found in the area. Among the 22 shrub species, *Scutia indica, Barleria prionitis, Murraya exotica, Cassia auriculata* and *Croton tiglium* were most common. The invasive species commonly encountered in the vegetation plots were *Calotropis gigantea, Lantana camara, Parthenium hysterophorus, Chromolaena odorata*, etc.

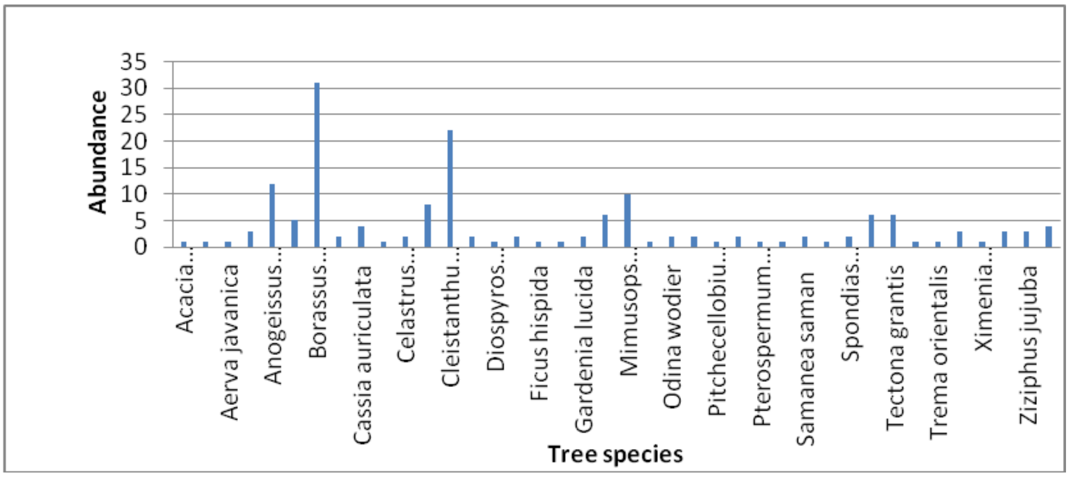


Figure 6.17 Relative abundance of floral species in submergence zone of PNP

6.5 Human disturbance

Figure 6.18 Tourist boat at Koruturu village, in PNP

Anthropogenic pressure data were also collected from the study area. Human trails were very common in the sampled area. Weed abundance, wood cutting, wood lopping and grass and bamboo cutting were also prevalent. Since many of the study plots were situated in agricultural fields, encounter rates of humans and livestock were also high. The high level of human disturbance recorded in the study area was expected since several agricultural villages lie in the submergence zone along the river. The villagers are also highly dependent on the surrounding forests for fuelwood, fodder, medicines, etc. Due to the high level of human disturbance in the study area, a very low abundance of animals was found. Opportunistic sightings of sambar and a group of langur were made from Mallukonda, near Tekuru village, where the human presence is very low. This suggests a possible inverse relation between anthropogenic disturbance and animal abundance in the region.

In addition to the foregoing, during the course of this study, several signs of poaching of birds and animals were also observed. According to the locals, one or two persons from each village in PNP are involved in poaching of Indian gaur, feral goats, etc.

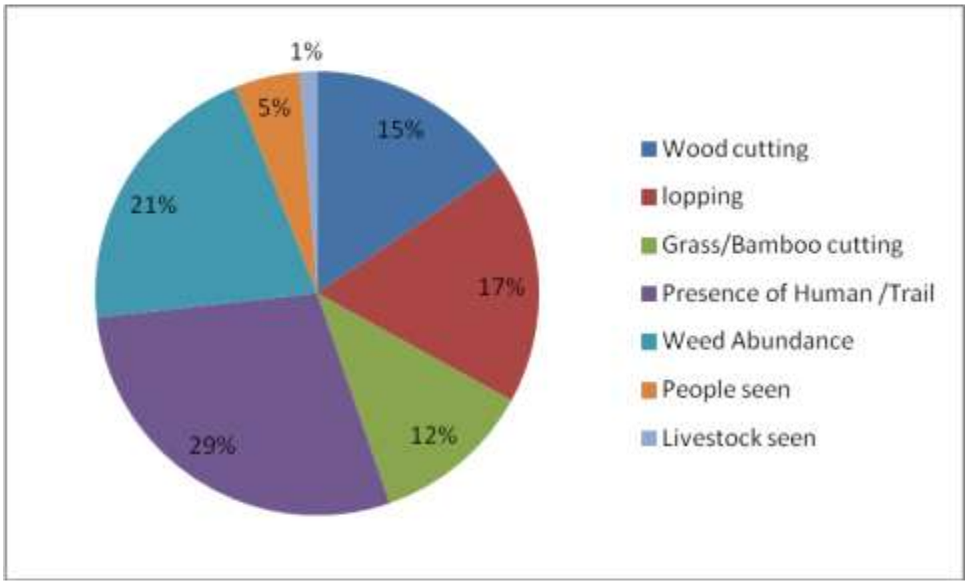


Figure 6.19 Human disturbance in submergence zone in PNP

Lists of mammals, birds and reptiles reported from PNP are provided in Annexures I, II and III, respectively.

6.6 Wild Faunal Values Along the Right Main Canal

The Right Main Canal, with a length of 174 km, is expected to irrigate 1,29,259 ha in 26 mandals, carrying 79.97 TMC of water for irrigation and 84.7 TMC for diversion to Krishna River, with 22 mandals (17 in West Godavari and 5 in Krishna District) in the command area. The main canal crosses three river courses, viz. the Yerrakalava, Tummileru and Gunderu.

Ten villages along the Right Canal were surveyed to assess the wildlife importance of the area. The command area is mostly agricultural land with patches of reserve forests along the canal, the nearest being 2.4 km from Nallajerla (Nallajerla RF). Kolleru Lake is situated at a distance of 8.75 km south-east of Denduluru.

Along the command area, 52 people were interviewed for the occurrence of any wild animals in the area. Four species of wild animal, viz. spotted deer, hare, wild boar and fox, were reported from five villages in the command area (Fig 6.20). Their occurrence was reported to be more frequent during summers, when they were probably coming in search of water.

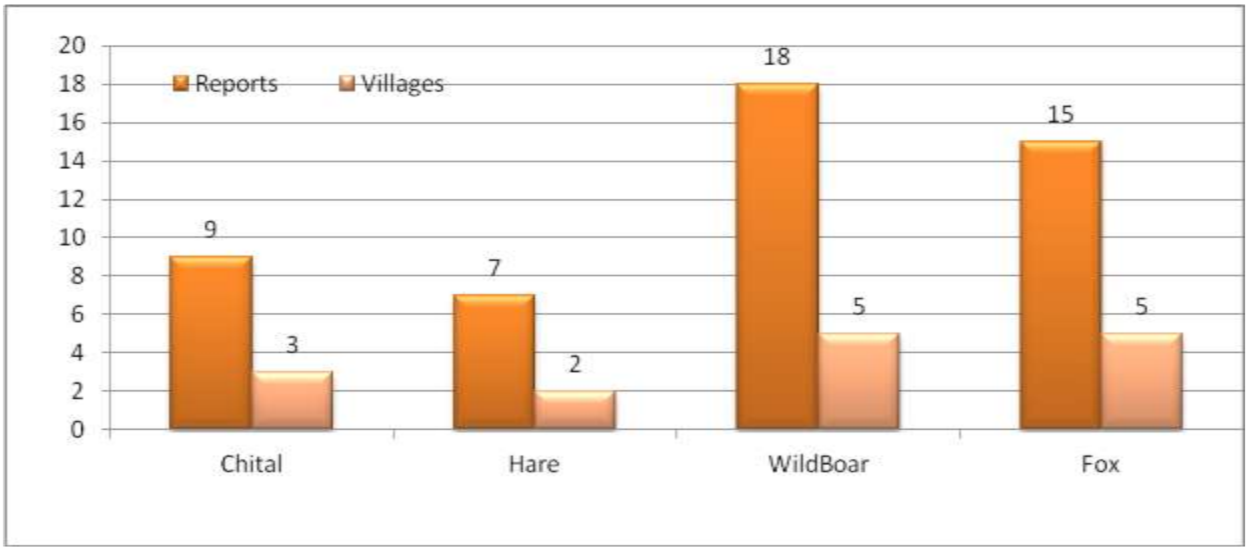


Figure 6.20 Reports of wild animals in the command area villages along the Right Main Canal

Table 6.16 List of places surveyed and wild animals reported along the Right Main Canal

Place	Animals reported								
	Cheetal	**Barking Deer**	**Gaur**	**Hare**	**Wild Boar**	**Sloth Bear**	**Fox**	**Leopard**	**Tiger**
Polavaram	—	—	—	—	—	—	—	—	—
Gopalapuram	—	—	—	—	—	—	—	—	—

Nallajerla	—	—	—	—	—	—	—	—	—
Ungutur	—	—	—	—	✓	—	✓	—	—
Dwaraka Tirumala	✓	—	—	—	—	—	✓	—	—
Denduluru	—	—	—	—	✓	—	✓	—	—
Pedavegi	—	—	—	—	—	—	—	—	—
Peddapadu	—	—	—	—	—	—	—	—	—
Agiripalli	✓	—	—	✓	✓	—	✓	—	—
Gannavaram	✓	—	—	✓	✓	—	✓	—	✓

6.7 Wild faunal values along the Left Main Canal

The 181.5 km long Left Main Canal takes off from the subsidiary reservoir at Nelakota, which has a head discharge of 230 cusec and is expected to irrigate an area of 1.62 lakh ha in the upland areas of East Godavari and Visakhapatnam districts, running through 26 mandals (16 in East Godavari and 10 in Visakhapatnam District). The main canal crosses 6 river courses, viz. the Buradakalava, Yeleru, Thandava, Varahala, Pampa and Sarada.

The command area is mostly agricultural land with patches of reserve forests along the canal, the nearest being 2.2 km from Sankhavaram (Nallavarapukonda RF). The terrain is mostly level, with occasional high lateritic mounds.

Thirteen villages along the command area of the canal were surveyed to assess the wildlife importance of the area. The areas along the Left Main Canal are more diverse and rich in wildlife compared with the Right Canal. Fifty-nine people were interviewed to estimate the occurrence of wild animals along the Left Canal. Five species of wild animal were reported to be found in the 13 villages surveyed (Table 6.16

Table 6.17 List of places surveyed and wild animals reported along the Left Main Canal

Place	Animals reported								
	Spotted deer	Blackbuck	Gaur	Hare	Wild Boar	Sloth Bear	Fox	Leopard	Tiger
Sitanagaram	✓	—	—	✓	—	—	✓	—	—
Korukonda	✓	—	—	✓	✓	—	✓	—	—
Rajanagaram	✓	✓	—	✓	✓	—	✓	—	—
Gandepalli	✓	✓	—	✓	✓	—	✓	—	—
Kirlampudi	—	✓	—	✓	✓	—	✓	—	—
Gollaprolu	✓	✓	—	✓	✓	—	✓	—	—
Sankhavaram	✓	✓	—	✓	✓	—	✓	—	—
Thondangi	✓	✓	—	✓	✓	—	✓	—	—
Nakkapalli	✓	✓	—	✓	✓	—	✓	—	—
S. Rayavaram	✓	✓	—	✓	✓	—	✓	—	—
Elamanchili	✓	✓	—	✓	✓	—	✓	—	—
Kasimkota	✓	✓	—	✓	✓	—	✓	—	—
Anakapalli	—	—	—	—	✓	—	✓	—	—

Wild boar, fox and spotted deer were reported to be among the more abundant species. About 61% of the people had reported the presence of blackbuck, in 10 villages that were surveyed (Fig 6.16). The visits of the animals were, however, restricted to the summer months, during which they probably came in search of water.

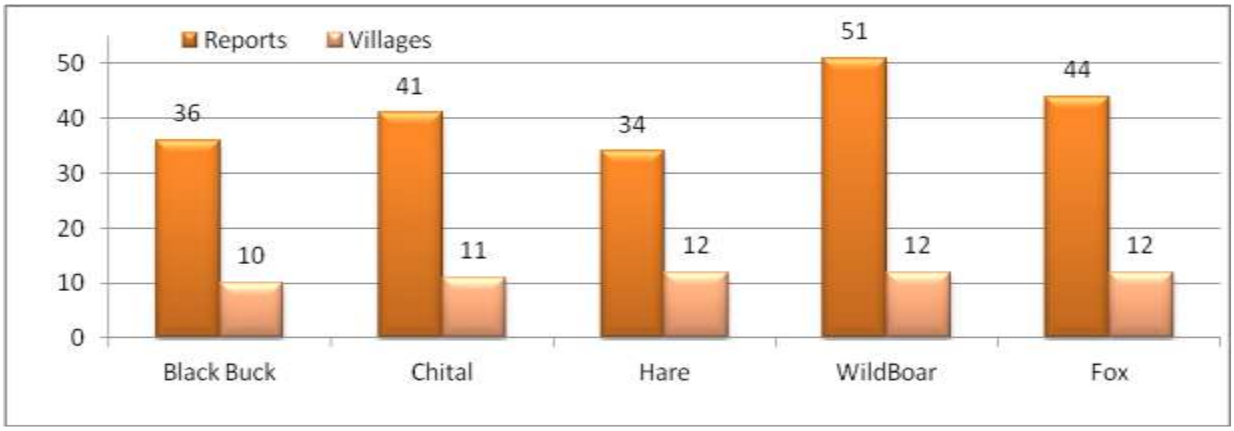


Figure 6.21 Reports of wild animals in the command area villages along the Left Main Canal

6.8 Discussion

A detailed and comprehensive assessment of the fauna of the study area was carried out during January–December 2013, spanning winter, summer and the monsoon. No direct evidence of the presence of wild mammalian carnivores and ungulates was recorded from the submergence zone during the transect walks. From discussions with locals and through our observations, it was gathered that a majority of the wild animals, especially the larger mammals, are mostly restricted to the upper reaches of the hills and deep forests of PNP. Due to the high level of human presence and habitat modifications due to farming, wild animals tend to avoid the submergence zone. However, the submergence zone has a highly diverse avifauna, with 101 species reported during the study period, several of which are threatened. Further, opportunistic sightings of threatened mammals such as sambar and wild dog have been made from the submergence area. According to the Forest Department, the area is also home to one or two tigers.

Since the results of this study indicate a very low abundance of animals in the submergence zone, the impact on the mammals might be minimal. However, there might be considerable impacts on the habitats of birds and reptiles, for which necessary mitigatory actions need to be taken.

The Right Main Canal runs for a length of 174 km from Totagondi until it reaches the Budameru River and ultimately the River Krishna. The Right Main Canal is expected to irrigate an area of 1,29,259 ha. The Left Main Canal, taking off from the subsidiary reservoir at Nelakota, runs for a length of 181.5 km until it reaches Visakhapatnam. This is expected to irrigate 1.62 lakh ha of *ayacut* in the upland areas of East Godavari and Visakhapatnam districts, as well as supply water for domestic and industrial purposes at Visakhapatnam.

Forty-five tree species, 12 shrubs, 11 herbs, 2 climbers and 16 bird species were recorded along the transects. The total basal area of all the species at all the places is estimated to be 594.62 m^2/ha, with *Tamarindus indica* contributing around 198.35 m^2/ha followed by *Borassus flabellifer* (110.17 m^2/ha), *Ficus hispida* (45.34

m^2/ha), *Terminalia tomentosa* (26.93 m^2/ha) and *Mangifera indica* (21.72 m^2/ha). Nine species of wild animal were reported to be sighted by people in the surveyed areas. A tigress was also reported to be sighted by a person in Tummuleru, Khammam District.

A total of 164 people were interviewed to understand their encounters with wild animals at the 34 sites that were surveyed (11 sites within the submergence zone of PNP, 13 along the Left Canal and 10 along the Right Canal). Ten species, viz. *the* tiger, leopard, gaur, wild boar, barking deer, spotted deer, blackbuck, hare, fox and sloth bear, were reported to have been sighted at various places in the study area. However, the research team could not find any direct evidence for the occurrence of these species except the hare. Apart from the submergence zone of the PNP, the areas adjacent to the Left Main Canal were observed to be more diverse, with frequent visits by wild animals, than the Right Main Canal.

Chapter 7

STATUS AND DISTRIBUTION OF FISH DIVERSITY IN THE IMPACT ZONE OF THE PROJECT IN THE RIVER GODAVARI

7.1 Introduction

The River Godavari is the second largest river in India and the largest river of peninsular India. It originates at Triambakeshwar, near Nasik, Maharashtra, travels a distance of around 1470 km and empties into the Bay of Bengal at Kakinada, Andhra Pradesh. It has a large catchment area, 3,12,812 km^2 (Bharati et al, 2009) and is fed by a number of tributaries along the way. After going across the Eastern Ghats in Andhra Pradesh, it emerges into the plains and finally branches into two distributaries—the Gouthami and Vashishta—just downstream of Dowlaiswaram Barrage, near Rajahmundry. The two distributaries further divide into smaller branches and form the Godavari delta or estuary.

Originating in the Western Ghats, flowing through the Eastern Ghats in its lower reaches and forming a huge estuarine system, the Godavari River is endowed with a huge diversity of fishes or ichthyofauna. This is well reflected by the findings of several scientific studies as well as surveys of the river conducted by various fishery institutes of Maharashtra and Andhra Pradesh. However, very few comprehensive studies have been carried out on the fish diversity of the lower reaches of the river.

Keeping this in mind, assessing the ichthyofaunal diversity of the lower reaches of the Godavari River became one of the main objectives of this study. Creation of baseline data on freshwater as well as estuarine species will help monitor any changes in the fish community of the river brought about by the proposed multipurpose project in the future.

7.2 Objective of the study

The specific objectives of this component are:

- To study the freshwater as well as estuarine fish diversity in the upstream as well as downstream regions of the proposed dam site.
- To study the fish diversity in the streams flowing inside PNP.
- To assess the threat status of the freshwater species in the lower reaches of the Godavari River.

7.3 Study area

For ichthyofaunal assessment of the Godavari River, the stretch from Bhadrachalam (inside PNP) to the estuary in Yanam, Pondicherry was selected. The fish market of Kakinada, where mainly marine fishes are sold, was also surveyed for any possible freshwater species. The study area was divided into four zones, which are listed in the following.

a) **Zone I:** Stretching from Karuturu village, in PNP, to Polavaram, this stretch will be submerged and be a part of the reservoir after the dam is constructed. Sampling for river fishes was mainly conducted in Karuturu, Kondamadlu, Tekuru, Teliperu, Konrukota, Ramayyapeta and Devipatnam villages as well as Polavaram and Devipatnam fish markets. A number of small and big streams flow inside PNP that empty into the river. The physico-chemical properties of the streams being different, they may harbour a number of specialized species that may not be found in the river. It is important to study these habitats as they are known to have a high rate of endemism (Easa and Shaji, 1997; Kottelat and Whitten, 1997). In addition, during the south-west monsoon (July–September), when the river has a very discharge rate, fishing is restricted to the big streams flowing inside the villages.

b) **Zone II**: This is the stretch of the river from Pattisema to the Dowlaiswaram Barrage, in Dowlaiswaram. In this stretch, Pattiseema, Rajamundry and Dowlaiswaram are the major fishing hubs. The fish markets of Rajahmundry and Dowlaiswaram were sampled in this zone. Fish catches from nearby canals and ponds are also sold in the Rajamundry fish markets, whereas the fishes sold at Dowlaiswaram are mainly caught at the barrage.

c) **Zone III:** The river divides into two downstream of the barrage—the Gouthami and Vashista. The focus of this study was the Gouthami River, which forms an extensive estuary near Yanam, Pondicherry. This stretch includes the areas downstream of the Dowlaiswaram Barrage up to Yanam, where the estuary starts. Fish markets of Ravulapalem and Yanam were sampled for both freshwater and estuarine fishes.

d) **Zone IV:** This only included the Kakinada fish market, which is mainly a centre for marine fishes. However, estuarine and, in some rare cases, freshwater species may also be encountered.

7.4 Methods

The sampling period of this study was January–July 2013. However, because of floods during the monsoon, sampling of the streams was only conducted from January to March 2013. In order to conduct a comprehensive study, three main techniques were adopted:

i. The major fish markets in each zone were visited regularly. All the freshwater or estuarine fishes were recorded and photographs of each fish taken for later identification. Specimens of any unknown or unique species were collected and preserved in 10% formalin in plastic bottles.

ii. Fishermen usually come to the river bank after fishing in the morning to sort their catch. Sampling of the fishermen's catch was done immediately after their return, and pictures of each species were taken for identification. Specimens of unique/unknown species were collected and preserved as above. This method of sampling was usually undertaken in Zone I, inside PNP.

iii. Three streams in East Godavari District and four streams in West Godavari District were selected for sampling in PNP. Each stream was divided into 1–3 sections of 100 m length each, depending upon the length of the stream. Efforts were made to cover the upper/upper middle, middle and mouth sections of the stream. All the microhabitats, such as pools, riffles and runs, were sampled in each section using cast nets of varying sizes and drag nets. Pictures of all the specimens were taken, and the specimens were preserved in 10% formalin solution.

Fishermen usually use gill nets of varying sizes in rivers, but other nets, such as cast nets, drag nets and seine nets, are also commonly used. A number of local methods are also adopted to catch fishes.

Identification of the species was using standard fish taxonomy books (Talwar and Jhingran, 1991; Jayaram, 2010). Information on the habitats and food habits of the species was collected from Fishbase and Talwar and Jhingran (1991). The threat status of each species was determined from the IUCN Red List.

7.5 Results

7.5.1 Species diversity

A total of 89 species belonging to 9 orders, 26 families and 50 genera were recorded from the main river as well as the streams inside PNP during this study. A site-wise list of all the species with their habitats and threat status is provided in Annexure IV. The species richness was highest in Zone I, i.e. PNP, closely followed by Zone II. The least number of species was found in Zone IV, which was expected since it is a marine fish centre.

In terms of species composition, cyprinids were the dominant group, with 32 species out of the total of 83 (Fig. 7.2As with the total number of species, the greatest number of cyprinids was also recorded from Zone I and Zone II. *Glossogobius giuris* was the most abundant species, especially during June–July. Commercial species such as *Catla catla, Labeo rohita, Oreochromis mossambicus, Wallago attu* and *Mastacembalus armatus* were reported from all the four zones; however, in Zone IV they were mainly cultured and not naturally occurring.

Bagarius sp. in Karuturu, PNP

Labeo calbasu (juvenile) in Karuturu, PNP

Figure 7.1 Some of the fish species from the submergence zone

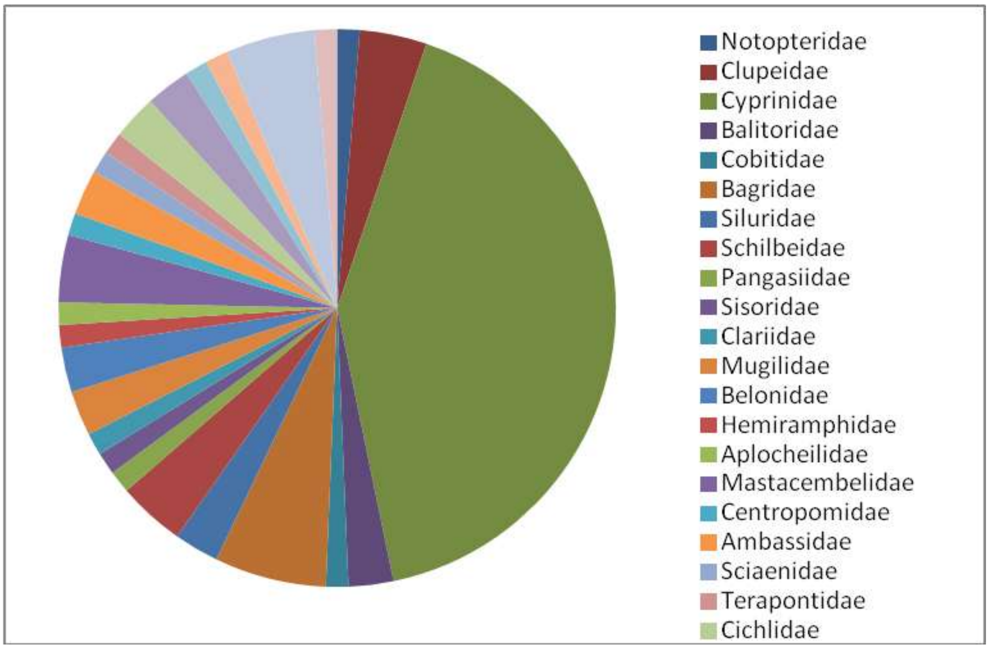


Figure 7.2 Pie diagram showing the relative proportions of the families of fishes recorded during the current study

7.5.2 Euryhaline species

Figure 7.3 *Rhinomugil corsula*, euryhaline species in Ravulapalem fish market

A number of estuarine species were recorded, mainly in Zone III. *Etroplus suratensis, Glossogobius giuris, Johnius coitor, Liza parsia, Mugil cephalus* and *Lates calcalifer* are some of the estuarine/brackish water species recorded from Zone II and Zone III, whereas *Terapon jarbua* was recorded from only Zone III. One of the highly prized fishes, *Tenualosa ilisha*, which is an anadromous species known to ascend several distances up the Godavari River, was also recorded from Zone II and Zone III, along with *T. keele*. *Nematalosus nasus* is also an anadromous species, and it was recorded only once, in Rajamundry fish market, in May. Interestingly, *Johnius coitor* is an estuarine fish that was recorded from the river as far as up as Pochavaram village, in Bhadrachalam District, in PNP.

7.5.3 Stream species

Sampling of the streams inside PNP was one of the main objectives of this study. Several interesting and rare species were recorded, and most of them were typical of stream habitats. *Danio rerio* was the most common species, being recorded in almost all the streams sampled. *Tor khudree*, the Deccan mahseer, was also recorded from one of the big streams, namely Jalataru Kalawa. An interesting species, possibly belonging to the genus *Garra*, was recorded from a stream in Teliperu and is yet to be identified. *Glossogobius giuris* and *Salmophasia horai* are two species that were reported from streams as well as the river. *Macropodus kupanus* and *Mystus cavasius* were also recorded in both types of habitats, though in much smaller numbers.

Figure 7.4 *Barilius bendalisis* from Gonduru stream, PNP

7.5.4 Conservation status

Figure 7.5 *Hypselobarbus kolus*, Vulnerable (IUCN, 2013)

Out of the 89 species, 4 are Near Threatened, 6 are Not Available, 2 are Data Deficient, 62 are Least Concern, 5 are Exotic, 6 are Near Extinct, 3 are Vulnerable and 1 is Endangered (IUCN, 2013). While *Cirrhinus cirrhosus, Hypselobarbus kolus* and *Salmophasia horai* are Vulnerable, *Ompok bimaculatus* and *Wallago attu* are Near Threatened due to over-exploitation. *Tor khudree* is listed as Endangered in the IUCN Red List.

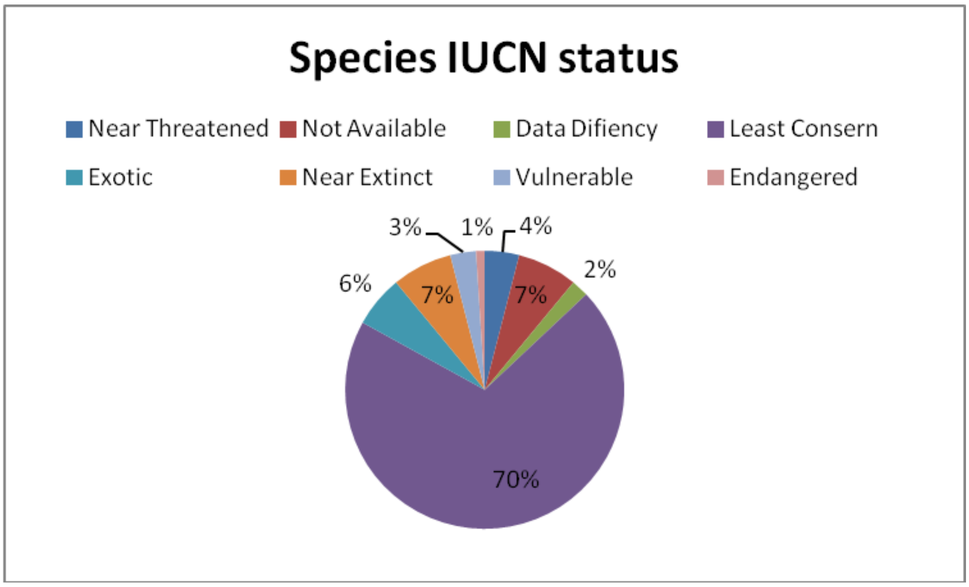


Figure 7.6 Status of species recorded from PNP

7.5.5 Interesting findings

This study has lead to quite a few interesting findings. *Hypselobarbus kolus*, a large barb that was initially reported as endemic to the Western Ghats, was recorded in Zone I, i.e. inside PNP. Though this species has been reported from the upper stretches of the Godavari in Maharashtra, this is the first report of this species from the Eastern Ghats and from the lower stretches of the river in Andhra Pradesh. Another species that was recorded from the river in Ramayyapeta village (Zone I) has still has not been identified and is possibly a primitive fish.

7.5.6 Exotic species

Figure 7.7 *Oreochromis mossambicus* from the river at Gonduru village, PNP

Four exotic species were recorded during the current study, viz. *Cyprinus carpio, Clarias gariepinus, Oreochromis mossambicus* and *Pygocentrus nattereri*. As stated in the foregoing, *O. mossambicus* was recorded in all the four zones though its distribution in Zone I was restricted up to Gonduru village. Information collected from fishermen indicated that it was rarely found in the region. *C. carpio* and *C. gariepinus* were not reported from Zone I. *C. carpio* and *O. mossambicus* have been listed among the worst exotic species of the world. One of the most surprising discoveries of this study was *P. nattereri*, the red-bellied piranha, which is a native of the Amazon River, in South America, in the Dowlaiswaram fish market (Zone II). Two individuals were recorded from the fish market, one each in May and July. These are perhaps the first official records of the presence of this fierce predator in India as its use, either commercial or recreational, is completely prohibited in the country.

7.5.7 Feeding habits

Information regarding the feeding habits of the fishes was collected from Talwar and Jhingran (1991) and the online source Fishbase. Out of the 77 species, information for 42 species could be collected. These 42 species were then divided into 4 groups based on their feeding habits, viz. herbivores, carnivores, omnivores and detritivores. The omnivores was the major group (18 species), closely followed by the carnivores (15 species). The high proportion of omnivores and carnivores possibly indicates a high level of competition among the various fish species. In addition, the exotic species that were been recorded in the region, especially *Pygocentrus nattereri*, are highly predatory in nature. Only 8 species of herbivore and 1 species of detritivore (*Cirrhinus mrigale*) were recorded from the study area.

7.6 Discussion

The rivers and streams of the Western Ghats have been studied extensively, but the east-flowing rivers of the Eastern Ghats are relatively unexplored. Several east-flowing rivers are under immense anthropogenic pressure and are highly regulated. It is very important to bridge this knowledge gap, or we may lose several endemic and rare species.

This study has lead to quite a few fascinating discoveries. The diverse habitats of Eastern Ghats and the Godavari estuary make the lower stretch of the Godavari River an ichthyofaunally rich ecosystem. The immense diversity supports lakhs of people in the region. The presence of 4 exotic species, all of which are highly predatory and are known to cause immense damage to the native fisheries, is, however, a cause of concern. This, along with sand mining on the river bed and discharge of effluents into the river, has already negatively impacted the fisheries of the river. *Labeo fimbriatus* was known to be a prominent riverine fish in this region but has been overtaken by *L. rohita*. The species has declined in numbers now (CICFRI, 2000). However, the construction of a multipurpose project across the river might lead to modification/destruction of several of the river's unique habitats (Nilsson and Berggren, 2000; Dynesius and Nilsson, 1994; Rosenberg et al, 1997), especially the downstream habitats.

The dam will act as a physical barrier to the movement of fishes, which will have a profound impact on the diadromous fishes of the river. One case in point could be *Tenualosa ilisha*, which was presumed to spawn all along the Godavari River (Devanesen, 1942) before the construction of the Dowlaiswaram Barrage. It is now only found up to the barrage, and recently it has suffered huge declines in its population due to over-exploitation. Hora (1942) had discussed the futility of fish passes and hatcheries in restoring *hilsa* fisheries. Other migrating species or native species of the river might meet the same fate.

The construction of the dam and subsequent creation of a reservoir in the upstream part might lead to the destruction of the stream habitats in PNP. These streams harbour a number of unique and threatened species of fish. They also act as alternate habitats for riverine species during the monsoon.

Another way in which dams can affect fisheries is through changes in the water quality as well nutrient content. Water released from the outlets in a dam (e.g. canals, turbines) may be low in dissolved oxygen or rich in hydrogen sulphide. Also, the water released may not be sufficient to dilute the domestic and industrial effluents being discharged into the main river. Because of the reduction in the downstream flow, the entry of the organic load into the main river this might lead to eutrophication, which in turn will lead to local fish kills.

The most profound impact of dams on the aquatic biota would be through changing the natural flooding patterns of the river. The variable flow discharge of the river, especially during the monsoon, is imperative for maintaining the intactness of downstream habitats such as the estuary, which in turn supports a large number of commercially important species such as *Tenualosa ilisha, Liza parsia* and *Rhinomugil corsula*. These species are stimulated by rising seasonal flood flows, which assist them to move into the floodplain to breed in the warm, organically rich water. As the flood subsides, fish move back to the river channel. If a dam reduces the flood peaks, the fish will fail to migrate and breed, reducing the size of the population and the economic returns for fish catchers (Adams, 2000). This has been reported from many rivers in the Asian and African regions (Benech, 1992; Lowe-McConnell, 1985; Adams, 1985).

Chapter 8

RIPARIAN VEGETATION INDEX

8.1 Background

Riparian (adj.) of or relating to a riverbank
Definition from *Webster's Dictionary: The New Lexicon of the English Language*, 1988

In simple terms, a riparian zone may be defined as the zone of vegetation growing at the banks of a river. However, it is one of the most complex ecosystems on the terrestrial part of the earth (Naiman et al, 1993, 1997). Acting as a transitional zone or ecotone between a terrestrial landscape and aquatic habitat, it has unique physico-chemical and biotic properties. The importance of riparian zones arises from their dynamic inter-relationship with the river ecosystem. Riparian zones are characterized by spatial and temporal diversity in their ecological properties, which are in turn shaped by the natural disturbance regime of a river. On the other hand, riparian zones play a major role in defining the regional biodiversity (Naiman et al, 1993) as well as long-term functioning and sustainability of the river (Arthington et al, 1993). They help stabilize the river bank, play an important role in addition and assimilation of organic matter from the river, act as a buffer against the huge volume of water of seasonal floods and provide a myriad of habitats for numerous aquatic organisms. Several fish species and crustaceans utilize such zones as their spawning grounds or for shelter.

Due to its intimate linkages with the aquatic habitat of a river, coupled with a high sensitivity to anthropogenic disturbances, riparian vegetation can help describe the ecological status of a particular river. It has been, therefore, used as a tool for watershed management and restoration for a long time. A number of indices and techniques focusing on the riparian vegetation have been devised to assess river systems. The Institute of Water Research, South Africa (Kemper, 2001) developed a simple and rapid index, the Riparian Vegetation Index (RVI), to assess the riparian vegetation along a river.

8.2 Riparian Vegetation Index and its components

The Riparian Vegetation Index (RVI) is a site-based index that was developed to "provide a condition index which can be compared to indicate trends in the condition of riparian vegetation at each site over time" (Kemper, 2001). It can be integrated into any biomonitoring programme and thereby can play an important role as a management tool. Initially an aerial-based method was adopted for riparian assessment; however, because of its obvious limitations, a site-based method was developed that generically gave a picture of the structure, composition and characteristics of the riparian vegetation at a particular site.

The RVI is derived from four sub-indices or components, namely Extent of Vegetation Cover (EVC), Structural Intactness (SI), Percentage Cover of Indigenous Riparian Species (PCIRS) and Regeneration of Indigenous Species (RIRS). Each of these components is described in brief in the following.

1. **Extent of Vegetation Cover (EVC):** EVC assesses the percentage of riparian vegetation coverage along the banks in two ways, direct (EVC 1) and indirect (EVC 2). EVC 1 was assessed on a 6-point scale, and EVC 2 calculated the extent of anthropogenic disturbance at the particular site on 4-point scale. EVC is a subtraction of the extent of anthropogenic and other disturbances from the perceived reference state (PRS), which is 100% (in most cases) or a lesser percentage, depending on whether the site is located on bedrock or not. EVC 2 = (10 - Disturbance Score). The mean of EVC 1 and EVC 2 represents the final EVC score.

   EVC (score out of 10) = [(EVC 1 + EVC 2)/2]

2. **Structural Intactness (SI):** Four scales of density/distribution for SI, namely, *continuous*, *patchy*, *scattered* and *sparse* are employed, and scoring

is on a 5-point scale for the tree (SI1), shrub (SI2) and grass (SI3) layers. The final SI score is the mean of SI1, SI2 and SI3.

SI (score out of 1) = [((SI1+SI2+SI3)/3×0.33)]

3. **Percentage Cover of Indigenous Riparian Species (PCIRS):** This considers the extent of exotic species present at a site, extent of terrestrialization of the riparian zone and presence of reed beds in the riparian zone. While the presence of exotic species naturally points to a certain degree of disturbance, terrestrialization of the riparian zone points to relative reductions in the river flow, and reed beds are common in rivers that are highly regulated and exposed to a high nutrient load.

   PCIRS (score out of 5) = [(EVC/2) - ((exotics×0.7) + (terrestrial×0.1) + (reeds×0.2))]

4. **Regeneration of Indigenous Species (RIRS):** This sub-index assesses the regeneration capacity of the most dominant riparian species at the site, and the score is based on a 5-point scale.

Finally, the RVI can be derived from the following formula:

RVI = [(EVC) + ((SI×PCIRS) + (RIRS))]

The RVI provides a final score out of 20, which is used to assess the state of the river based on six ecological reserve assessment classes as follows:

Table 8.1 Ecological reserve assessment classes based on RVI score

RVI score	Assessment classes	Description
19–20	A	Unmodified, natural
17–18	B	Largely natural, with few modifications. A small change in the natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged.
13–16	C	Moderately modified. A loss and change of the natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
9–12	D	Largely modified. A large loss of the natural habitat, biota and basic ecosystem functions have occurred.
5–8	E	The loss of the natural habitat, biota and basic ecosystem functions is extensive.
0–4	F	Modifications have reached a critical level, and the system has been modified completely, with an almost complete loss of the natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

8.3 Objectives of the study

- To calculate the RVI at different points along the left bank and right bank of the Godavari River.

- To assign an ecological reserve assessment class to each site and predict the current status of the river based on the classes.
- To map the RVI at different points along the Left and Right banks of the river.

8.4 Description of site

The downstream stretch of the river (about 130 km), extending from Karuturu village, in PNP, to Yanam, Pondicherry, where the Godavari River opens into an estuary, was sampled. The stretch was divided into 3 zones:

Zone 1: Karuturu Village, PNP to dam site, Polavaram

Zone 2: Polavaram to Dowlaiswaram Barrage, Dowlaiswaram

Zone 3: Dowlaiswaram Barrage to Yanam, Pondicherry

Each zone is described in detail in the following.

a) **Zone 1:** In this stretch, the river traverses the winding gorges of the Eastern Ghats in PNP. Several villages dot the river bank, with farming being the main occupation of the locals. Several of these villages will be submerged after the dam is constructed. At many sites, agricultural farms were observed right next to the river. There are 7 sites on each bank in this zone. Human presence was relatively low on the left bank as the terrain was more hilly and treacherous. On the right bank, except Kammavaram all other sites have apparently a sizeable human presence as evidenced by several village settlements and hutments. This zone also included the dam site, near Ramayyapeta village.

b) **Zone 2:** Here the river enters the plains and widens out enormously, branching out and creating numerous sandy islands. Right after the Dowlaiswaram Barrage, the river divides into two distributaries—the Gautami and Vashista. There are 8 sites on the right bank and 7 sites on the left bank in this zone, including the Dowlaiswaram Barrage, Dowlaiswaram. Human disturbance markedly increases in this zone due to an increase in farming along the river banks, the presence of an inter-city gas pipeline, two road and rail bridges across the river and several big villages and towns. Rajahmundry, one of the biggest industrial cities of Andhra Pradesh, also lies in this zone, and hence the level of human disturbance near the city is very high.

c) **Zone 3:** The Gautami–Godavari River here gradually emerges into the delta, forming an estuary at Yanam, Pondicherry. In this zone, 11 sites were sampled on each bank. In this zone too, several big villages and towns are situated along the river, including Yanam, a major city. The human disturbance in this zone, therefore, is very high, as in Zone 2.

8.5 Methodology

The method used to calculate the RVI was adapted from Kemper (2001) with slight modifications. A random stratified sampling approach was selected. In each zone, after every 5 km, a stretch of 1 km was sampled on both the right and left banks of the river. At each site, data, including presence of wildlife, were recorded in data sheets (Annexure I) that were later used to calculate the RVI for each site using the above-mentioned formula. Subsequently, each site was assigned an ecological reserve assessment class (EC). Using GIS software, all the RVI sites were plotted on a map along with the corresponding RVI score and ecological assessment class.

In order to achieve a comprehensive assessment, seasonal sampling is being carried out. Sampling for two seasons, viz. summer and pre-monsoon, has already been completed. The results, therefore, are based on two seasons' data.

8.6 Status of riparian vegetation

8.6.1 Results

The RVI results are provided here.

Table 8.2 Site-wise RVI and assessment class (AC) for the right bank and left bank for January–March and May–July**[Please approve the renumbering of the table.]**

Name of site (RB)	RVI	AC	Name of site (LB)	RVI	AC
JAN–MARCH					

Zone 1					
Kuruturu	8.4	**D**	Tadivada	0.5	**F**
Chidduru	1.5	**F**	Teliperu	1.9	**F**
Kammavaram	3.1	**F**	Gonduru	3.9	**F**
Erravaram	3.3	**F**	Manturu	3.6	**F**
Kothuru	5.5	**E**		1.9	**F**
Paidipaka	2.2	**F**	Devipatnam	2.2	**F**
Ramayyapeta	4.2	**F**	Gandipochamma temple	6.3	**E**
Old pattisema	8.7	**D**	Ramchandrapuram	8.9	**D**
Zone 2					
Pattisema	5.1	**E**	Seethanagram	4.6	**E**
Thalapudi	11.7	**D**	Rajampeta	8.2	**E**
Chidipi	3.3	**F**	Bobbilanka	8	**E**
Kovvur	3.9	**F**	Katheru	7.4	**E**
Ishukarum	4.9	**E**	Rajamundry	5.3	**E**
Bobbarlanka	4.7	**E**			
Vijjeswaram	7.3	**E**	Dowlaiswaram barrage	8.5	**D**
Zone 3					
Peravaram	2. 8	**F**	Burrilanka	9.6	**D**
Vutchilly	4.3	**F**	Badugu vani lanka	6.9	**E**
Bellapalem	4.1	**F**	Jonnada	10.6	**D**
Agraharamlanka	3.9	**F**	Nathapudi	1.9	**F**
Kedarlanka	5.2	**E**	Kapileswarapuram	5.6	**E**
Vanapilli	Inaccessible		Dulla	1.9	**F**
Mukteswaram	10.1	**D**	Kotipalli	9.6	**D**
Kondukuduru	Inaccessible		Kothakoppala	Inaccessible	
Muramella	9.0	**D**	Brahmapuri	6.6	**E**
Yedurlanka	8.2	**E**	Kanakala peta	10.7	**D**

Karavaku Lanka	5.8	**E**	Yanam	Inaccessible	
MAY–JULY					
Zone 1					
Kuruturu	5	**E**	Tadivada	Inaccessible	
Chidduru	Inaccessible		Teliperu	Inaccessible	
Kammavaram	1	**F**	Gonduru	5.5	**E**
Erravaram	Inaccessible		Manturu	0.8	**F**
Kothuru	4.3	**F**		1.0	**F**
Paidipaka	2.5	**F**	Devipatnam	4.0	**F**
Ramayyapeta	3.3	**F**	Gandipochamma temple	5.7	**E**
Old Pattisema	2.5	**F**	Ramchandrapuram	3.3	**F**
Zone 2					
Pattisema	4.0	**F**	Seethanagram	3.5	**F**
Thalapudi	4.5	**E**	Rajampeta	4.4	**E**
Chidipi	3.7	**F**	Bobbilanka	5.8	**E**
Kovvur	4.5	**E**	Katheru	5.0	**E**
Ishukarum	4.5	**E**	Rajamundry	5.1	**E**
Bobbarlanka	5.0	**E**	Dowlaiswaram Barrage	5.0	**E**
Vijjeswaram	7.4	**E**			
Zone 3					
Peravaram	4.7	**E**	Burrilanka	7.1	**F**
Vutchilly	6.1	**E**	Badugu Vani Lanka	5.3	**E**
Bellapalem	5.3	**E**	Jonnada	8.2	**E**

Agraharamlanka	5.0	**E**	Nathapudi	6.9	**E**
Kedarlanka	5.2	**E**	Kapileswarapuram	4.5	**E**
Vanapilli	Inaccessible		Dulla	5.0	**E**
Mukteswaram	7.1	**E**	Kotipalli	1.3	**F**
Kondukuduru	8.6	**D**	Kothakoppala	8.3	**E**
Muramella	4.1	**F**	Brahmapuri	5.1	**E**
Yedurlanka	4.7	**E**	Kanakala Peta	5.6	**E**
Karavaku Lanka	4.3	**F**	Yanam	Inaccessible	

After calculating the RVI for each site on each bank, ecological reserve assessment classes (AC) were assigned. These assessment classes denote the ecological status of the river for each site. The highest score for AC is 'D', which denotes a large-scale modification of the river with huge loss of habitats, biota and ecosystem functions. This indicates that the river has already undergone a lot of modification and destruction. To reverse this destruction might be difficult. Therefore, our immediate aim can be to improve the assessment class score and restore the ecology gradually.

Comparing the AC scores for the two seasons indicates that the left bank is in better condition than the right bank. Surprisingly, if we compare the three zones, Zone 2 is in the best ecological condition, followed by Zone 3 and then Zone 1, which lies inside PNP. In Zone 1, out of 16 sites surveyed during January–March, 12 sites achieved an 'F' score. Evem during May–July, out of the 12 sites, 9 sites achieved an 'F'. 'F' signifies that the 'modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota with an irreversible change'. This zone also secured the lowest RVI scores among the three zones, with Tadivada getting an all-time lowest RVI score of 0.5 in March.

In the period January–March, Thalapudi, on the right bank, in Zone 2, secured the highest RVI score, 11.3, whereas for the period May–July, Kondukuduru secured the higest score of 8.6.

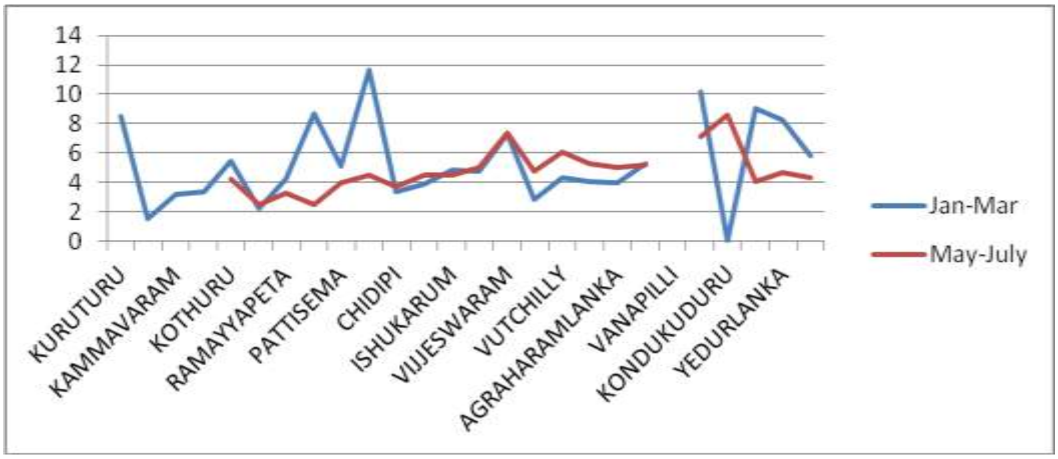


Figure 8.1 Site-wise RVI for right bank

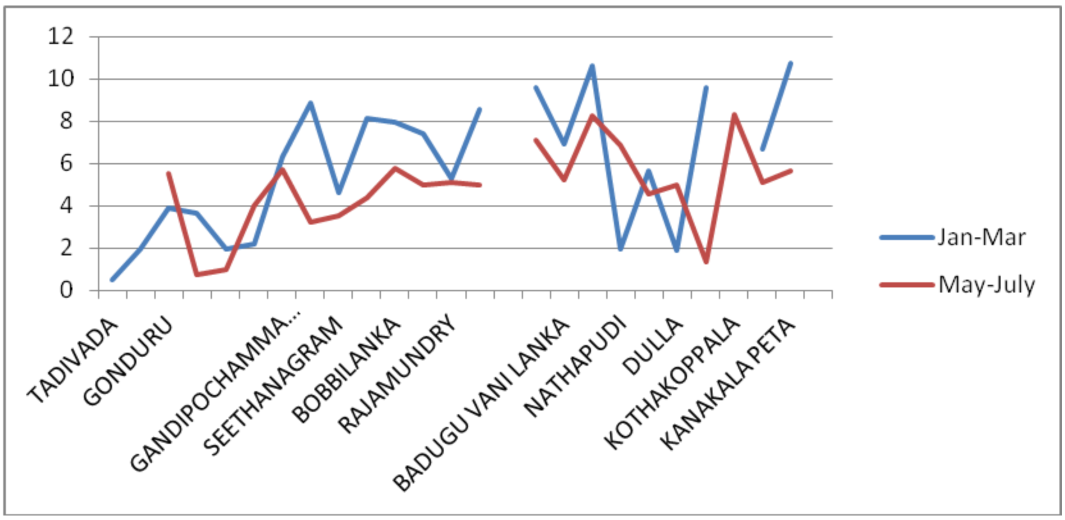


Figure 8.2 Site-wise RVI for left bank

If we compare the RVI scores for the two seasons, we find a lot of variations in the two banks. For the left bank (Fig. 8.1 and 8.2),[there is a general trend of a slight decrease in RVI scores from January–March to May–July, though some sites showed an increase in the RVI. Along the right bank (Fig. 1), Zone 1 showed a decrease in RVI scores from January–March to May–July, whereas the RVI scores remained relatively unchanged in Zone 2. However, in Zone 3, along the right bank there was a decrease in the RVI at some sites and an increase at some sites.

Figure 8.3 Sand mining on the river bank near Kovvur (right bank in Zone 2)

Most of the sites received an assessment score (AC) score of 'F', which denotes irreversible changes in the riverine ecosystem. This indicates the high degree of anthropogenic interference and dependence on the river. In Zone 1, the major anthropogenic disturbances were related to agriculture, fishing and tourism activities. We observed that in several villages, agricultural fields were situated just along the river bank. Since the villagers were also found to use insecticides in their fields, these will definitely enter the river along with the runoff. Villagers were also found to abstract water from the river and the streams using motors for irrigating their fields. The river was also used for several other purposes such as bathing, washing clothes and defaecating. Tourism boats also caused a lot of disturbance, both in terms of sound and water pollution. At several sites in Zone 1, we found plastic plates, glasses and bottles thrown by the tourist boats lying along the bank.

In Zone 2, the major anthropogenic disturbance was again agriculture, in addition to industrialization. In this zone we came across a few projects such as the Secunderabad–Vishakapatnam gas pipeline, which runs across the river, near one of the sites, Kovvur. There are also two bridges, one railway bridge and a rail-cum-road bridge, connecting the two banks. Rajamundry, Kovvur and Dowlaiswaram are the big industrial cities and towns located in this zone. Near Rajamundry, a huge paper plant is located right beside the river bank. We also came across sand mining at two RVI sites, both in Rajamundry. As mentioned earlier, at Dowlaiswaram the barrage regulates the flow of river and several fishermen could be seen fishing near the barrage in winter (January–March). Also, in Vijjeswaram a huge power plant belonging to GMR Vemagiri Power Generation Limited was situated near the river bank. The pump house that extracts water for use in the boilers of the power plant was situated right next to the river.

In Zone 3 also, the major activity was agriculture. There were plantations of banana and coconut and horticultural farms along the river. We also came across large-scale sand mining near Kotipalli and Jonnada. In Kedarlanka, a brick industry and in Muramella an iron industry were situated near the river. The Yanam–Yedurlanka highway is constructed across the river, joining the two cities on opposite banks. Two of our RVI sites were situated near this highway. In Karavaku Lanka, salt pans as well as aquaculture ponds were observed near the river bank.

8.6.3 Usage by wildlife

In spite of such a high degree of human presence, we came across wild animals at several of our sites. Aquatic birds such as egrets, sandpipers, red-wattled lapwings, cormorants and kingfishers were recorded at several sites in Zone 1, Zone 2 and Zone 3. In Karavaku Lanka, lying on the right bank of Zone 3, we also encountered river terns. A patch of mangrove forests was situated right next to our RVI site. In the months of May–July, we recorded the presence of open-billed storks at two RVI sites, Kovvur (Zone 2) and Bobbarlanka (Zone 2). At both sites, the birds were present on the riverine islands and not on the actual river bank. In addition to this, the vegetation lining the river banks provided habitats to several terrestrial bird species.

In terms of mammals, there were no sightings except for one site in Zone 1. In May, while approaching the RVI site of Manturu, on the right bank, by boat, we encountered a sambar fawn near the river bank. Again while returning, we saw groups of langur and rhesus macaques on the vegetation lining the bank. This site is located right at the foot of a large hill named Mallu Konda. Being devoid of human presence due to its terrain, it might harbour several wild faunal species. Similarly, in February, when conducting an RVI survey in Gonduru (again in Zone 1), we encountered a quail at its nest on the river bank. Therefore, in spite of getting the lowest RVI scores, this zone, by virtue of being situated inside a protected area, might be a good habitat for wild species of mammal as well as bird.

8.7 Discussion

Figure 8.4 The riparian zone of Mallu Konda near Kammavaram (right bank in Zone 1), PNP

As mentioned in the previous section, the left bank in zone 1, being of rocky and hilly terrain was slightly undisturbed as compared to the right bank which offered flat plains, favourable for agricultural activities as well as hutments.. Similarily, in Zone 3 a lower degree of human disturbance was recorded on the left bank. This was because the density was low in this region and villages were located far from each other. On the other hand, the degree of human interference was higher on the right bank, with numerous plantations and agricultural fields right at the bank. A higher degree of cattle grazing and exotic species were also observed on the right bank.

Even though Zone 1 is situated inside a protected national park, it had the lowest RVI scores in both the seasons. The local villages situated near the river are highly dependent on it for their daily requirements as well as for agriculture and fishing. Even so, the human disturbance is relatively lower compared with the other two zones. There was very little riparian vegetation in this zone. One possible reason for the low RVI scores in Zone 1 could be the geomorphology of the river. The river here meanders through the hills of the Eastern Ghats, often with sharp curves. This renders the bank relatively unstable, which might lead to lower recruitment of riparian vegetation.

Zone 2, had high RVI scores in spite of having the highest human presence. The presence of exotic and terrestrial species was highest in this zone, but there were some pockets, such as Vijjeswaram, with a good growth of riparian vegetation. Similar stretches with good riparian vegetation were observed in Zone 3, particularly on the left bank (e.g. Kothakopalla and Brahmapuri). Such pockets should be identified and protected. These can act as models for other sites where the riparian zone is completely lost.

The RVI survey shows a very high degree of degradation of the riparian zone along the river. Even though recovery of riparian zone to its natural pristine condition is highly unlikely, there is scope for improving the conditions. The importance of a healthy riparian zone has already been highlighted, not only from the ecological point of view but also for other purposes such as bank stabilization, protection from floods, groundwater recharge and fishery resources, which are one of the major sources of income of the local people.

8.8 Land use land cover

Viewing the Earth from space is now crucial for understanding the influence of man's activities on his natural resource base over time. 'Land cover' refers to the physical characteristics of the Earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities, e.g. settlements. 'Land use' refers to the way in which land has been used by humans and their habitat, usually with an accent on the functional role of land for economic activities. It is the intended employment of the land cover by human agents and/or managers.

The land use land cover (LULC) pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressures. Hence, information on land use land cover and optimal use is essential for the selection, planning and implementation of land use schemes to meet increasing demands. This information also helps monitor the dynamics of land use resulting from the changing demands of an increasing population. Advances in vegetation mapping have greatly improved research on LULC. Thus, providing an accurate evaluation of the spread and health of the world's forest, grassland and agricultural resources has become an important priority.

8.8.1 Land cover mapping of PNP

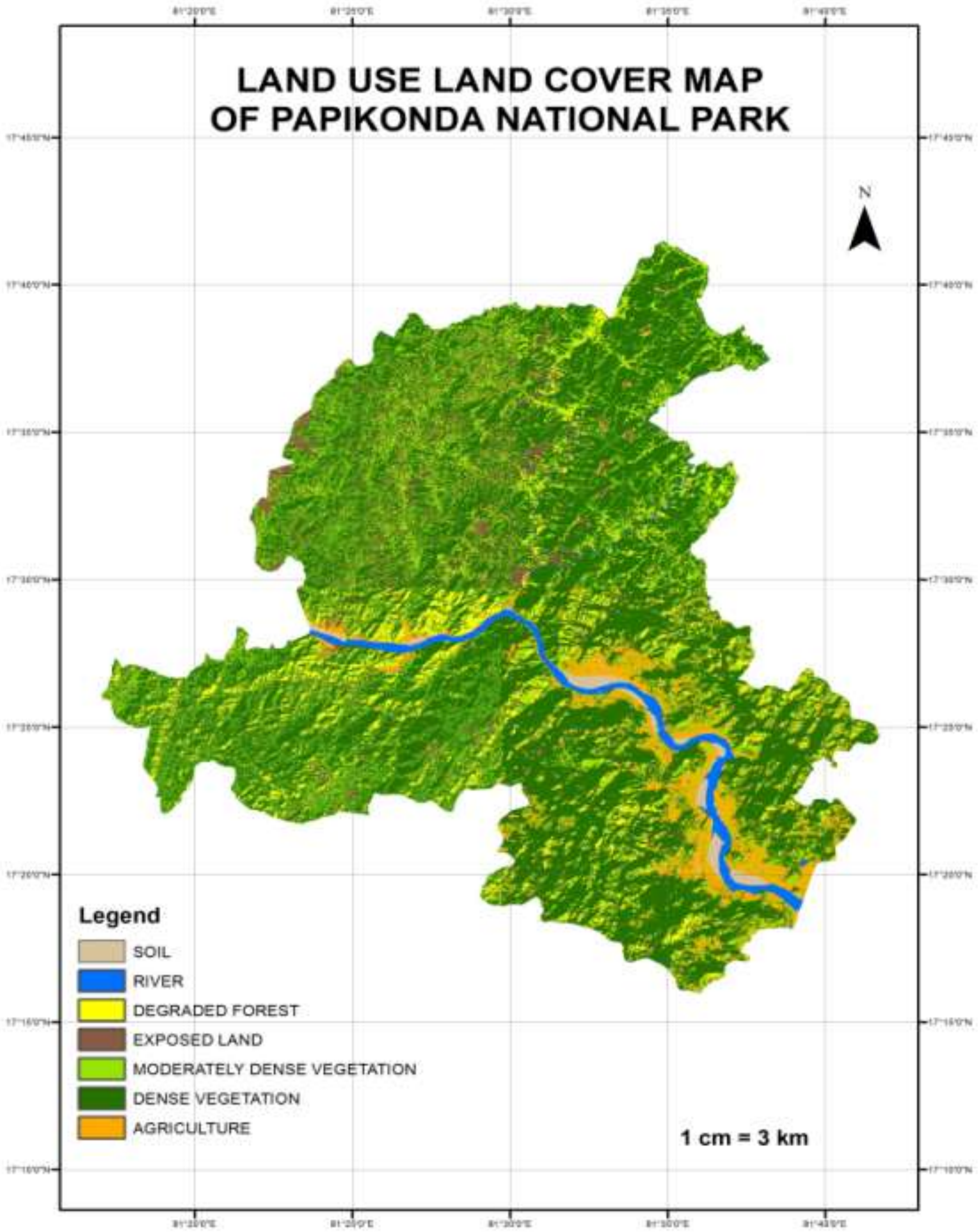
Prior mapping investigations were carried out in the study region by Naik et al (2011) and the AFCL (2005). Both these studies were focused on the submergence region, i.e., the region that is expected to be submerged because of the construction of the Indira Sagar Multipurpose Dam in Polavaram, inside PNP. However, in the present study, it was attempted to produce a land cover land use map for the entire national park. Naik et al (2011) estimated that about 59 km^2 of the park area would be submerged.

An LULC map for the PNP was prepared using LISS III images that were downloaded from the Bhuvan Open Data Archive, hosted by the National Remote

Sensing Centre (NRSC). The available images are from the years 2008 and 2009 (May and July). The LISS III images have a spatial resolution of 23.5 m. The LULC map was prepared using the unsupervised classification method as sufficient ground truth data could not be collected for using the supervised classification method. The steps involved are briefly discussed here.

The downloaded images were geographically registered using scanned toposheets of Survey of India. The geographic coordinate system WGS '84 was used. The shape file containing the boundary of the national park, acquired from the Forest Department of Andhra Pradesh, was used to mask the study area from the images. To avoid any changes in the pixel values, the masking was done band by band for all images, and then the masked bands were stacked together to get a false colour composite. Masked data from each image were classified separately. The classification was carried out in ERDAS IMAGINE 2013, which has a Google Earth plug-in. This feature was very useful in observing the point in question in Google Earth, on the fly. This feature helped in compensating forthe lack of sufficient ground truth points. However, the classification had to be confined to a broad-level classification system. The classification system followed by the Forest Survey of India was used here. All the four classified sections were opened together in the map view of ArcGIS 10.1, and the final map was created.

Further, Cartosat-II, which was also available from the Bhuvan Open Data Archive of NRSC, was used to prepare the digital elevation model (DEM) of the area. A contour map was derived from the DEM, and regions under 45 m elevation were masked out from the LULC map. Since the maximum height of the upcoming dam is estimated to be 48 m, a submergence buffer of 45 m was taken, assuming that a uffer of 3 m will be kept with reference to the maximum capacity of the



dam.

Figure 8.5 LULC map of PNP

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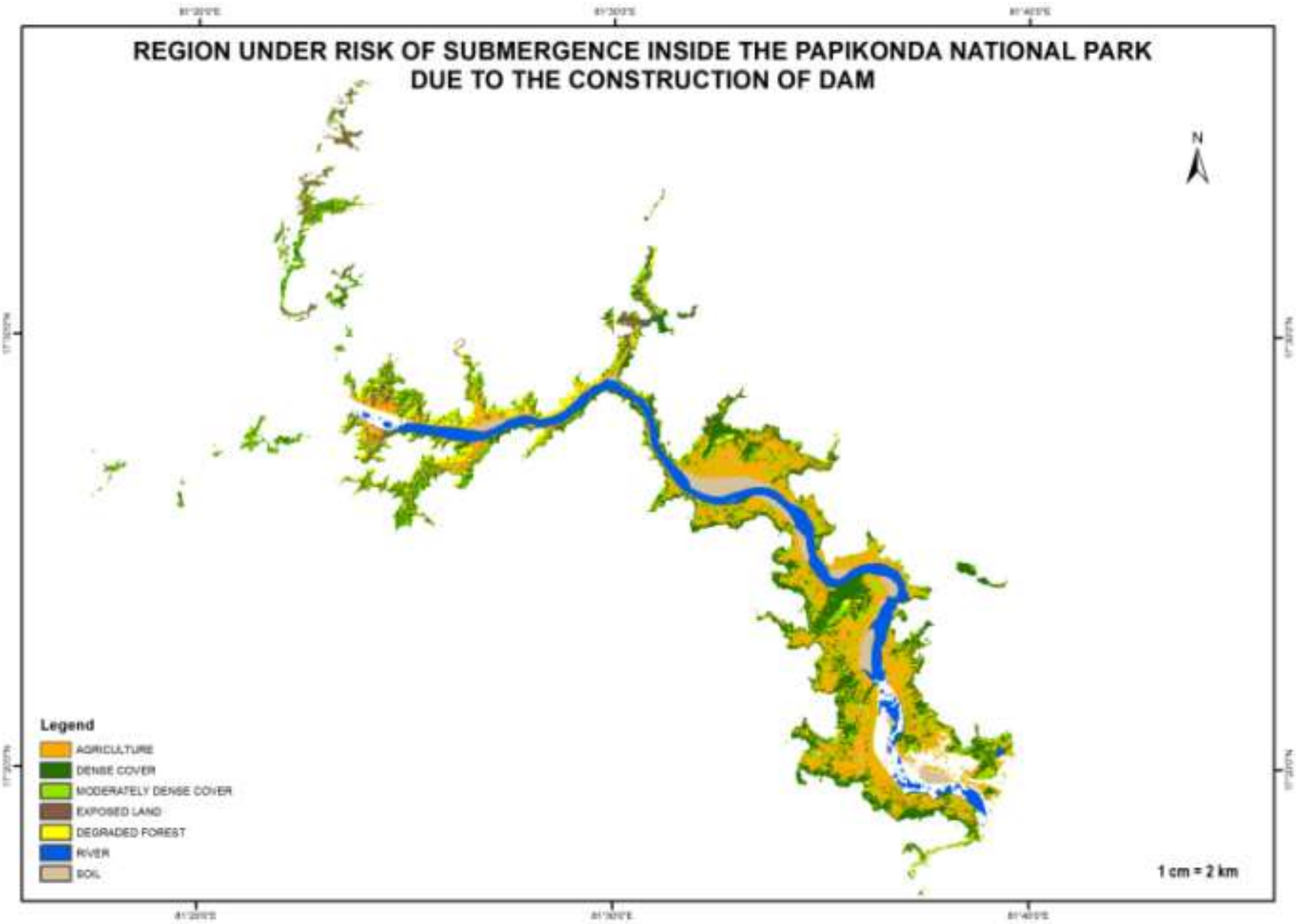

Figure 8.6 Submergence map of Indira Sagar multipurpose dam

Table 8.3 Area under each land use type

Land cover type	Total area (km^2)	Area under submergence (km^2)
Dense vegetation	609.01	31.94
Moderately dense vegetation	146.79	18.75
Degraded forest	104.93	6.97
Non-forest	104.93	7.14
Agriculture	49.76	31.97
Soil	8.33	6.12
River	19.03	14.92
Total area	1042.78	117.80

Apart from the LULC map of PNP and the potential areas to be affected, a land use map for the region downstream of the dam was also generated. A buffer of 50 km of land on either side that would come under direct impact due to the changing water flow was assumed.

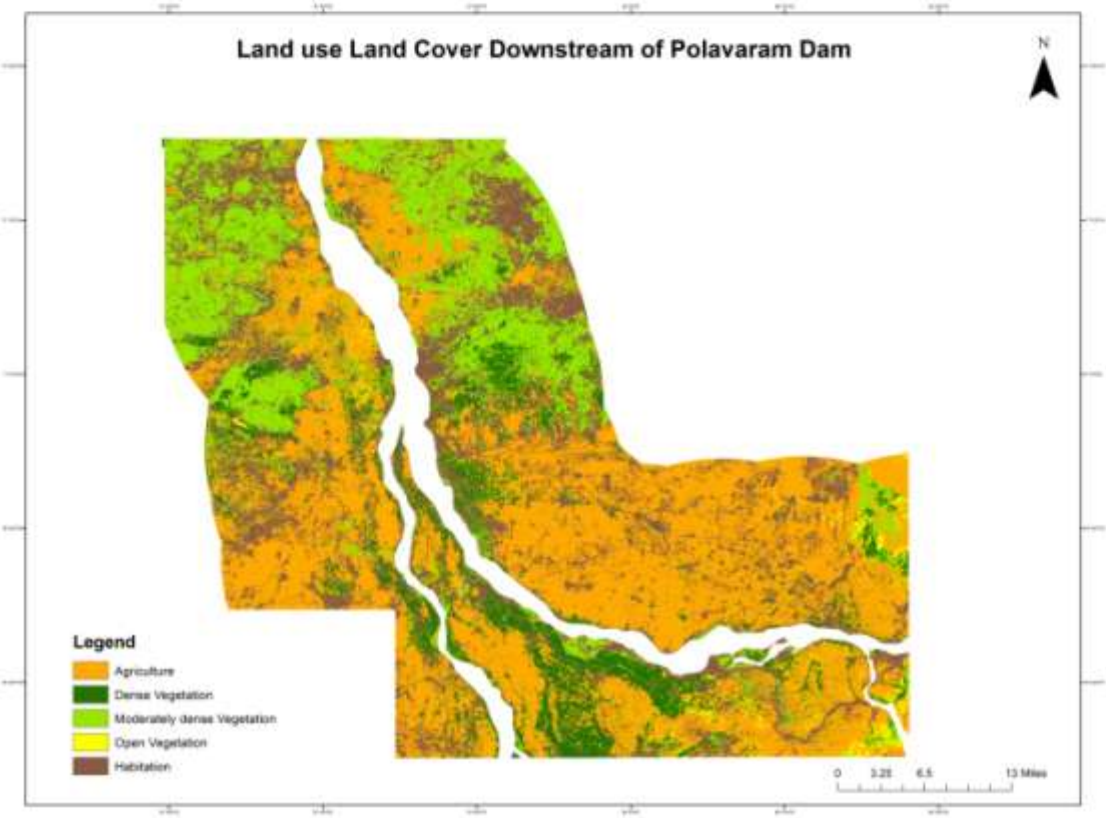

Figure 8.7 Land cover classes dependent on the river water downstream of the dam

Table 8.4 Area under each land use type

Sl. no.	Land use land cover	Area (km^2)
1	Agriculture	1566
2	Dense vegetation	357
3	Moderately dense vegetation	702
4	Open vegetation	100
5	Habitation	876
6	Total	3601

Chapter 9

POTENTIAL IMPACT OF THE PROJECT

The Polavaram Hydro Project is expected to provide enormous benefits to agriculture, industry and human communities by providing electric energy, controlling floods, providing a supply of water and recreation areas, etc. in the region. This civil work is also expected to bring about significant economic development in the region. Meantime, it may also cause severe ecological, environmental and socio-economic damage. This damage can be estimated before it takes place if we consider all the factors that affect the ecology, physical environment and socio-economic and cultural aspects of the region through the different phases of this project. These different phases are the planning (completed), construction and operation phases of the dam. In this context, this chapter analyses various potential impacts of the Polavaram Hydro Project during two phases, the construction phase and the operational phase.

9.1 Construction phase

9.1.1 Aquatic biodiversity

The construction phase of a hydro power project of such a magnitude as the Polavaram project might lead to short-term, yet important, impacts on the surrounding environment. Soil erosion and sediment runoff entering the river will be the major impacts due to clearing and excavation activities during the construction phase. This will not only lead to changes in the water quality but can also lead to loss of habitat for fishes (Bernacsek, 2001). Increased silt runoff might also lead to blocking of key fish breeding, nursery and feeding habitats in the river. Dredging of the river banks as well as clearing of riparian vegetation during the construction phase also might lead to loss of key habitats for aquatic organisms.

Blasting might not only lead to physical changes of aquatic habitat but may also alter the assemblage structure of organism. Several water bodies, such as ponds and small streams were recorded very close to the construction site. These are used by the local communities for aquacultural purposes, and they also serve as good feeding grounds for a number of aquatic bird species. Such water bodies will be directly impacted by the various construction activities and the associated traffic flow. If proper steps are not taken, such water bodies as well as the river might also be subjected to increased water pollution due to various human activities during the sonstruction phase.

Of the 89 species of fish recorded from the impact zone of the Godavari River, it is believed that 59 species will be affected during the construction phase as these species are reported from the close proximity of the dam site. Of these 59 species, the decan mahseer Tor khudree is an endangered species (as per IUCN redlist data), which has very good distribution record in streams/ rivers in the submergence zone of Pollavaram project area. Apart from that three vulnerable species namely Hypselobarbus kolus, *Chirrhinus cirhosus* and solmophysia horai also recorded from the impact zone of this region. Further, 4 exotic species (*Cyprinus carpio, Clarias gariepinus, Oreochromis mossambicus* and *Pygocentrus nattereri*) were recorded close to the dam site. These species may take advantage of native species due to man-made changes in the ecology of aquatic habitat.In addition to that the following listed species may be immediately affected by changes in the habiotat as well as construction activities. Since these species are typical stream/ flowing water fishes, the changes in the lotic habitat may have adverse effect on these species.

Table 9.1 List of fish species that may be immediately affected during the construction phase of the dam

Name	**Status (IUCN)**
Acanthocobius botia	NA
Amblypharyngodon mola	NA
Aplocheilus punchax	LC
Bagarius yarrellii	NT
Bangana dero	LC
Barilius bendalisis	LC
Catla catla	LC
Channa striatus	LC
Chela laubuca	LC
Cirrhinus cirrhosus	VU
Cirrhinus fulungee	LC
Cirrhinus macrops	NE
Cirrhinus mrigale	LC
Cirrhinus reba	LC
Danio rerio	LC
Devario aequipinnatus	LC
Eleotris gusca	LC
Esomus dandrica	LC
Etroplus suratensis	LC
Eutropiichthys goongwaree	NA
Garra mullya	LC
Glossogobius giuris	LC

Heteropneustes fossilis	LC
Hypselobarbus kolus	VU
Johnius coitor	LC
Labeo bata	LC
Labeo calbasu	LC
Labeo fimbriatus	LC
Labeo rohita	LC
Lepidocephalichthys guntea	LC
Mastacembelus armatus	LC
Mystus cavasius	LC
Notopterus notopterus	LC
Ompok bimaculatus	NT
Osteobrama cotio peninsularis	DD
Osteobrama godavariensis	LC
Osteobrama vigorsii	LC
Pangasius pangasius	LC
Parambassis ranga	LC
Parambassis thomassi	LC
Proeutropiichdhys takree	LC
Pseudosphromenus cupanus	LC
Puntius chola	LC
Puntius conchonius	LC
Puntius sarana	LC
Puntius sophore	LC
Puntius ticto	LC
Pygocentrus nattereri	NE
Roasbora daniconius	LC
Rohtee ogilbii	LC
Salmophasia horai	VU
Schistura denisonii	LC
Sperata aor	LC
Sperata seenghala	LC
Tor khudree	EN
Wallago attu	NT
Xenentodon cancila	LC

9.1.2 Impact on terrestrial biodiversity

Since a very low density of wild animals was recorded in the immediate vicinity of the dam construction site as well as along the two main canals, the construction phase might not have great negative impacts on them. However, there will be significant damage to their habitats due to blasting, excavation and other civil activities. Blasting may cause physical damage to the terrestrial birds, reptiles and other smaller animals and might cause considerable damage to their habitats and nests/nesting grounds. Construction activities will mainly affect the flora of the area as huge tracts of forests and vegetation have to be cleared for construction and associated activities.

The construction activities will also lead to suspension of huge amounts of silt and fine particles in the air, which might get settled on and damage the agricultural crops and other vegetation. This has already been observed near the dam construction site, where the leaves of the trees and shrubs have turned red due to deposition of silt. A lot of noise and sound will be generated during the various stages of construction, which will also disturb the wild animals in the forests and hills nearby. Moreover, human disturbance during the construction and operational phases of hydro projects keep away several shy wild animals from the vicinity.

9.2 Operational phase

9.2.1 Aquatic biodiversity

Habitat loss

In general, hydro projects often have significant effects on the aquatic biodiversity. They tend to fragment a riverine ecosystem and change the flowing river into a stagnant reservoir. Both these factors bring about drastic changes in the physico-chemical properties of the river, which in turn lead to a change in its biotic community. The reservoir of the Polavaram Hydro Project may positively affect certain reservoir fish species (and fisheries) or generalist fish species, but the net impact of this project on the fish diversity will eventually be negative (McCully, 1996).

Changes in the flow volume and patterns can adversely impact the structure, distribution and composition of fish communities in the region. The ecology of a stretch of the Godavari River of about 118 km length downstream of the dam site is expected to be affected due to regulated or low or nil flow from the dam. Of stretch, a 40 km long river stretch between the dam and the Rajmundry Barrage will comparatively be better than the rest of the downstream stretch, i.e. a 78 km long stretch of the river between Rajmundry and the Godavari estuary. Similarly, the flow in a stretch of about 80 km length upstream of the dam site will be affected by to the reservoir, which will change the lotic ecosystem to a lentic ecosystem, which will also affect the composition of fish and other aquatic species in the river. It is also expected that a few species in the river, including exotics, will be benefited by changes in the hydrology of the river brought about by the reservoir. Therefore, a significant extent of the fish habitat will either be modified or lost due to this project.

Barrier effect

A dam is expected to serve as a physical barrier to the movement of certain migratory species, notably fishes. This prevents brood-stock from reaching their spawning grounds during the breeding season, resulting in massive failure of recruitment and eventual extinction of the stock above the dam (Berkamp et al, 2000). Many river-adapted fish and other aquatic species cannot survive in artificial lakes. Changes in downriver flow patterns adversely affect many species and water quality deterioration in or below reservoirs can kill fish and damage aquatic habitats. Freshwater molluscs, crustaceans and other benthic organisms are even more sensitive to these changes than most fish species because of their limited mobility.

Most profoundly impacted will be species such as the mahseer, eels and the Indian shad because the dam blocks upriver fish migrations and downriver passage through turbines or over spillways is often unsuccessful (Ledec and Quintero, 2003). The *hilsa*, which is an anadromous species, has to migrate several kilometres upstream to find a suitable habitat for spawning. The *hilsa* is known to have once ascended the Ganga in its pursuit of suitable spawning grounds even up to Allahabad and Delhi (Hora, 1942). However it has suffered severe declines in many places after the construction of dams across the Ganges. Similarly, the *hilsa* used to be caught in large numbers in the downstream and estarine parts of the Godavari River, but catches nowadays have been significantly reduced, probably due to the barrage near Rajmundry. However, a few specimens of *hilsa* were collected during the study period near Polavaram and upstream of Rajmundry, which shows that this species still makes an attempt to migrate upstream for spawning and will be adversely affected after the construction of the dam.

A dam or any construction across a river is always a barrier for fish that move from one part of the stream/river to another as part of its life cycle processes. These structures are always detrimental to the survival of fishes, especially migrants that use different habitats for different life history requirements. At least 17 estuarine/marine fish species were recorded upstream of the Rajmundry Barrage, revealing that these species are migratory in nature. The dam at Polavaram will break their normal migratory behaviour, which will ultimately affect the breeding cycle. Therefore, there would be a decline in the population. A decline has already been observed due to the Rajmundry Barrage, which seems to have prevented the migration of *hilsa* and eels upstream significantly.

Changes in sedimentation flows

Changes in the sediment transport and water quality are other important environmental impacts of this project. The dam will tend to trap the sediments and nutrients, starving the downstream stretches of the river. Due to this, the water flowing below the dam will tend to erode the banks (McCully, 1996), which might render them weak and susceptible to subsidence. Reduction in sediment transport in rivers downstream of dam will also influence the morphology of the channels, floodplain and coastal delta, altering habitats for fish and other groups of animals and plants in the Godavari estuary and Coringa mangroves. Rao et al (2010) studied shoreline recession in the delta of the Godavari and Krishna rivers and found that the suspended sediment load decreased three times in the Godavari delta, from 150.2 million tons during 1970–1979 to 572 million tons by 2000–2006, which they attributed to increased sediment retention in the reservoirs of dams on the river. In a similar study (Gupta et al, 2012), it was estimated that there would be a 74% decline in the historic sediments of the Godavari after the construction of dams in the Godavari. In this context, the ongoing Polavaram dam will further diminish the flow of sediments downstream, and that will adversely affect the Coringa mangrove and Godvari estuarine ecosystems.

The sediment flow in a 118 km long stretch downstream of the dam site is expected to be reduced due to trapping of these sediments by the dam. Similarly, sediment will be trapped in the reservoir area, which extends about 80 km upstream from the dam site. These changes in the sediment both upstream and downstream of the dam may not be good for several biota, especially the benthic and pelagic animals and plants of the Godvari River.

Changes in environmental flows

It is increasingly recognized that the distribution and abundance of riverine species are limited by the effects of flow regulation (Sivakumar and Choudhury, 2008; Sivakumar, 2008; Sarkar et al, 2011. A strong correlation exists between the stream flow and a river's physico-chemical characteristics, such as the temperature of the water and habitat diversity. Research on the distributional ecology of fishes suggests that fish assemblages form in response to the physio-chemical factors of the environment. Change in the assemblage structure of stream fishes or species composition is imposed by temporal variations in the stream flow, which ultimately affects the entire biodiversity of the river ecosystem. However, the ever-increasing human population requires water for drinking, agriculture, etc., which affects the health of the river. Therefore, it becomes necessary to estimate the minimum environmental water flow and minimum environmental water level for rivers with reference to their biodiversity and the hydrological regimes.

Three kinds of adverse impacts on the aquatic biodiversity are expected because of changes in the natural flow due to the Polavaram dam in the Godavari River: (a) stagnated water in the submersible zones, which may not be conducive for certain stream/river fishes such as the mahseer; (b) less or no water flow in the dry zones of the project area, which is also expected to adversely affect the aquatic biodiversity (but it may be mitigated by maintaining the minimum environment flow); and (c) changes in the natural flow, which may also fail to provide the natural environmental cues to the aquatic biodiversity (such as *hilsa* and eels) to breed or maintain annual life histories (but this can again be mitigated by following minimum environmental flows even though it would help partially to maintain the current status of an aquatic ecosystem and its biodiversity).

In addition, the peculiar flow regime of the river is also essential for the geomorphology of the river as well as for riverine communities. Periodic droughts or floods provide signals to the fishes for breeding and spawning. For a large river such as the Godavari, the floodplain is the most important feature, which, according to McCully (1996), has 65 times greater diversity per unit area compared with the sea. This is a result of the annual flow regime of the river. However, a dam across the river will try to regulate this natural flow and change the seasonal lows or peaks of discharge.

Riparian vegetation is also an important component of an aquatic ecosystem. Riparian vegetation in the project area is very important for providing shelter and cover for fish. It also provides shade and regulates the temperature and helps flood regulation. Expected changes in the river flow and its level will affect the riparian vegetation downstream in the Godavari River. It was observed that the riparian vegetation downstream of the Dowlaiswaram Barrage was adversely affected compared with upstream due to significant changes in the water flow between upstream and downstream of Dowlaiswaram. Therefore, it is expected that the Polavaram Project will further affect the riparian vegetation, which is a critical habitat for many aquatic plants and animals.

Changes in nutrient flow

The Indira Sagar Hydro Project at Polavaram sill stop or regulate the nutrient flow downstream. A stretch of the river at least 40 km long will be submerged after the construction of the dam. The submerged sections will act as nutrient traps. Changes in the nutrient flow will adversely affect the downstream fishes and other aquatic biodiversity, especially in the mangrove and estuarine ecosystems.

Moreover, a few species may benefit from the reservoir water, which will again affect the fish composition in the region. Nutrient availability is the major environment factor that determines the fish species composition in rivers (Sivakumar, 2008). Therefore, any changes in the nutrient flow will affect the overall composition of the fish community. Although these habitats may be useful for promoting fisheries, they will be detrimental to the native fish diversity of the region.

Trapping of nutrients will also lead to changes in the water quality of the reservoir as well as the downstream stretches. In the reservoir, in the initial years the biological oxygen demand will tend to be very high due to decomposition of the vegetation, which will lead to a reduction in the dissolved oxygen, suffocating other aquatic organisms. Subsequently, algal blooms may occur due to warm weather, which will increase the productivity of the reservoir. While reservoir species and exotic species may benefit, there may be population declines of native river fishes. On the other hand, the lower stretches will experience severe depletions in nutrients and dissolved oxygen, which is again harmful for aquatic communities.

Further, there might be several effects on the way of life of the local communities who live in the floodplains, i.e. around the Godavari Estuarine Region. These effects will arise from biological changes due to physical changes downstream of the dam: (a) a reduction in the river flow, (b) saline intrusion close to the coast, (c) loss of deposition of nutrients in flooding valleys because flooding is stopped (which may affect agricultural activities), (d) problems (such as dry wells) related to fluctuations of underground water levels and (e) the risk of the failure of a dam upstream, which might produce a disastrous flood.

9.2.2 Impact on terrestrial biodiversity

Filling of the Indira Sagar dam/reservoir will result in permanent flooding of the riverine and terrestrial habitats upstream. The effects of inundation are expected to be severe on agriculture where the river valleys are usually the most productive landscape elements. Impoundment causes all terrestrial animals to disappear from the submerged areas, and populations decrease within a few years in proportion to the habitat area that is lost (Dynesius and Nilsson, 1994). Flooding can result in both local and global extinctions of animal and plant species. Particularly hard hit are the species dependent upon riverine forests and other riparian ecosystems and those adapted to the fast-flowing conditions of the main river course. From a biodiversity conservation standpoint, the terrestrial natural habitats lost to flooding are usually much more valuable than the aquatic habitats created by a reservoir (McAllister et al, 1999).

An extent of 3267 ha of forest land in Bhadrachalam (S), Bhadrachalam (N), Paloncha, Krishna, Eluru, Kakinada and Visakhapatnam forest divisions will be affected due to submergence, construction of a power house, digging of canals, etc. Of this, an area of 187.29 ha falls inside Papikonda WLS in Bhadrachalam (S), Paloncha, Kakinada and Eluru divisions. Only 47 common langur and 1 wild boar were directly sighted and there was no sighting of any other major mammalian species during the transect walks (89.92 km) in this forest land. However, a sambar and a palm civet were sighted outside the transects. During the carnivore sign surveys, which which were carried out over 37 km of trails, indirect evidence was noted of the presence of only the jungle cat *Felis chaus* and sloth bear *Melursus ursinus*, and that in small numbers. This indicated that the submergence zone is comparatively poorly used by wild mammals. Further, camera trapping also confirmed that the presence of mammals in this area is poor. Discussions with locals and our observations indicate that most of the wild animals, especially the larger mammals, are restricted to the upper reaches of the hills and deep forests of PNP. Due to high level of human presence and habitat modifications due to farming, wild animals tend to avoid the submergence zone. However, the submergence zone has a highly diverse avifauna, with 101 species reported during the study period, several of which are threatened. Further, opportunistic sightings of threatened mammal species such as the sambar and wild dog were made in the submergence area. According to the Forest Department, the area is also home to one or two tigers. Naik et al (2012) carried out extensive faunal surveys in the submergence region of the Polavaram dam and concluded that the populations of the 9 mammals, 22 reptiles and 70 bird species that are present in the submergence region will be easily affected.

Since the findings indicate that the abundance of animals in the submergence zone is very low, the impact on the mammals might be minimal. However, there might be considerable impacts on the habitats of birds and reptiles, for which necessary mitigatory actions need to be taken.

9.2.3 Impact on overall landscape

As shown in Fig. 8.6, construction of the dam will cause submergence of low-lying areas in the catchment. Of the total area of the PNP, which is 1042 km^2, about 117 km^2 is at risk of submergence. The land cover type that will be impacted the most is dense vegetation cover, which was observed during the field surveys to be a mixed deciduous teak and bamboo forest. The land use type that will undergo an immense loss is ‘cultivated land’ since most of the cultivation is carried out in low-lying regions in close proximity to the river banks. This impact can be seen within the designated boundary of

PNP. However, there will be certain adverse impacts in areas lying downstream of the dam because of the changed flow of the river. The accompanying map (Fig. 8.7) was generated to assess the threat to the landscape downstream.

Fig. 8.7 shows the land cover pattern in the land around the river downstream of the dam. Assuming that about 50 km of landsurrounding the river basin is directly and solely dependent on the river water, the downstream areas may be directly affected during the dry season when the water flow from the dam is restricted. About 1566 km^2 of agricultural land can be expected to come under the direct threat of running dry during the dry season. This agricultural area may also be affected by way of reduced productivity as the river will not be able to carry down the silt load after the construction of the dam. Eventually, since there will be continued erosion with arrested siltation, the slope of the land may also change downstream, making the region more prone to cyclonic floods.

Apart from agriculture, the basin supports about 800 km^2 of human habitations, which are most probably directly dependent on the river for water for domestic use. Close to 1000 km^2 of riparian vegetation will also be affected in view of the declining water flow.

9.2.4 Impact on coastal landscape

All parts of a river ecosystem are inter-connected. Therefore, a disturbance in one part will create a greater or lesser response over much of the system. The Polavaram dam can the stop migration of certain fish to their spawning grounds in the headwaters, impacting the estuarine fishery at the other end of the system. Management of rivers and their flows should thus consider all likely responses of the river to a planned disturbance.

Hydro projects are always viewed as a benign alternative to other forms of power generation, but dams and their reservoirs have also been implicated in a wide range of environmental effects, including severe alteration of deltas and estuaries; increased coastal erosion; reduced biodiversity and productivity of fisheries; and changes in the dynamics of the coastal phytoplankton. Dams are known to inhibit the transport of sediments required to prevent coastal erosion. For example, the Mississippi River now carries only half of its original sediment load, which has contributed to an extensive loss of Louisiana's wetlands. Prior to 1930, the Colorado River annually supplied an estimated 125–150 million tons of suspended sediment to its delta at the Gulf of California; now no sediment (or freshwater) from this river ever reaches the sea. Further, reduction of the freshwater flow into estuaries can reduce their naturally high productivity and species diversity. This occurs via declines in essential nutrient input, alterations to the salinity regime and increases in the concentrations of toxic chemicals entering the system. The alteration of flood cycles and runoff patterns also may affect those biological processes attuned to seasonal flow dynamics.

Polavaram dam may provide various benefits for society including generation of electricity and reducing the incidence of devastating floods, as well as providing a controlled supply of water which that be used for alleviating drought and meeting a variety of municipal and industrial demands. However, it will also constitute an important component in the overall degradation occurring in the Godavari estuary and delta and various nearshore environments.

Dams are thought to affect the physical environment of an estuary primarily via flow regulation. Flow regulation prevents floods, which are important physical and biological structuring mechanisms in riverine systems. Floods transport large amounts of sediment through the estuary, providing physical energy for circulation and promoting biological production. With the suppression of large floods by the dam, downstream sediment transportation will further decrease, and in situ estuarine production may further decline. Suppression of floods also might decrease the fluvial energy available for water movement and alters circulatory patterns and salinity intrusion at the Godavari delta. Because the intrusion of salt water into the estuary depends on the amount of freshwater resisting the salt water, decreased maximum flows and increased minimum flows (regulated by dams) will reduce the seasonal variability of saltwater intrusion.

Decreased variability in saltwater intrusion affects the distribution of most estuarine organisms because their distributions are determined primarily by salinity tolerance. This may have allowed range extensions or altered the distributions of many species because areas that were formerly subjected seasonally to salinity levels that are intolerable for those species may now be habitable throughout the year. The tradtional ecological knowledge (TEK) of fishermen confirms that the drastic decline in the catches of many brackish water species from the Godavari estuary might be due to alterations in the flow because of the Rajmundry Barrage.

Further, a significant reduction in the river flow will reduce the amount of sediments transported to the coast and hence the extent of the estuarine plume, an important migration cue for fish, either during their larval or adult stages. Thus, the abundance of marine fishes that use the estuary as a spawning ground or as a nursery area decreases—for example, *hilsa* and eels. Therefore, the Polavaram dam can cause a further decline in coastal fisheries.

Mangroves are best developed in areas that receive freshwater run off and are subjected to tidal water flushing. Rajmundry Barrage which was constructed for diverting water for irrigation has resulted in poor flow of freshwater into Godavari mangrove swamps. The poor flows of tidal water and freshwater have resulted in a highlevel of salinity in the mangrove swamps and thus reduced the growth of mangroves.

To cite an example, in Pichavaram, south India, the mangroves are largely dying due to hypersalinity and other associated factors such as increasing temperatures, poor precipitation, poor flushing of mangrove soil by tidal waters, etc. The current population structure of the mangroves and associated mangroves in Godavari estuary indicates that the abundance of typical mangrove species is less in the Godavari estuary compared with other halophytes or associated mangrove species. This might be due to topographical changes, aquacultural activities and reduced flow of water because of the Rajmundry Barrage.

Further, the Godavari delta mangroves are already threatened due to climate change-related impacts such as sea level rises, increased atmospheric CO_2 concentrations, fluctuations in the annual precipitation, fluctuations in temperature, high-water events such as storms and floods, etc. A rise in the sea level is also expected to cause erosion of sediments due to high-water events such as flooding and can prevent sediment accretion, which is crucial for mangrove survival in the Godavari mouth. As the hydrology is an important factor in an mangrove ecosystem, a rise in the sea level could alter the local salinity regime by bringing in more saline water, and freshwater mangroves along the landward side will be affected and more salt-loving mangroves will grow near the landward side. In this context, the expected reduced flow of the Godavari River due to the Polavaram dam will further aggravate the problems.

These adverse impacts can be minimized through careful management of water releases, and in this regard, variability is very important. Therefore, the objective in optimizing water releases from the dam is to closely mimic the natural flooding regime.

In conclusion, the Godavari River is the second largest peninsular river and has a huge area as its floodplain. Due to its peculiarity of seasonal floods during the monsoons, huge amounts of nutrient-rich alluvium have been deposited in its downstream reaches, which has also led to the formation of an intricate deltaic ecosystem at its mouth. It is due to the Godavari River and its delta that the region is blessed with agricultural and fisheries wealth. However, as discussed in the foregoing, regulation of the flow regime and entrapment of sediments in the reservoir of the Polavaram dam might lead to severe consequences not only for the flora and fauna of the region but also for its millions of people who are dependent on agriculture and fisheries.

Chapter 10

MITIGATION AND RECOMMENDATIONS FOR THE POLAVARAM PROJECT

10.1 Introduction

Among all the types of development projects, dams are seen as the most controversial. Issues linked to dams and especially to large dams such as Polavaram are often highly polarized. Critics of hydro projects express their concerns about the wide range of negative environmental and related social impacts, from the destruction of unique biodiversity to the displacement of vulnerable human populations. Defenders of dams emphasize that these are often the economically least expensive source of electric power available from renewable sources. Further, they also emphasize that larger dams that are aimed at improving agriculture and drinking facilities in the region are expected to bring socio-economic benefits to the region.

Diversion of rivers from their channels has enabled expansion of human civilization to inland areas that were otherwise unproductive (from the economic standpoint) or too remote to provide adequate water for essential life processes. Opponents of water resource developments charge that dams cause significant damage to human and natural resources, resulting in impoverishment of human populations and loss of plant and animal species and their habitats. The literature on the consequences of dam development (Goldsmith and Hildyard, 1984; Graf, 1999; Adams, 2000; Berkamp et al, 2000) indicate that the impacts of dams on ecosystems are profound, complex, varied, multiple and mostly negative. By storing or diverting water, dams alter the natural distribution and timing of stream flows. This, in turn, changes the sediment and nutrient regimes and alters the water temperature and chemistry, resulting in impacts on the ecosystems and biodiversity elements that these streams support and on their attendant socio-economic aspects. These ecosystem impacts may result in consequent changes in the freshwater biodiversity, which is already threatened on account of several other factors (Berkamp et al, 2000). Further, in the case of the Polavaram Hydro Project, the impact of the dam may also result in changes in the Godavari Estuarine Ecosystem and its ecological services, which will also affect the socio-economic profile of the estuary-dependent communities, such as fishermen. Experiences around the world show that large improvements are achieved in a dam project when the environmental effects of the dam are considered appropriately. In this context, the Ministry of Environment and Forests, Government of India approved the Indira Sagar project with certain conditions (vide their letter F.No. 8-123/2005-FC, dated 26 December 2008). In additon, it was suggested in the letter that a better mitigation plan for wildlife conservation be included with help of the WII. Against this background, this chapter suggests various possible mitigatory measures that will minimize the adverse impacts of the Polavaram Hydro Project on the biodiversity, its ecological functions and the socio-economic profile of the impact zone, which includes the estuarine region.

10.2 Suggestions for submergence zone forests management plan

The Environment, Forest, Science and Technology Department, Government of Andhra Pradesh notified an area of 1012.8588 km^2 in and around the Papikonda WLS as the PNP as a part of mitigatory measures to minimizee/compensate the adverse impacts of the Indira Sagar Hydro Project. Most of the submergence area of the project has been included in the national park, which will be available for both terrestrial and aquatic wildlife. Further, this area, which will be comparatively free from human pressure, is expected to become a better habitat for the wildlife of the Papikonda Hills and the Eastern Ghats. However, an integrated management plan is required to manage the new PNP. The plan should be prepared in consultation with all the line departments, including the local communities.

The vision of the integrated management plan of the PNP should be long-term landscape-level conservation of the biodiversity of the region and sustaining the normal ecological services of the Papi Hills and their biodiversity. The emphasis needs to be on the riverine ecosystem and its biodiversity. During the operational stage of the dam, the reservoir may attract several species of migratory bird, and the riverine habitats will attract the wild animals of the Papi Hills, especially during summer. Therefore, an intensive monitoring and management protocol is required in the management plan to conserve these migratory birds and other animals that may move towards the reservoir area during summer. Since the river will be continously used for navigation by local people and pilgrims, there should be an adequate boat traffic management plan in the management plan of the PNP.

Further, if require the entire submergence zone of the PNP may be divided into different zones. Boat nagivation zone, tourist zone and 'no use zone' are need to be clearly demarked and managed. Entire submergence zone may be considered as a separate range and an exclusive ACF level officer with adequate staff and logistic may be developed at Polavaram to assist the DFO of PNP. Eco-friendly tourism only be allowed inside the PNP with adequate tourism management planning that should also be placed as part of the Management Plan of the PNP.

Soil conservation activities along the reservoir could serve to limit erosion in the terrestrial parts of PNP and sedimentation of the reservoir. Therefore, implementation of a well planned soil conservation programme along the reservoir is important, and it should be part of the management plan of the PNP.

10.3 Suggestions for fish and fisheries management plan

10.3.1 Fish passes (ladders)

The Indira Sagar Dam will be a barrier for fish that move from one stream/river to another as part of their life cycle processes. This dam will always be detrimental to the survival of certain fishes, especially migrants that use different habitats for different life history requirements. At least 17 estuarine/marine species of fish were recorded upstream of Rajmundry Barrage, indicating that these species are migratory in nature. The dam at Polavaram will break their normal migratory behaviour, which will ultimately affect their breeding cycle. Therefore, there will be a decline in their populations. This has already been observed for *hilsa* and eels, the upstream migration of which has been prevented by the Rajmundry Barrage. It was also observed that there were about 600 fishermen's families directly dependent for their livelihoods on the freshwater fish resources in the impact zone of the Indira Sagar Project (upstream and downstream).

Fish passes are often believed to be an engineering mitigation measure for reducing impacts on fish, especially migrants. In general, the efficiency of fish passes is considered to be low, and fish migrations are severely affected (WCD, 2000), possibly due to poor engineering. Even where fish passes have been installed successfully, migrations can be delayed by the absence of better navigational cues, such as strong currents. Therefore, a fish pass with better navigational cues should be planned and that will help the most profoundly impacted species, such as the mahseer, eels and the Indian shad, move upward.

The composition of the fish communities of the Godavari River and estuary is different from that of other rivers in India. Therefore, it is advised that the help of the Central Inland Fisheries Research Institute (CIFRI), Kolkota be sought to design a better fish pass to cater to the specific behavioural propensities and physical capabilities of fish species inhabiting this river. The fish pass should have an adequate number of baffles of sufficient width and depth so that even larger fish can pass through it. The distance and slope of the fish pass should be decided based on the requirements of the 17 migratory species identified in the river. Most importantly, adequate protection should be provided for the fish pass even during the non-migratory period. Further, the fish pass should not be used as a fish trap.

10.3.2 Fish hatcheries

Any kind of ex-situ conservation programme (as an alternate conservation strategy) to artificially restock (through ranching) the fish populations of species that will be threatened by the construction of dams or any other kind of barrier across rivers or streams may not fully compensate the natural breeding phenomenon of migration. Moreover, species that are non-migratory and less significant to fisheries are largely ignored in an ex-situ (fish ranching) conservation programme. Migratory fishes in the region will therefore be affected adversely by hydro-electric projects. Therefore, the state fisheries department should design a fish hatchery in consultation with the forest department to enhance the stock of native fish species that are already threatened in the river. It is strictly advised that there should be no introduction of exotic fish species in the region. Further, it is also suggested that a brackish water fish hatchery be established in the estuarine region to enhance the stock of brackish water fishes that will be affected by changes in the freshwater flow.

10.3.3 Promoting of traditional methods of fishing

The fisheries of the Godavary estary and river used to target certain species, depending upon the season. This traditional fishing practice was gradually changed with the use of modern fishing gear and crafts that promote larger fishing sceine which capture all kinds of fishes including non-targeted aquatic fauna, fry and fingerlings. Therefore, there was a decline in the overall fish diversity of the region. In this context, it is suggested that the traditional fishing knowledge of the region be documented and the practice of the same be promoted.

10.4 Suggestions for estuarine/mangrove conservation plan

The problems caused by the reduction of sediment transported to the coast can only be solved through expensive engineering works, namely beach nourishment and ultimately shoreline protection. Inhibition of floods results in marine sedimentary deposition at the river mouth, which may be solved only through dredging. Therefore, the management plan of the Coringa WLS or management plan of the Godavari estuarine area should clearly list out all action plans required to nourish the shoreline and remove marine sediments regularly from the mouth so that the marine flow into the estuarine is maintained. Further, the existing or proposed management plans of Coringa WLS and Godavari estuary should contain a preparedness plan with respect to the Indira Sagar Project as well as climate change.

In the Godavari estuary, where the river flow would be greatly controlled by the dam, there is a time lag between the maximum rainfall and maximum river discharge. This delay can sometimes compromise the recruitment of estuarine fish species. This would cause some negative impacts on fish populations and shifts in the natural patterns of other biological communities. It is in this sense that minimum flows should be allowed from the dam.

Sometimes, it is difficult to make a compromise between effective nature conservation and economical improvement of an area. Positive impacts in the local economy should be achieved through sustainable and rational development of human activities in the area, including tourism. Tourism is regarded as one of the solutions for achieving economic development in the Godavari Estuarine Region. Therefore, the scope of the eco-tourism plan of Coringa WLS may be extended to the estuarine region. But, the development of economically viable tourism in this region has to be ecologically sensitive and culturally appropriate. Therefore, nature protection and understanding the worth of the natural patrimony that characterize the Godavary estuary/mangroves should not be neglected or forgotten.

Mangrove forests are the major coastal ecosystem found in the Godavari estuary and are among the richest and most productive ecosystems. A number of commercial and traditional products are provided by mangrove ecosystems. These include nutrient enrichment for the aquatic and terrestrial flora and fauna. Mangrove vegetation plays an indirect but very important role in coastal protection. Mangrove forests occupy a unique ecological niche and form a habitat for a variety of marine and terrestrial animals. Similarly, estuarine and sandy beaches are known to be the nesting areas of sea turtles. Therefore, an integrated coastal zone management plan is required in the estuarine region of the Godavari River that addresses the entire gamut of issues related to conservation and sustainable use of biodiversity of the region.

The functioning of the Godavari mangrove ecosystem is closely linked to land use practices. In particular, changes in water-flow regimes affect mangroves, and overdrawing of ground water may increase the danger of aquifer salinization and contamination. Consequently, the coastal zone should be considered an integral component of overall regional land use planning and development so that appropriate land use policies and action programmes may be formulated. Priority should be given not only to rehabilitation of degraded coastal lands but also rational use of land on a sustainable basis, including planned development of sustainable forest/marine products. Many of the uses and services of mangroves are compatible, such as honey collection, coastal protection and small-scale capture fisheries. Others are less so, and hence a zonation of the area according to primary land-use objectives is necessary. This underscores the need for a holistic approach within the framework of integrated coastal zone management planning.

This integrated management planning should also ensure that all goods, services and values are catered for. Management planning should therefore include periodic environmental impact assessment, and the actual management should be monitored periodically by environmental auditing. Good environmental management promotes conservation of biodiversity. However, there is limited information on the biodiversity value of the Godavari rstuary—hence the need for research.

The mangrove/estuarine management action plan cannot succeed without taking into consideration the requirements and aspirations of all the people. Success depends, inter alia, on being able to match management objectives with the interest of local populations and, through extension, securing their support and commitment. Therefore, a degree of 'self management' should be encouraged among the various users of the mangrove environment so that they can be involved in protecting their own environment. In the recent past, there have been large numbers of incidental captures of whale sharks from off the Godavari mouth. The whale shark is one of the most highly threatened sharks in the world, and it is protected under the Wildife (Protection) Act, 1972. The Gujarat Government initiated an innovative compensation programme for fishermen who release incidentally captured whale sharks. A similar model may be taken up in the region to prevent killing of this species in this region.

A lack of understanding of the importance of mangroves is an important cause of mangrove depletion and degradation. The state forest department should justify its mangrove management programme to the general public and other line departments. The authority should ensure that awareness and education programmes that inform the public about mangroves, their uses and services and how to maintain them, as well as government plans in relation to management of these resources, should therefore be developed and implemented. These programmes should be aimed primarily at the people who live near the mangroves/estuary and depend on them for various needs. These programmes should also be developed for planners, decision makers and the agricultural and public works sectors since their actions can have serious impacts on mangroves. Relevant audio–visual and visual aids should be developed, and seminars, talks, workshops and exhibitions on mangrove products and services targeted at various audiences should be conducted to create public awareness.

10.5 Expansion of ecosenstive zone around Coringa WLS

It is important in the context of the Indira Sagar Project that all the degraded mangroves around Coringa WLS sanctuary be declared either the eco-sensitive zone of Coringa WLS or a conservation reserve so that the necessary management interventions can be made to restore these mangroves habitats. The state forest department should strengthen its ongoing mangrove restoration programme and the sea turtle conservation programmes in the region with financial support from the Indira Sagar Polavaram Project.

10.6 Riverine landscape management plan

The Polavaram dam will cause submergence of the low-lying areas in the catchment area. Of the total area of the newly notified PNP, which is 1042 km^2, about 117 km^2 is at risk of submergence. The land cover type that will be impacted the most is dense vegetation cover, which was observed during the field surveys to be mixed deciduous teak and bamboo forest. Similarly, the area lying downstream of the dam will also experience adverse impacts because of the changed flow of the river. Therefore, an intensive plantation programme needs to be intiated to compensate this loss along both banks of river as well as along the Left and Right canals of the project. It is important to note that no exotic species should be encouraged in this plantation programme. Further, plant species that are compatible with the local riverine ecosystem should be planted.

At present, the riverine habitat on the left bank downstream of the dam is in a better condition relative to the right bank. The human disturbance recorded in the left bank was relatively less. On the other hand, the degree of human interference was higher on the right bank, with numerous plantations and agricultural fields right at the bank. A higher degree of cattle grazing and prevalence of exotic species was also observed on the right bank.

The RVI survey shows that there is a very high degree of degradation of the riparian zone. Even though recovery of the riparian zone to its natural pristine condition is highly unlikely, there is scope for improvement. The importance of a healthy riparian zone has already been highlighted, not only from the ecological point of view but also for other purposes such as bank stabilization, protection from floods, groundwater recharge and sustaining fishery resources, which are one of the major sources of income for the local people. Therefore, it is proposed to strengthen both the banks by planting natural vegetation without using any exotic species.

In this context, it is suggested that both the banks of the river (with a width of 50 m) from the dam site to the Godavari estuary be declared an econsenstive zone. A green belt needs to be developed using only native plants in this ecosensitive zone without disturbing its natural landscape.

Otters and fishing cats in the Godavari mangroves need special attention in the integrated management plan of Coringa WLS or the Godavari Estuarine Ecosystem. These two species are the umbrella or flagship species of this ecosystem. Any adverse impact due to the dam or climate change on the mangroves will ultimately affect the populations of these two species. Therefore, the integrated management plan of Coringa WLS should consider these two species as flagship species and try to restore their populations and their habitats. Interestingly, otters were observed close to human habitations but only at the fringes of mangroves. It was also observed that there was some conflict between the otters, fishing cats and aquaculture farmers. These wild animals are known to hunt fishes in the aquaculture farms nearby. In this context, it is important get the support of farmers for conservation of the otters and fishing cats in the region as these species are already highly threatened in India.

Chapter 11

ENVIRONMENTAL FLOWS

11.1 Introduction

Environmental flows are flows that are essential to maintain the normal ecological services of a river. Their purpose could be as general as maintenance of a 'healthy' riverine ecosystem or as specific as enhancing the chances of survival of a threatened species and other associated fauna (Smakhtin et al. 2007). The flow regime is one of the important components of a river ecosystem. The flow can reflect its health, its geographic location and the geological and topographic features of the area, apart from maintaining the socio-economic status of the region. Ecosystem components such as channel morphology and patterns, water chemistry and temperature and the biota of the channels, banks and associated wetlands reflect the nature of a river's flow pattern. In this study, the environmental flow was defined in the context of maintaining the health of river stretches downstream from Polavaram, the estuary and the mangroves of the mouth of the Godavari River.

11.1.1 Discharge of Godavari River in the project area

Figure 11.1 Flood waters in River Godavari seen from Gowthami Ghat, Rajamundry (July 2013)

The Godavari River has a catchment area of 3,14,685 km^2 and a long-term average annual surface flow of 110 km^3. During the south-west monsoons (June–September), when the region receives almost 80% of the average annual rainfall, the discharge of the river is highest. Floods are also a common feature of the river during August–September as in addition to the catchment area of the region, the river also receives water from its upper and middle reaches in Maharashtra. The flow regime of the river (Fig. 11.1 and Fig. 11.2) can be ascertained from monthly discharge data of the past 40 years from two points, Polavaram and Rajamundry.

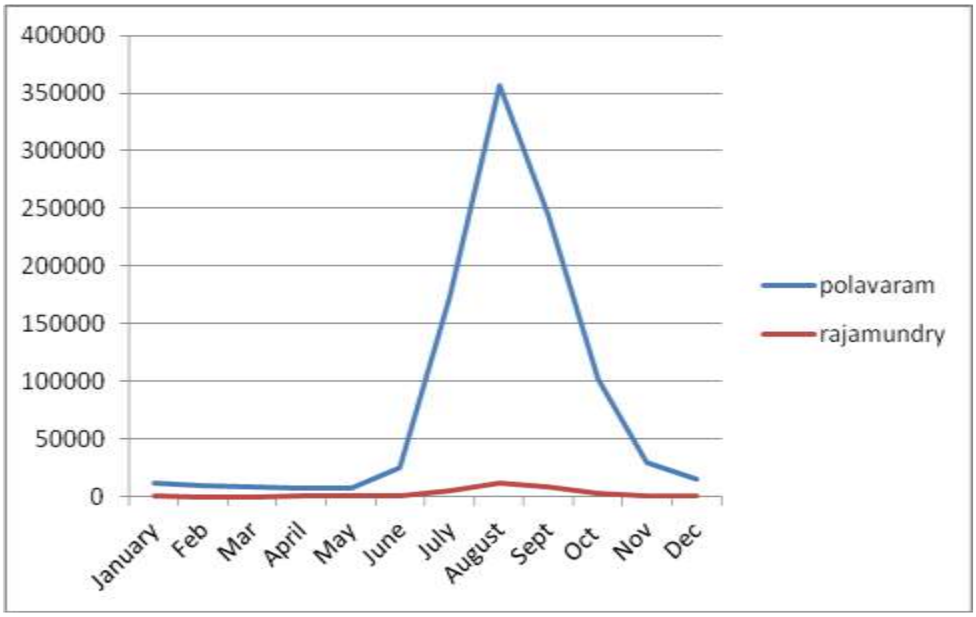

Figure 11.2 The average monthly discharge (cumecs) of the lower reaches of the Godavari River (1971–2012)

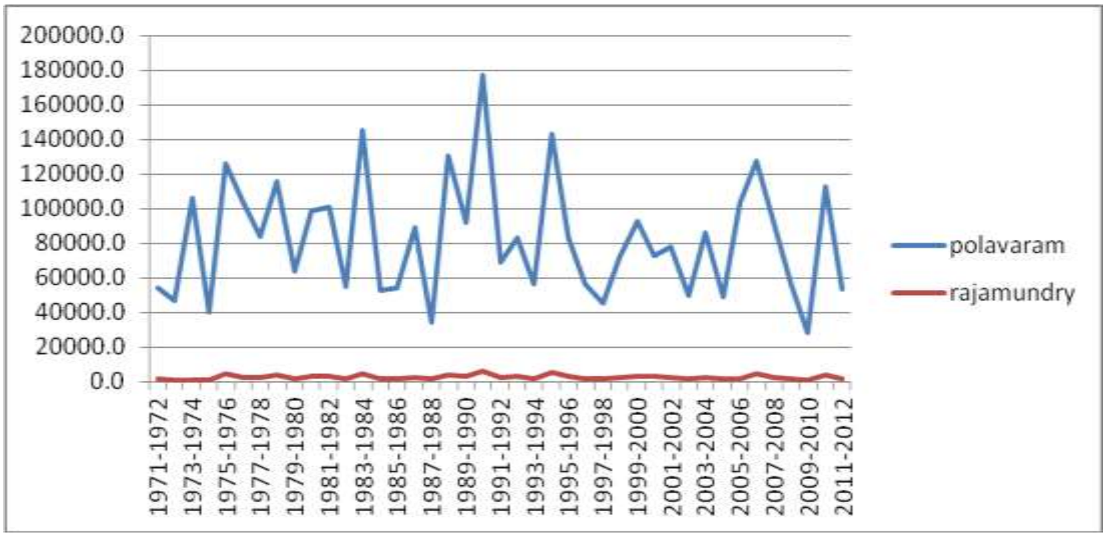

Figure 11.3 The yearly trend of discharge (cumecs) of the lower reaches of the Godavari River (1971–2012)

Fig. 11.2 shows the average monthly discharge of the Godavari River at Polavaram and Rajamundry from 1971–1972 to 2011–2012. The figure clearly shows that the discharge of the river is at its peak in August at both the points (around 3.5 lakh cumecs at Polavaram and 12,000 cumecs at Rajamundry), coinciding with the peak of the south-west monsoon in the region. The water flow remains high during this season, i.e. from June to October, after which the water level continues to recede. The water discharge decreases considerably from January to the summer months of April and May, with the lowest average discharge at Polavaram being recorded in April.

Fig. 11.3shows the yearly trend in the flow discharge of the river at the same two points. The graph for Polavaram clearly shows an irregular pattern of increases and decreases in the flow of the river. Interestingly, several times in the past 40 years, if in one year the discharge was very low, the next year experienced a steep rise in the discharge. The highest annual average discharge in the past 40 years at both the points was in 1990–1991, with Polavaram getting around 1,77,315.4 cumecs and Rajamundry getting 6218.8 cumecs of water. In addition to this, a general trend of decreasing annual average discharge in the past four decades emerges from the graph. If we compare the peak annual discharges of the four decades, in the first decade (1971–1981) the highest annual discharge was

1,26,189.3, in 1975–76. During 1981–1991, the highest annual discharge was 1,77,315.4 cumecs, whereas for 1991–2001 it was 1,42,846.6 cumecs. The decade of 2001–2012 saw a peak annual discharge of around 1,27,187.9 cumecs in 2006–2007, which is a considerable decline from the previous two decades. Also, the annual discharge at Polavaram has generally remained below 1 lakh cumecs during 2001–2012, with an all-time lowest discharge being recorded in 2009–2010 (27,993.0 cumecs).

Therefore, the flow regime of the Godavari River in its lower reaches may be deduced from the two graphs. The first deduction from the two graphs is the wide gap between the discharges at the two points, with Polavaram getting considerably higher discharges compared with Rajamundry. This can be explained by the geomorphology of the river basin. At Polavaram, the river passes through several hills and gorges which cause the river to narrow. As it emerges into the plains after Polavaram, the width of the river widens and thus the volume decreases in the downstream areas, such as Rajamundry. Further, the stretch near Polavaram lies inside a protected area, which prevents large-scale extraction of water by locals. However, in the downstream stretches, the river is lined by several big and small agricultural towns and industrial cities, which imposes a huge pressure on the river.

The flow regime of the river is characterized by a peak monthly flow in August and a general but irregular trend of increases and decreases in the annual discharge. As pointed out earlier, the annual discharge of the river has decreased in the past decade.

11.2 Methods

A global review of the present status of environmental flow methodologies revealed the existence of more than 200 individual methodologies, from 44 countries, covering all realms of the world (Tharme, 1996; Stalnaker and Arnette, 1976; Wesche and Rechard, 1980; Morhardt, 1986; Estes and Orsborn, 1986; Stewardson and Gippel, 1997). These methods could be categorized into hydrological, hydraulic rating, habitat simulation and holistic methodologies. In an international context, the development and application of methodologies for prescribing environmental flow requirements (EFRs) began as early as the 1950s, in the western USA, with marked progress during the 1970s, primarily as a result of new environmental legislation (Stalnaker, 1982; Trihey and Stalnaker, 1985). Outside the USA, the process by which environmental flow methodologies evolved and became established for use is less apparent as there is little published information on environmental flows (Tharme, 1996). In India, environmental flow assessment is a less advanced field, with little published literature that deals specifically with environmental flows (Rajvanshi, 2012). Further, many countries in Asia have just started recognizing the importance of environmental flow assessments in the long-term maintenance and sustainability of freshwater systems.

There are also a number of hybrid approaches that contain elements of one or more of these main types of methodology to assess environmental flows. They are the flow stressor–response (FSR) approach, downstream response to imposed flow transformations (DRIFT) approach and in-stream flow incremental methodology (IFIM) approach. However, there is no single method for flow assessment that can be used universally without any modification(s). This is largely due to variations in the topography, climate and other environmental settings across the globe. Moreover, flow requirements vary with different regional needs.

Environmental flows should also provide the required environmental cues for the various life history traits of a species because their important activities such as breeding, growth, metamorphosis and migration are mainly dependent on the seasonal variations in natural flows pattern. Moreover, the flow requirements for the life history stages of many fishes are dependent on the seasonal flow. Taking this into account, in this study the environmental flows required for different sectors of the river were calculated from the mean seasonal flow (MSF).

In the recent past, most of the environmental flow estimators have used hydrological indices for assessment of impacts due to water-associated developments. Thus, in the present study, there were constraints to the use of a holistic method, and hydrology-based and habitat rating methods of ecological flow assessment had to be used. In this connection, we used a method that is a combination of the modified building block (King et al, 2000) and habitat rating (Loar et al, 1986; Dunbar, 1998) methods. Moreover, we also arrived at alternate flows based on the environmental management class of the Godavari River (Smakhtin et al, 2007).

11.3 Minimum environmental flows based on ecological status of river (EMC)

In rivers where the natural river flow pattern has been altered by man, all the ecological components are likely to have changed from their historical condition. The degree to which this happens reflects the severity of the flow manipulation. As far as fishes are concerned, the water flow is one of the important limiting factors for distribution and abundance. Most of the riverine fishes are attracted towards flows for two important reasons: (i) to get more dissolved oxygen and (ii) flowing water carries a lot of nutrients from upstream, which may serve as the main food for many fishes. The natural flow during different seasons stimulates the reproductive systems of aquatic organisms and facilitates spawning-related activities. A modified flow pattern in a stream or river produces adverse effects on the water quality and species diversity, as well as distribution, migration, spawning and survival of many aquatic organisms.

A background paper prepared for IUCN/UNEP/WCD (McAllister et al, 2001) also reveals that about 60% of the world's river flow is regulated largely due to dams/barriers. The major adverse impacts of dams are (a) blocking movements of migratory species up and down rivers, causing extirpation or extinction of genetically distinct stocks or species; (b) possibly fostering exotic species, which tend to displace the indigenous biodiversity; (c) possible colonization of reservoirs by species that are vectors of human and animal diseases; (d) filtering out of woody debris, which provides habitats and sustains a food chain downstream; and (e) changing conditions in rivers flooded by reservoirs—running water becomes still, silt is deposited, deepwater zones disappear and temperature and oxygen conditions are created that are unsuitable for riverine species.

Therefore, a suitable river flow is necessary for maintaining the health, function and integrity of river and estuarine ecosystems. Moreover, seasonal variations in the flow are equally important to maintain the life history cycle of the aquatic biodiversity of these ecosystems. The major aquatic biotic components of the Godavari River are periphyton, phytoplankton, macrophytes, zooplankton, benthic macroinvertebrates, fish, reptiles, birds and mammals. Moreover, the estuarine region of the Godavari River is a biodiversity-rich area, with the largest mangrove habitats of Andhra Pradesh, housing certain threatened species such as the fishing cat and otter.

Smakhtin and Anputhas (2006) defined six environment management classes (EMCs) of rivers corresponding to their default levels of environmental flows (Table 11.1). A river that falls into classes C–F would normally be present in densely populated areas with multiple human-induced impacts. Poor ecosystem conditions (Class E and F) are sometimes not considered or acceptable from the management perspective, and the intention of management is always to 'move' such rivers up to the least acceptable, class D, through rehabilitation measures. It can be noted that the ecosystems in class F are likely to be those that have been modified beyond rehabilitation to anything resembling a natural condition.

Table 11.1 Environmental management classes (EMCs) (modified from Smakhtin et al, 2007)

EMC	Status	Ecological description	Management perspective	Default FDC shift limit
A	Natural	Pristine condition or minor modification of in-stream and riparian habitat	• Protected rivers and basins • Reserves and national parks • No new water projects (dam, diversions, etc.) allowed	Lateral shift of reference FDC one percentage point to the left along the time axis from the original FDC position
B	Slightly	Largely intact biodiversity and	Water supply schemes or	Lateral shift of reference FDC

EMC	Status	Ecological description	Management perspective	Default FDC shift limit
	modified	habitats despite water resource development and/or basin modifications	irrigation development present and/or allowed	one percentage point to the left along the time axis from the position of the FDC for A class
C	Moderately modified	The habitat and dynamics of the biota have been disturbed, but basic ecosystem functions are still intact. Some sensitive species are lost and/or reduced in extent. Alien species present	Multiple disturbances associated with the need for socio-economic development, e.g. dams, diversion, habitat modification and reduced water supply	Lateral shift of reference FDC one more percentage point to the left along the time axis from the position of the FDC for B class
D	Largely modified	• Large changes in natural habitat, biota and basic ecosystem functions have occurred. • A clearly lower-than-expected species richness • Highly reduced presence of intolerant species • Alien species prevail.	Significant and clearly visible disturbances associated with basin and water resource development, including dams, diversions, transfers, habitat modification and water-quality degradation	Lateral shift of reference FDC one more percentage point to the left along the time axis from the position of the FDC for C class
E	Seriously modified	• Habitat diversity and availability have declined. • A strikingly lower-than-expected species richness • Only tolerant species remain. • Indigenous species can no longer breed. • Alien species	High human population density and extensive water resource exploitation	Lateral shift of reference FDC one more percentage point to the left along the time axis from the position of the FDC for D class

EMC	Status	Ecological description	Management perspective	Default FDC shift limit
F	Critically modified	• Modifications have reached a critical level, and the ecosystem has been completely modified, with almost total loss of natural habitat and biota. • In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible.	This status is not acceptable from the management perspective. Management interventions are necessary to restore the flow pattern, river habitats, etc. (if still possible/feasible) to 'move' a river to a higher management category.	Lateral shift of reference FDC one more percentage point to the left along the time axis from the position of the FDC for E class

11.3.1 Assessment of ecological status downstream of the Godavari River

The catchment area of the Godavari River is about 3,13,000 km^2, with a mean annual runoff (MAR) of 110 BCM. Normally, the ecological status of such larger rivers is assessed based on the EMC of that river. The definition of the EMC should be based on existing empirical relationships between flow changes and ecological status/conditions, which are associated with clearly identifiable thresholds (Smakhtin et al, 2007). Limited evidence or knowledge is available of such thresholds (e.g., Beecher, 1990). In this connection, the EMC is a management concept that has been developed and used globally because of a need to make decisions regardless of the limited lucid hydro-ecological knowledge available (Smakhtin et al, 2007). In these conditions of uncertainty with regard to which EMC is required for a particular river, the EMCs may be used as default 'scenarios' of environmental protection and associated environmental flows as 'scenarios' of environmental water demand (Smakhtin and Anputhas, 2006). It is possible to estimate the environmental demand corresponding to all or any of such default EMCs and then consider which one is the most feasible for a river in question, given the existing and future basin developments. We followed the methodology prescribed by the International Water Management Institute (Smaktin et al, 2007) to assess the EMC of the downstream section of the Godavari River.

Table 11.2 Ecological status of the downstream section of the Godavari River (Polavaram to estuary)

Indicator	**Value**	**Score**	**Remarks**
Rare and endangered aquatic biota	High	4	There are at least 16 threatened fish species in the reach, forming about 20% of the total fish diversity of the reach. Moreover, this is 13% of threatened species of fish in the country. The presence of other threatened species such as the otter and fishing cat in the river mouth is also important to note.
Unique aquatic biota	Moderate	3	*Hypselobarbus kolus*, which is endemic to the Western Ghats, was recorded for the first time in this reach during this study. Although this reach has at least 2 important threatened mammals, the otter and fishing cat, many species are unique to this catchment and use this part of the river for breeding migration, such as mahseer and *hilsa*. The mangroves and estuarine ecosystems that are close to the dam site are also unique because of their ecosystem services.
Diversity of aquatic habitats	Moderate	3	Presence of sandy banks, slow- and fast-flowing reaches, confluences of different rivers, streams, diversity of substratum, formation of islands and estuary
Presence of protected or pristine areas	High	4	Parts of both PNP and the Coring WLS fall inside the impact zone of this project.

Sensitivity of aquatic ecosystems to flow reduction	Very high	5	Any changes in the water flow will affect the estuary and its biodiversity as well as the mangrove ecosystem. Both estuarine and mangrove ecosystems are highly sensitive to the flow.
Percentage of watershed remaining under natural vegetation	Moderate	3	Large portions of the catchment of the Godavari are relatively disturbed.
Percentage of floodplains remaining	>50%	3	Floodplains area reduced and degradation of floodplains also observed
The degree of flow regulation	High (reverse value)	3	Because of presence of Cotton Barrage (Rajmundari) the reach has already been fragmented and water flow is highly regulated at least in summer and winter.
Percentage of watershed closed to movement of aquatic biota by structures or degree of flow fragmentation	Moderate (reverse value)	3	Movements of mahseer, *hilsa*, etc. have already been blocked by the Rajmundary Barrage.
Percentage of aquatic biota that are exotic	Moderate (reverse value)	3	At least four exotic species are present in the reach (*Cyprinus carpio, Clarias gariepinus, Oreochromis mossambicus* and *Pygocentrus nattereri*). *Pygocentrus nattereri*, a new exotic fish species for India, was recorded in this reach. Further, there might be more exotics in the estuarine region.
Aquatic species' relative richness	High	4	For the available area, 89 species of freshwater and brackish water fish represents a very high species richness. Several threatened animals and plants occur in this region, including eight threatened species of fish, the otter and the fishing cat.
Human population density as	High	4	Compared with parts of the Ganges, this stretch has a moderately low

percentage of that in the main floodplains			population.
Overall water quality	Moderate (summer)	3	The quality of water is moderate due to various anthropogenic activites downstream, especially the estuarine areas.
Sum of indicator scores		45	
Maximum possible sum of scores		65	
Percentage of the maximum		69	
Probable EMC		C	The habitats and dynamics of the biota of these rivers have been disturbed, but basic ecosystem functions are still intact. Some sensitive species are lost and/or reduced in extent. Alien species present (Smakhtin et al, 2007)

11.3.2 Environmental water requirement as per EMC

In general, the habitats and dynamics of the biota of the rivers in this basin were seen to be disturbed, but the basic ecosystem functions still seem to be intact. Some sensitive species are lost and/or reduced in extent, and alien species are present. Therefore, the EMC of the Alaknanda and Bagirath Basins was assessed as 'C' (as per Smakhtin et al, 2007).

Smakhtin and Anputhas (2006) suggested 24.59% of the MAR as the environmental water required (EWR) for the Godavari River at Dowlaiswaram to maintain a uniform EMC status throughout the stretch if it is assessed as 'C'. This study also found that there will be no major issue with respect to water availability between the dam site and Dowlaiswaram except for changes in the flow regime. However, the water flow from Dowlaiswaram was the major concern even before the construction of the Polavaram dam. Further, calculations of minimum environmental flows (MEFs should also recognize that these releases are ensured specifically for environmental purposes, especially to fulfil the different life history cycle processes of aquatic biota and provide required cues to migratory species such as the *hilsa* to migrate upward for breeding. They should not include flows only for downstream commercial activities or for water supply purposes (Acreman and Dunbar, 2004; Petts, 1996). Therefore, this study has calculated that the minimum EWR for the river stretch starting from Dowlaiswaram as 24.5% from November to May, 30% during the months of June, September and October and 35% during the months of July and August.

Table 11.3 Estimates of long-term EWR volumes (expressed as percentages of the natural mean annual runoff (MAR)) at river basin outlets for different EMCs obtained using the FDC shifting method (Smakhtin and Anputhas, 2006)

River	Natural MAR (BCM)	Present day MAR (BCM)	Long-term EWR (percentage of natural MAR)					
			Class A	Class B	Class C	Class D	Class E	Class F
Brahmaputra	585		78.2	60.2	45.7	34.7	26.5	20.7
Cauvery	21.4	7.75	61.5	35.7	19.6	10.6	5.8	3.2
Ganga	525		67.6	44.2	28.9	20.0	14.9	12.1
Godavari	110	105	58.8	32.2	16.1	7.4	3.6	2.0
Krishna	78.1	21.5	62.5	35.7	18.3	8.4	3.5	1.5
Godavari at Dowlaiswaram	96.6		45.4	32.7	24.5	19.2		

Four main seasons occur annually in this region. These are: (a) *Season I.* It is considered a high-flow season, influenced by summer and the monsoon. It is from July to August. (b) *Season II.* This season is considered an average-flow period, and it falls in the months of September and October. (c) *Season III.* This season is considered a low- or lean- or dry-flow season, including the months from November to May. (d) *Season IV.* This season is considered an average-flow period, like Season II. It falls in June. Based on this classification of seasons, the MSF expected to provided the required environmental cues to the biota of the region to complete their normal life cycles was estimated and recommended.

11.4 Environmental flow using physical habitat simulation (PHABSIM) modelling.

A recent review of minimum flow methods suggested the use of procedures that link biological preferences for hydraulic habitats with hydrological and physical data (Gore et al, 2001). Physical habitat simulation (PHABSIM) is a hydraulic model based on components of the in-stream flow incremental methodology (Bovee et al, 1998) and its associated software for determining changes in habitat availability associated with changes in the flow. PHABSIM analysis requires acquisition of data about the channel composition, hydraulics and habitat suitability or preferences of individual species or groups of organisms. The channel composition data that are required include dimensional data, such as the channel geometry and distance between sampled cross-sections, and descriptive data about the substrate composition and cover characteristics. Hydraulic data that are required include measurements of the water surface elevations and the discharge at each cross-section (Figure 11.4). These data are collected under a range of flow conditions for model calibration. Habitat suitability criteria are required for each species or group of interest. Criteria may be empirically derived or developed using published information.

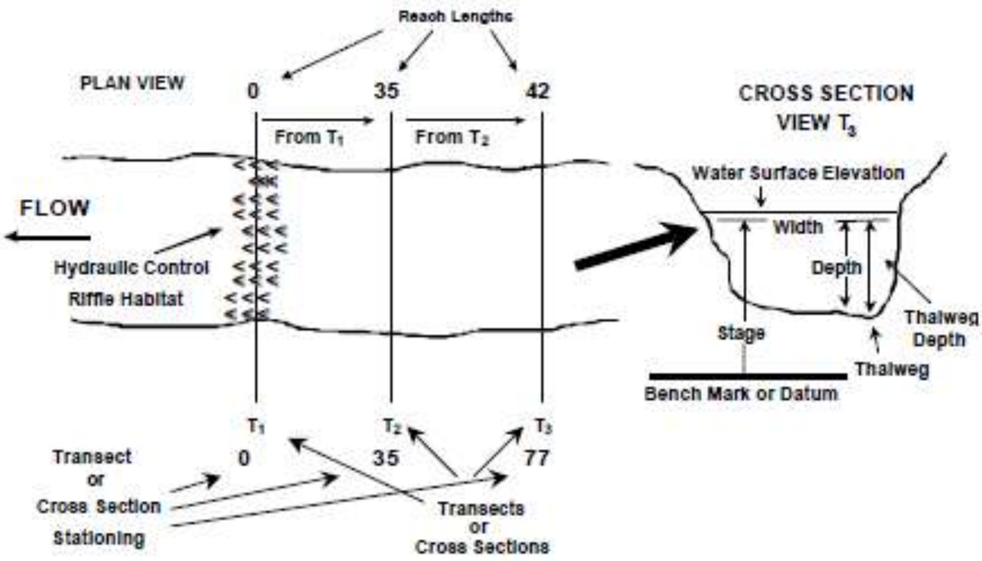

Figure 11.4 Schematic of a representative reach and a typical transect of a PHABSIM model

Hydraulic and physical data are utilized in PHABSIM to predict changes in velocity in individual cells of the channel cross-section as the water surface elevation changes (Figure 11.5). Predictions are made using a series of back-step calculations. Predicted velocity values are used in a second program routine (HABTAT) to determine cell by cell the weighted usable area (WUA) or habitat available for various organisms at specific life history stages. The WUA–discharge relationship can then be used to evaluate modelled habitat gains and losses with changes in discharge. Once the relationships between hydraulic conditions and the WUA are established, they are examined in the context of optimum habitat availability, and a given discharge is recommended as the minimum flow requirement for aquatic life.

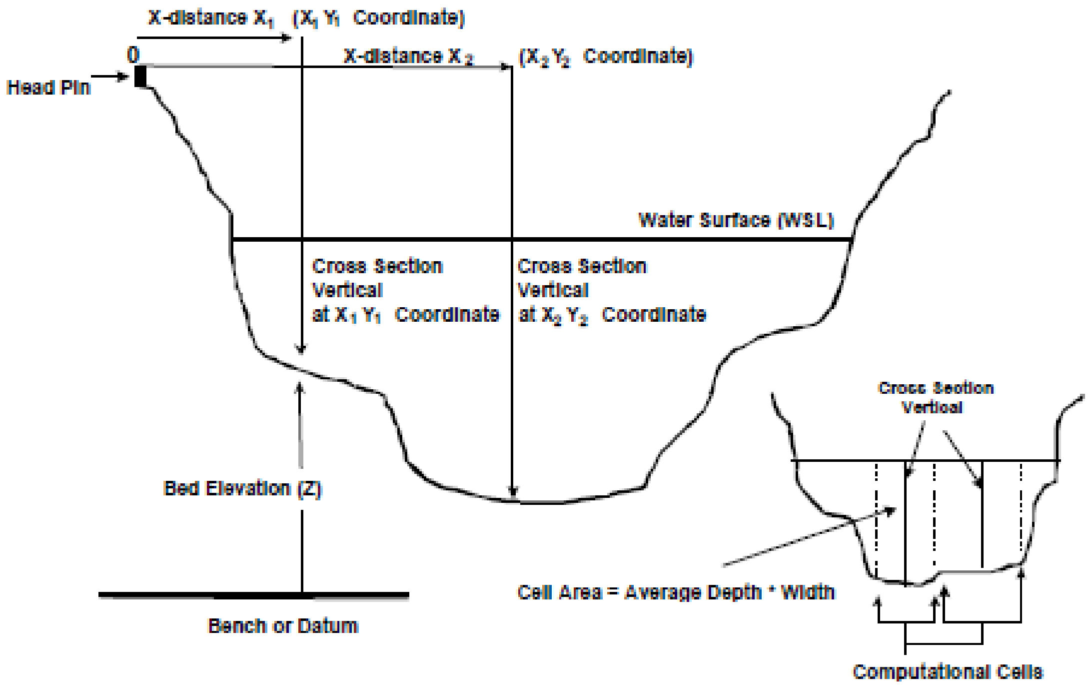

Figure 11.5 Schematic view of cross section showing hydraulic measurements and modelling terms

11.4.1 Procedure for running the model

Field sampling for developing MEFs for the Lower Godavari River, below the proposed Polavaram dam, involved characterization of cross-sectional, physical, hydrologic and habitat features. Four cross-sectional data were collected below the proposed dam (near Polavaram) for assessment of the flow requirements for the aquatic biodiversity using a PHABSIM model.

Four cross-sections were designed to quantify specific habitats for five economically important fishes (*Labeo fimbriatus, L. calbasu, Bangano dero, Cirrhinus cirhosus* and *Wallago attu*) for different flow conditions in PHABSIM. The site was located approximately 5 km downstream of the proposed dam site, near Polavaram. PHABSIM analysis required acquisition of field data about the channel habitat composition and hydraulics. At each transect, across the channel, the flow, depth and substrate type were recorded at 5 m intervals. The water velocity was measured using a Pygmy water current meter (propeller type). The channel depth was recorded using a conventional graduated depth rope. Other hydraulic descriptors measured included the channel geometry (river bottom—ground elevations), water surface elevations across the channel and water surface slope determined from points upstream and downstream of the cross-sections. Elevation data were also collected for each cross section. Life history trait and habitat requirement of fish species that have been selected for this model are as follows;

1. Labeo fimbriatus – IUCN status: Least Concern (LC)

This species is a migratory species attains a length of about 90 cm and this species is well known for its utility in fisheries. Body short and deep, dorsal profile is more convex than ventral. Mouth is sub-terminal, overhanging type and devoid of lateral lobes. Colour: Dorsal greenish, flank and ventral silver in colour (Fig...). This species is native to Peninsular river system and distributed in major rivers. It occurs in flowing rivers with rocky bottom and riverine pools. The fish is a bottom dweller, feeds mostly algae, diatoms, aquatic plants and some time feeds on organic matters.

Figure... Labeo fimbriatus

Table 1. Summary of the biology and flow-related ecological requirements of Labeo fimbriatus in Godavari river.

Observed Requirements	Adults	Juveniles	Spawning	Incubation and Larval development
Depth	Deep (>3 m)	Shallow (<0.75 – 1.5 m)	Shallow to high (0.5 -	Shallow to high (0.3 -

			2.00 m)	2.00 m)
Velocity	Medium to high (1.0 - 1.5 m/s)	Low to medium (0.1-1.0 m/s)	Low to medium (0.1 -0.5 m/s)	Low to medium (0.1-0.5 m/s)
Habitat	Riffles and pools	Pools, backwater pools closer to the banks and run habitats	Backwater pools and under the aquatic weeds near bank	Backwater pools and under the aquatic weeds
Substratum	Bed rock, Boulders, Cobbles, gravel to sandy bottom	Cobbles, gravel to sandy bottom	Aquatic weeds	Aquatic weeds
Temperature	18-22 °C	18-20 °C	<18 °C	18-20°C
Dissolved O2	6-8 mg/l	6-8 mg/l	6-8 mg/l	6-8 mg/l
Food	Algel feeder	Feeds on diatoms, phytoplankton	No information	Periphytic algae and diatoms
Breeding Period	June to July (Dowlaiswaram-Dummagudem, Godavari River documented by Ramachandra Rao in 1974)			
Passage Requirement	Moves against water current, short distance to upstream in search of breading habitat			
Migration Timings	During South-West monsoon			
Migration cues	Monsoon flood water triggers the movement of this species			

2. Labeo calbasu – IUCN status: Least Concern (LC)

This is one of the Indian Major Carp, inhabits mostly in large rivers of India. L. calbasu attains a length of about 90 cm and it is very popular known as 'Black rohu', and form economically important food fish. Body deep, dorsal and ventral profile equally arched. Dorsal fin is long, sail like structure and caudal fin is deeply forked. Body back-green in colour and ventral grey in colour (Fig.....). This species is wildly distributed in Himalayan rivers, Central India and also in Peninsular river system. It occurs in rocky and deep pools and also in sandy habitat. The fish is a bottom dweller, feeds mostly algae, diatoms and detritus.

Figure… Labeo calbasu

Table 2. Summary of the biology and flow-related ecological requirements of Labeo calbasu in Godavari river.

Observed Requirements	Adults	Juveniles	Spawning	Incubation and Larval development
Depth	Deep (>3 m)	Shallow (<0.75 – 1.5 m)	Shallow to high (0.5 - 2.00 m)	Shallow to high (0.3 - 2.00 m)
Velocity	Medium (0.5 - 1.0 m/s)	Low to medium (0.1-1.0 m/s)	Low to medium (0.1 -0.5 m/s)	Low to medium (0.1-0.5 m/s)
Habitat	Large river pools	Pools, backwater pools closer to the banks	Backwater pools and under the aquatic weeds near bank	Backwater pools and under the aquatic weeds
Substratum	Bed rock, sandy bottom	sandy bottom	Aquatic weeds	Aquatic weeds
Temperature	20-22 °C	18-20 °C	<18 °C	18-20°C
Dissolved O2	6-8 mg/l	6-8 mg/l	6-8 mg/l	6-8 mg/l
Food	Algel feeder	Feeds phytoplankton and algae	No information	Unicellular algae, planktons and diatoms
Breeding Period	Spawning period is not known, but artificial breeding is common in aquaculture			
Passage Requirement	Non migrants			
Migration	No information			

Timings	
Migration cues	No information

3. Bangana dero – IUCN status: Least Concern (LC)

It is commonly called as Kalabans, inhabits fast flowing streams/ rivers. This species is a migratory species attains a length of about 75 cm and this species is very popular minor carp, contribute substantially in river fishery. Body elongated, dorsal profile is more convex than ventral profile. Snout very prominent marked with well-marked grove along the snout. Colour: Greenish-black on back and greenish-silvery on the flank and belly (Fig. ..). This species is wildly distributed in Himalayan rivers, Central India and also in Peninsular river system. It occurs in flowing rivers with rocky bottom, sandy habitat and riverine pools. The fish is a column dweller, feeds mostly algae and aquatic plants.

Figure…Bangana dero

Table 3. Summary of the biology and flow-related ecological requirements of Bangana dero in Godavari river.

Observed Requirements	Adults	Juveniles	Spawning	Incubation and Larval development
Depth	Deep (>2 m)	Shallow (<0.75 – 1.5 m)	Shallow to high (0.5 - 2.00 m)	Shallow to high (0.3 - 2.00 m)
Velocity	Low to high (0.5 - 1.5 m/s)	Low to medium (0.1-1.0 m/s)	Low to medium (0.1 -0.5 m/s)	Low to medium (0.1-0.5 m/s)

Habitat	Riffles and pools	Pools, backwater pools closer to the banks and run habitats	Backwater pools and under the aquatic weeds near bank	Backwater pools and under the aquatic weeds
Substratum	Bed rock, Boulders, Cobbles, gravel to sandy bottom	Cobbles, gravel to sandy bottom	Aquatic weeds	Aquatic weeds
Temperature	22 °C	18-20 °C	<18 °C	18-20°C
Dissolved O2	6-8 mg/l	6-8 mg/l	6-8 mg/l	6-8 mg/l
Food	Algel feeder	Feeds phytoplankton and algae	No information	Unicellular algae, planktons and diatoms
Breeding Period	June to July in Godvari River; April to May in Himalaya September to November in Cauvery and Tamiraparani rivers			
Passage Requirement	Moves against water current, short distance to long distance migrant.			
Migration Timings	During South-West monsoon in Godaveri			
Migration cues	Monsoon flood water triggers the movement of this species			

4. Cirrhinus cirhosa – IUCN status: Vulnerable (VU)

It inhabits fast flowing streams and rivers. It is one of the minor carps of India, reaches maximum length of 1 meter. This species is wildly cultured in inland aquaculture. Body elongate and deep, dorsal profile is more curved than ventral profile (Fig….). Colour: silver colour with grey on the dorsal. Adults are entirely herbivorous, feed on algae, diatoms and phytoplankton. Spawning occurs in swift rivers, mostly marginal areas of the water body with a depth of 50-100 cm depth and over with sand or clay substrate, but fails to breed naturally in ponds. Fingerlings are in great demand for stocking ponds between July and November.

Figure… Cirrhinus cirhosa

Table 4. Summary of the biology and flow-related ecological requirements of Cirrhinus cirhosa in Godavari river.

Observed Requirements	Adults	Juveniles	Spawning	Incubation and Larval development
Depth	Deep (>3 m)	Shallow (1.00 – 2.00 m)	Shallow to high (0.5 - 1.00 m)	Shallow to high (0.3 - 1.00 m)
Velocity	Low to high (0.5 - 1.5 m/s)	Low to medium (0.1-1.0 m/s)	Low to medium (0.1 -0.5 m/s)	Low to medium (0.1-0.5 m/s)
Habitat	deep pools and runs	Pools, backwater pools closer to the banks and run habitats	Backwater pools and under the aquatic weeds near bank	Backwater pools and under the aquatic weeds
Substratum	Bed rock, Boulders, Cobbles, gravel to sandy bottom	Cobbles, gravel to sandy bottom	Aquatic weeds	Aquatic weeds
Temperature	22 °C	18-20 °C	<18 °C	18-20°C
Dissolved O2	6-8 mg/l	6-8 mg/l	6-8 mg/l	6-8 mg/l
Food	Algel feeder	Feeds phytoplankton and algae	No information	Unicellular algae, planktons and diatoms
Breeding Period	June to July			
Passage	Moves against water current, short distance to long distance			

Requirement	migrant.
Migration Timings	During South-West monsoon in Godaveri
Migration cues	Monsoon flood water triggers the movement of this species

5. Wallago attu – IUCN status: Near threatened (NT)

Wallago attu is one of the largest cat fish, inhabited in rivers, reservoirs and lakes of India. It reaches maximum length up to 240 cm. It is a predatory catfish, predate on fish, craps and frogs. This is also one of the highly favoured food fish and it is well known for its utility in capture fisheries. The population of this species has been declined due to over harvesting. Body elongate and lateral side of the body compressed. Dorsal fin is short with five simple rays. Ventral fin is long and continuous up to caudal fin. Mouth wide and both jaws are aided with sharp conical teeth. Barbel two pairs: maxillary (barbells at upper jaw) long reaches up to anal fin origin. Colour: Dorsal greyish, flank dull grey with white shining. Ventral pale white in colour (Fig...). It occurs in flowing rivers with marginal vegetation, mostly hide under holes in the river bank and canals.

Figure...Wallago attu

Table 5. Summary of the biology and flow-related ecological requirements of Wallago attu in Godavari river.

Observed Requirements	Adults	Juveniles	Spawning	Incubation and Larval development
Depth	Deep (>3 m)	Shallow (1.5 – 2.00 m)	Shallow to high (0.5 - 1.00 m)	Shallow to high (0.5 - 1.00 m)

Velocity	Low to high (0.5 - 1.5 m/s)	Low to medium (0.1-1.5 m/s)	Low to medium (0.1 -0.5 m/s)	Low to medium (0.1-0.5 m/s)
Habitat	Deep pools and slow flowing rivers, bank holes	Pools, backwater pools closer to the banks	Backwater pools and under the aquatic weeds near bank	Backwater pools and under the aquatic weeds
Substratum	Heels with grassy margin	Cobbles, gravel to sandy bottom	Aquatic weeds	Aquatic weeds
Temperature	22 - 25 °C	No information	No information	No information
Dissolved O2	5-6 mg/l	5-6 mg/l	6-8 mg/l	6-8 mg/l
Food	Algel feeder	Feeds phytoplankton and algae	No information	Unicellular algae, planktons and diatoms
Breeding Period	May - June			
Passage Requirement	Migrate to small streams, canals and flood plain during flood season			
Migration Timings	April- May (summer, prior to monsoon)			
Migration cues	No information			

11.4.2 Generation of habitat suitability curves (HSCs)

Successful implementation of PHABSIM requires acquisition of accurate and realistic habitat suitability criteria for the target organism(s) being evaluated. HSCs needed for a PHABSIM model include continuous-variable or univariate curves designed to encompass the expected range of suitable conditions for water depth, water velocity and substrate/cover type. There are three types of suitability curves. The habitat suitability criteria were generated for five species, namely *Labeo fimbriatus, L. calbasu, Bangano dero, Cirrhinus cirhosus* and *Wallago attu*. The habitat utilization of these species was generated based on the known habitat information of the species (Talwar and Jhingran, 1991; Rajvanshi 2012) and direct observations made during field surveys. The frequency distributions of certain variables such as flow and depth, which are measured at locations used by fishes, were also used to generate the HSCs in PHABSIM (Figure 11.6-11.10

HABITAT SUITABILITY CURVES

Labeo calbasu

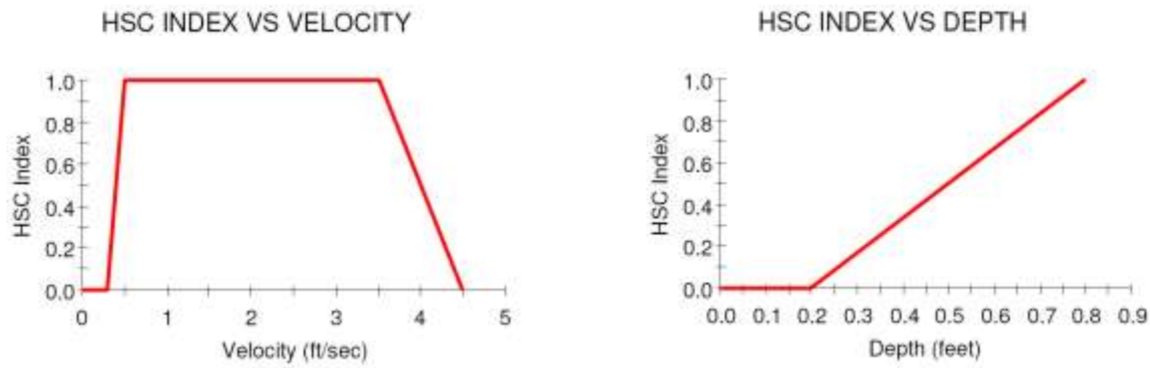

Figure 11.6 Habitat suitability curve of *Labeo calbasu*

Bangano dero

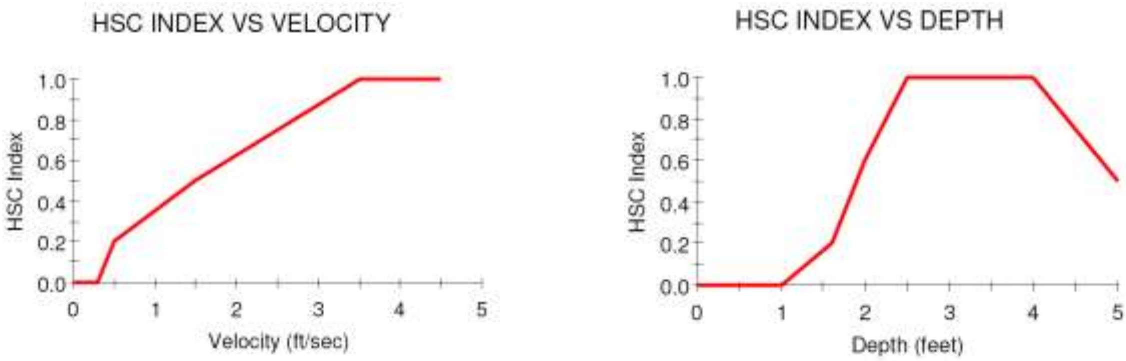

Figure 11.7 Habitat suitability curve of *Bangano dero*

Labeo fimbriatus

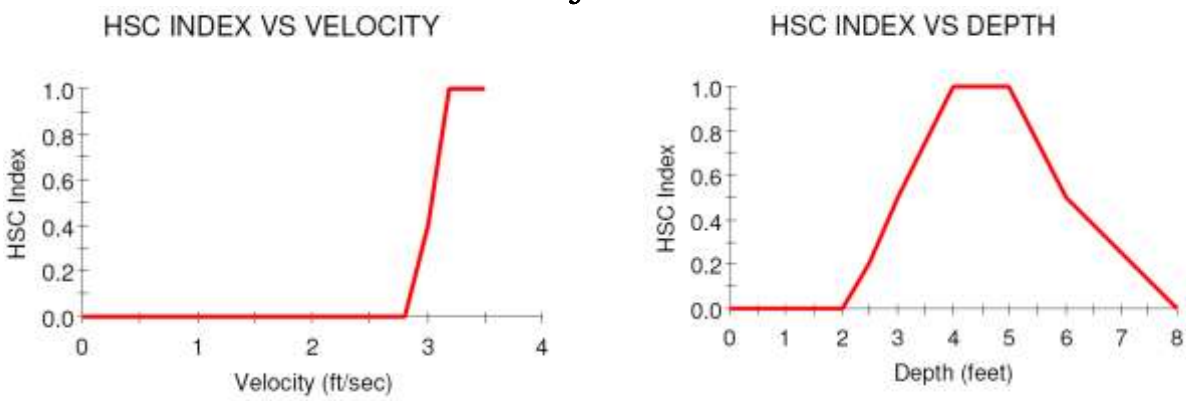

Figure 11.8 Habitat suitability curve of *Labeo fimbriatus*

Cirrhinus cirhosus

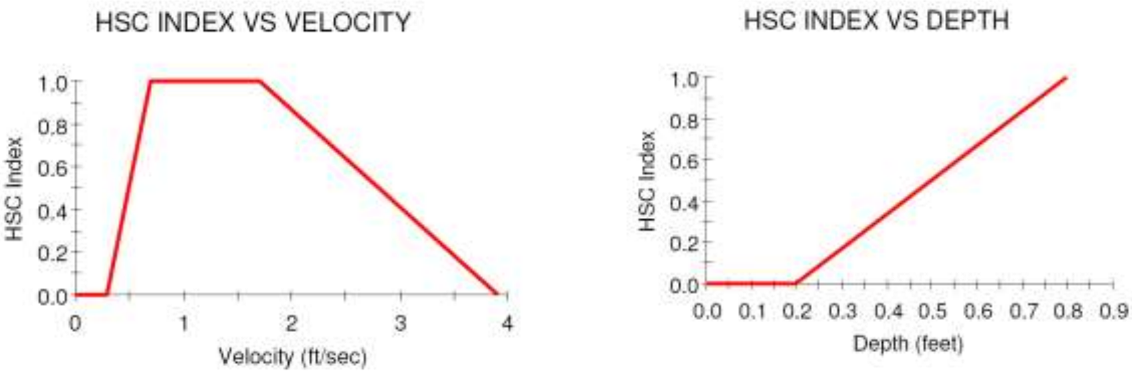

Figure 11.9 Habitat suitability curve of *Cirrhinus cirhosus*

Wallago attu

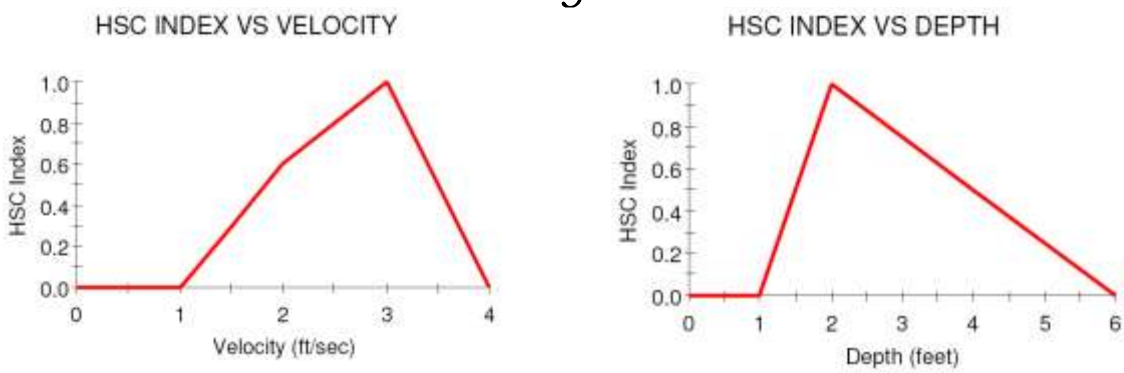

Figure 11.10 Habitat suitability curve of *Wallago attu*

11.4.3 Habitat modelling and generation of WUA in PHABSIM

In the present study HABTAE hydraulic modelling was used to determine the characteristics of the river in terms of depth and velocity as a function of discharge for the full range of discharges considered. In the habitat modelling process, this information is integrated with habitat suitability criteria (HSC) to produce a measure of the available physical habitat as a function of discharge. The general principle behind the habitat modelling programs within PHABSIM is based on the assumption that aquatic species will respond to changes in the hydraulic environment. These changes are simulated for each cell in a defined reach of a river/stream. The stream reach simulation takes the form of a multi-dimensional matrix of the calculated surface areas of a stream having different combinations of hydraulic parameters (i.e. depth, velocity, and channel index), as illustrated in Figure 11.11. The depth and velocity of each cell is the average of the simulated depth and velocity values obtained from the hydraulic simulation phase of PHABSIM. Depth and velocity attributes vary with simulated changes in discharge, causing changes in the amount and quality of the available habitat. The end product of the habitat modelling is a description of the habitat area as a function of discharge as the WUA (PHABSIM for WINDOWS, 2001).

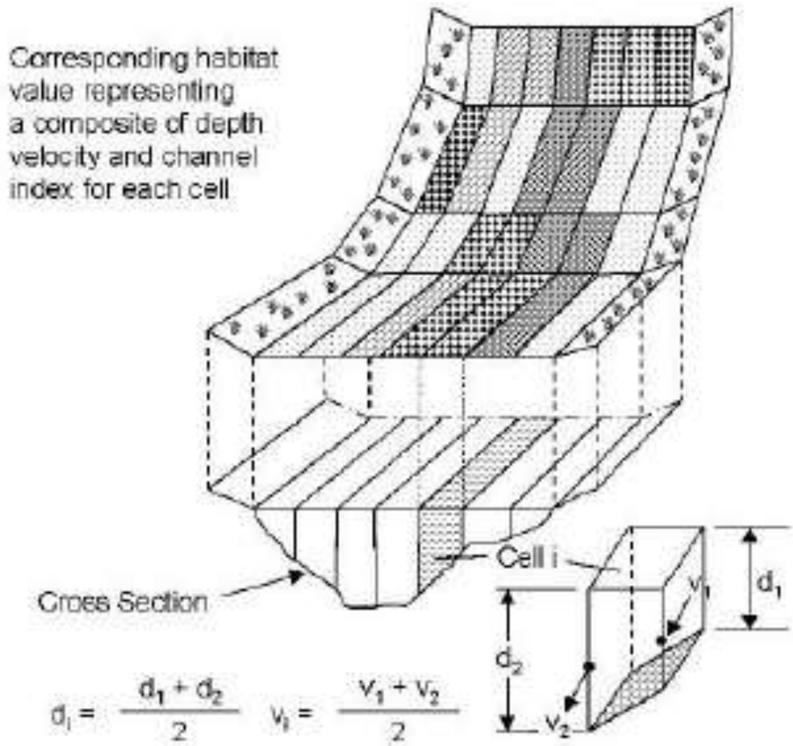

Figure 11.11 Matrix of habitat cell attributes at a PHABSIM study site

11.4.4 Results of habitat modelling

After generating cross-sectional data and HSCs for target species, the HABTAE program allows integration of biological requirements of target species, represented in the form of HSCs, with hydraulic simulation results. This integration generates a number of indices of the quantity and quality of the available habitat. These include the WUA, bed area and volume. The results can be computed for each cross-section as well as for aggregated summaries at the study site level.

Before running the model, the data were subjected to surface profile modelling and quality control. VELSIM was run for the following hydraulic simulations: 15, 30, 75, 140, 250, 625, 1250, 1750, 2500, 4000, 6000 (values are in cfts). After simulating the velocity, HABTAE was executed, and the combined habitat suitability area and WUA was generated for each species at different simulated flow scenarios. The generated results are presented here to provide a better understating of the minimum flow requirements of the target species (Figure

11.12). The WUAs predicted for low, moderate and high flows 250, 1750 and 4000 cfts) are presented in Figures 10, 11 and 12. Based on the PHABSIM results, the estimated optimum flow requirement of selected species of fish in April is about 1750 cfts (i.e. 49.55 cums), which is approximately 26% of the mean flow (192.51 cumecs) observed during April 2012, which coincidentally matches with the flow suggested by the EMC method.

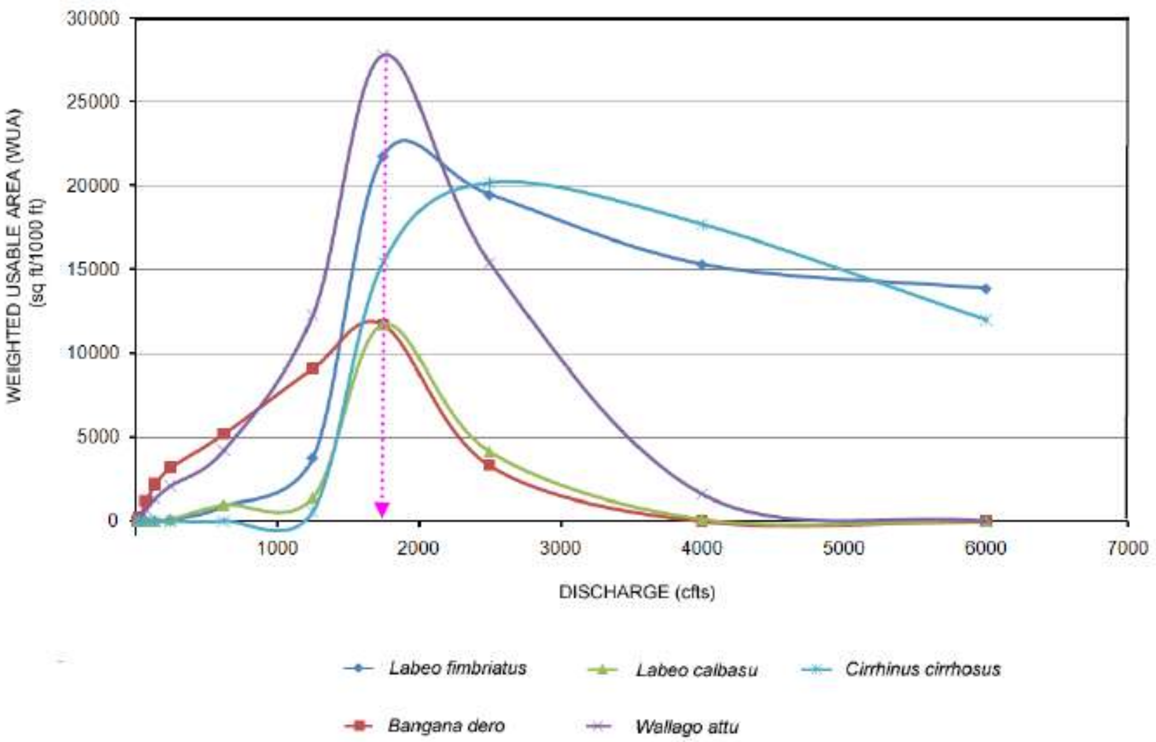

Figure 11.12 Habitat–flow relation for 5 species derived from PHABSIM analysis. The curve peaks indicate the optimum suitable habitat for each species in a given discharge.

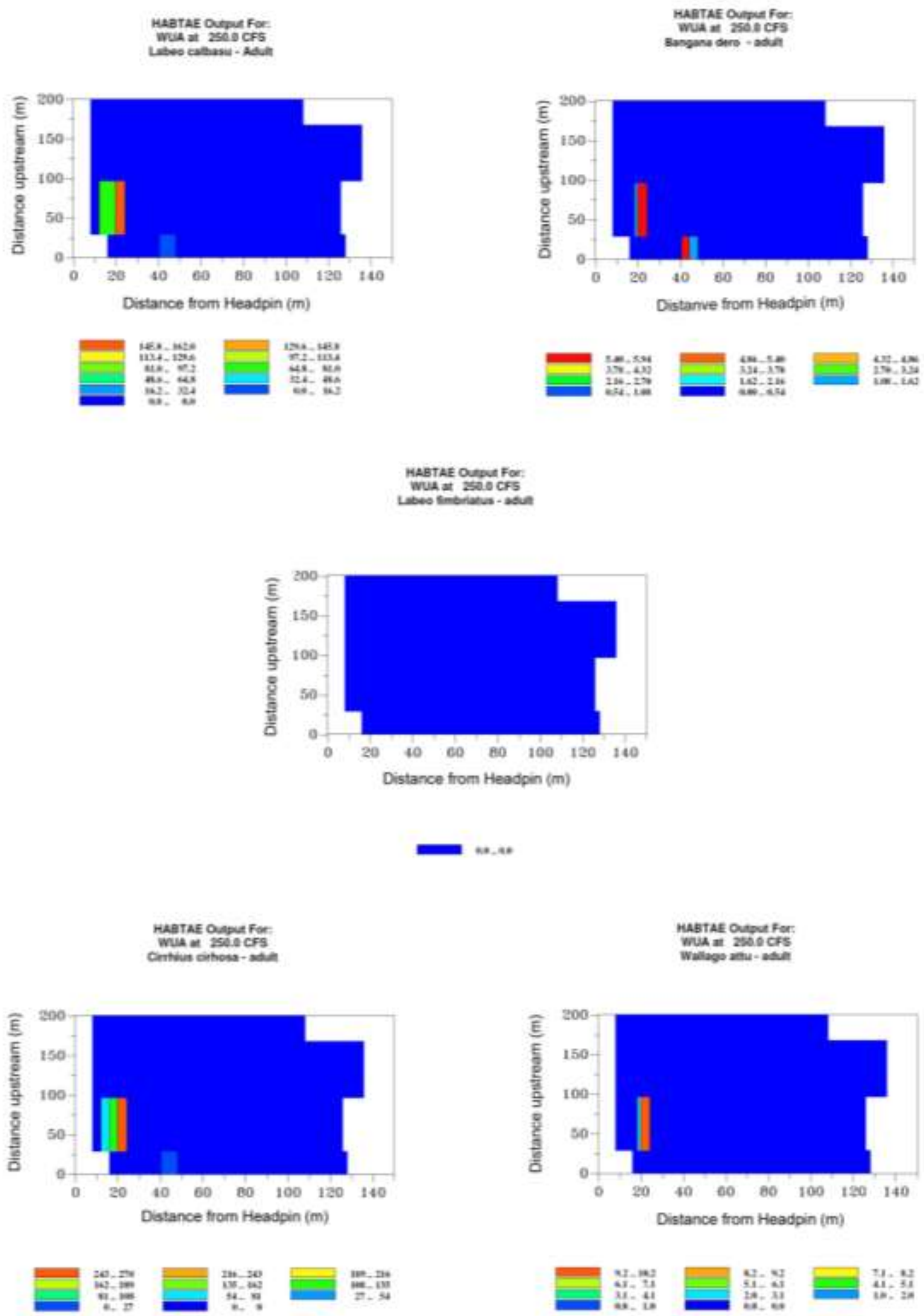

Figure 11.13 Weighted usable area predicted for selected species at 250 cfts discharge using PHABSIM

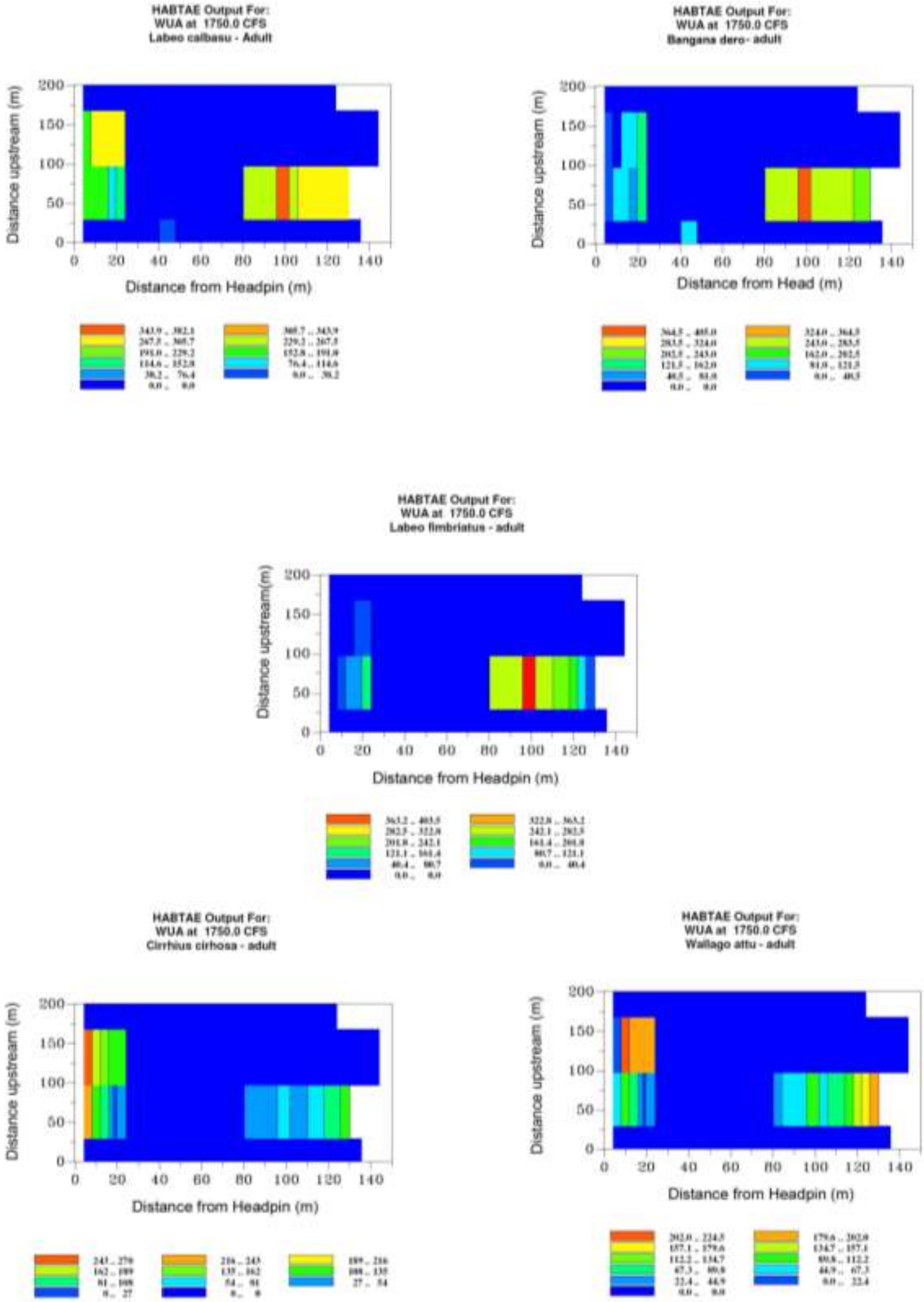

Figure 11.14 Weighted usable area predicted for selected species at 1750 cfts discharge using PHABSIM

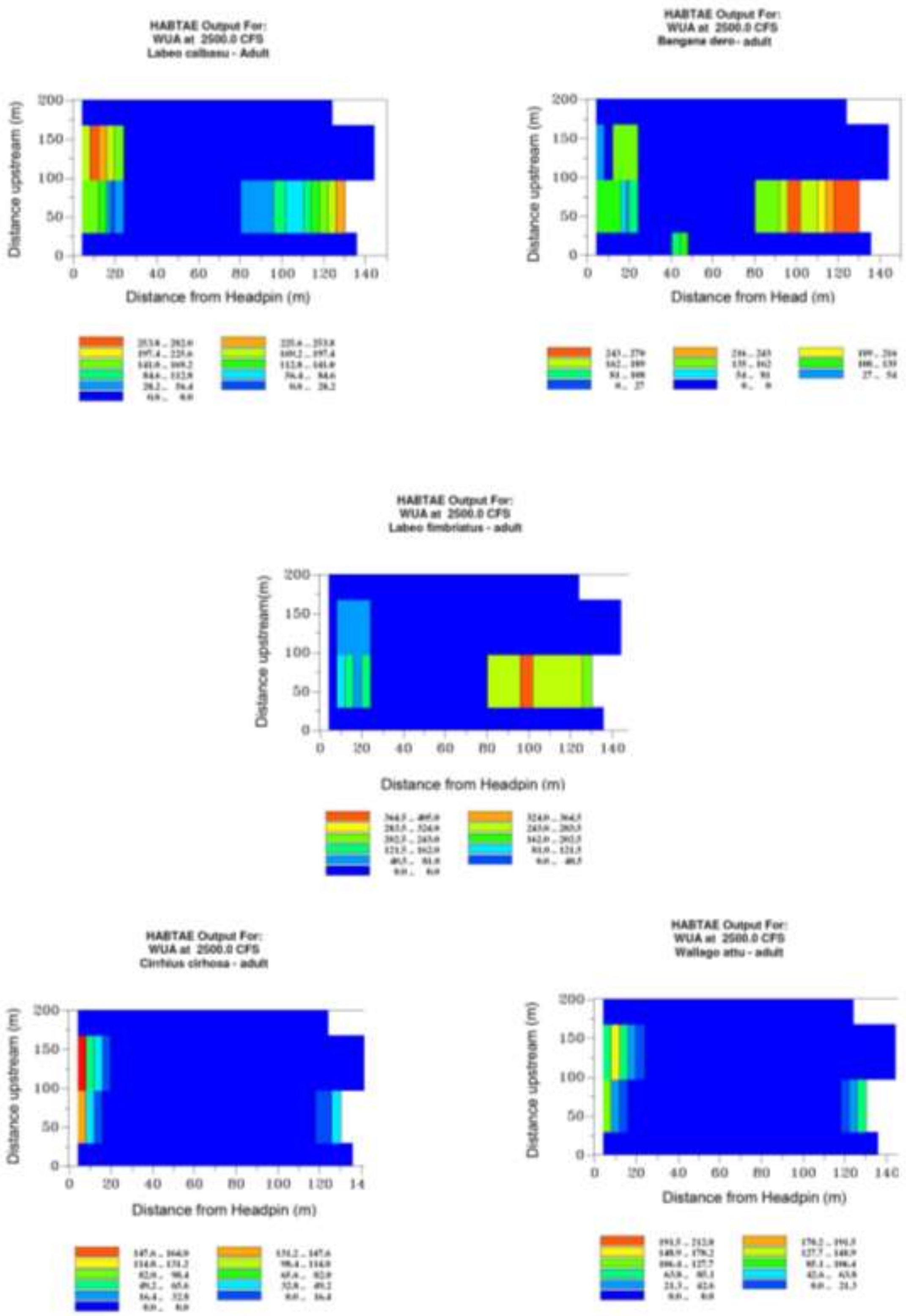

Figure 11.15 Weighted usable area predicted for selected species at 2500 cfts discharge using PHABSIM

11.5 Recommendations for environmental water flow

The region experiences four main seasons as described in the foregoing.Appreciating the importance of seasonal variations, the mean monthly flow (MSF) that was expected to provided the required environmental cues to the biota of the region to complete their normal life cycles was estimated and recommended. Two methods used for estimating required minimum environmental flow yielded more or less the same required minimum flow for the lean season (summer). Therefore, this study suggests the release of 26% cumecs from November to May, 30% cumecs during the months of June and October and 35% cumecs during July–September.

Table 11.4 Mean monthly flow (MMF) (cumec) that needs to be released from Dowlaiswaram (Rajmundry) Barrage, Andhra Pradesh

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Percentage of MMF	26	26	26	26	26	30	35	35	35	30	26	26

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Annexure I

List of mammals found in the submergence zone of PNP

Sl. no.	Common name	Scientific name	IUCN status	Wild Life Act sta
1	Leopard	*Panthera pardus*	Near Threatened	Schedule I
2	Barking deer	*Muntiacus muntjak*	Least Concern	Schedule III
3	Indian bison	*Bos gaurus*	Vulnerable	Schedule I
4	Common langur	*Semnopithecus entellus*	Least Concern	Schedule II
5	Rufous-tailed hare	*Lepus nigricollis*	Least Concern	Schedule II
6	Indian porcupine	*Hystrix indica*	Least Concern	Schedule IV
7	Jungle cat	*Felis chaus*	Least Concern	Schedule II
8	Wild boar	*Sus scrofa*	Least Concern	Schedule III
9	Wild dog	*Cuon alpinus*	Endangered	S
10	Sloth bear	*Melursus ursinus*	Vulnerable	Schedule I
11	Indian mongoose	*Herpestes edwardsi*	Least Concern	Schedule II
12	Sambar	*Rusa unicolor*	Vulnerable	Schedule III
13	Tiger	*Panthera tigris*	Endangered	Schedule I
14	Mouse deer	*Moschiola meminna*	Least Concern	Schedule I
15	Rhesus macaque	*Macaca mulatta*	Least Concern	Schedule II
16	Bonnet macaque	*Macaca radiata*	Least Concern	S
17	Striped hyaena	*Hyaena hyaena*	Not assessed	Schedule III
18	Indian giant squirrel	*Ratufa indica*	Least Concern	Schedule I
19	Jackal	*Canis aureus*	Least Concern	Schedule III
20	Common giant flying squirrel	*Petaurista philippensis*	Least Concern	Schedule II
21	Greater short-nosed fruit bat	*Cynopterus sphinx*	Least Concern	Schedule V
22	Wild goat	*Capra aegagrus*	Vulnerable	Not included

Annexure II

List of birds found in the submergence zone of PNP

Sl. no.	Common name	Scientific name	IUCN status	Wild Life Act 1972 status	Family	Distribution
1	Short-toed snake-eagle	*Circaetus gallicus*	Least Concern	I	Accipitridae	Resident
2	Black-shouldered kite	*Elanus caeruleus*	Least Concern	IV	Accipitridae	Resident
3	Unidentified falcon				Accipitridae	
4	Shikra	*Accipiter badius*	Least Concern	I	Accipitridae	Resident
5	Black kite	*Milvus migrans*	Least Concern	I	Accipitridae	Resident
6	Brahminy kite	*Haliastur indus*	Least Concern	I	Accipitridae	Resident
7	Ashy-crowned sparrow-lark	*Eremopterix grisea*	Least Concern	IV	Alaudidae	Resident
8	Rufous-winged lark	*Mirafra assamica*	Least Concern	IV	Alaudidae	Unconfirmed
9	Singing bush lark	*Mirafra cantillans*	Least Concern	IV	Alaudidae	Isolated records
10	Greater short-toed lark	*Calandrella brachydactyla*	Least Concern	IV	Alaudidae	Isolated records
11	White-breasted kingfisher	*Halcyon smyrnensis*	Least Concern	IV	Alcedinidae	Resident
12	Lesser pied kingfisher	*Ceryle rudis*	Least Concern	IV	Alcedinidae	Resident
13	Ruddy shelduck	*Tadorna ferruginea*	Least Concern	IV	Anatidae	Winter visitor
14	Lesser whistling duck	*Dendrocygna javanica*	Least Concern	IV	Anatidae	Resident
15	Indian darter	*Anhinga melanogaster*	Near Threatened	IV	Anhingidae	Resident
16	White-throated needle-tail	*Hirundapus caudacutus*	Least Concern	Not included	Apodidae	Unconfirmed
17	Asian palm-swift	*Cypsiurus balasiensis*	Least Concern	Not included	Apodidae	Resident
18	Cattle egret	*Bubulcus ibis*	Least Concern	IV	Ardeidae	Resident
19	Intermediate egret	*Mesophoyx intermedia*	Least Concern	IV	Ardeidae	Resident
20	Indian pond heron	*Ardeola grayii*	Least Concern	IV	Ardeidae	Resident
21	Grey heron	*Ardea cinerea*	Least Concern	IV	Ardeidae	Resident
22	Coppersmith	*Megalaima*	Least	IV	Capitonidae	Resident

	barbet	*haemacephala*	Concern			
23	Grey nightjar	*Caprimulgus indicus*	Least Concern	IV	Caprimulgidae	Resident
24	Little ringed plover	*Charadrius dubius*	Least Concern	IV	Charadriidae	Resident
25	Red-wattled lapwing	*Vanellus indicus*	Least Concern	IV	Charadriidae	Resident
26	River lapwing	*Vanellus duvaucelii*	Near Threatened	IV	Charadriidae	Uncertain record
27	Asian open-billed stork	*Anastomus oscitans*	Least Concern	IV	Ciconiidae	Resident
28	Spotted dove	*Stigmatopelia chinensis*	Least Concern	IV	Columbidae	Resident
29	Emerald dove	*Chalcophaps indica*	Least Concern	IV	Columbidae	Resident
30	Oriental turtle dove	*Streptopelia orientalis*	Least Concern	IV	Columbidae	Resident
31	Indian roller	*Coracias benghalensis*	Least Concern	IV	Coraciidae	Resident
32	Large-billed crow	*Corvus macrorhynchos*	Least Concern	IV	Corvidae	Resident
33	Rufous tree-pie	*Dendrocitta vagabunda*	Least Concern	IV	Corvidae	Resident
34	Pied cuckoo	*Clamator jacobinus*	Least Concern	IV	Cuculidae	Summer visitor
35	Drongo cuckoo	*Surniculus lugubris*	Least Concern	IV	Cuculidae	Former range
36	Greater coucal	*Centropus sinensis*	Least Concern	IV	Cuculidae	Resident
37	White-throated flowerpecker	*Dicaeum vincens*	Near Threatened	IV	Dicaeidae	Unconfirmed
38	Yellow-bellied flowerpecker	*Dicaeum melanoxanthum*	Least Concern	IV	Dicaeidae	Unconfirmed
39	Pale-billed flowerpecker	*Dicaeum erythrorhynchos*	Least Concern	IV	Dicaeidae	Resident
40	Black drongo	*Dicrurus macrocercus*	Least Concern	IV	Dicruridae	Resident
41	White-bellied drongo	*Dicrurus caerulescens*	Least Concern	IV	Dicruridae	Resident
42	Spangled drongo	*Dicrurus bracteatus*	Least Concern	IV	Dicruridae	Resident
43	Scaly-breasted munia	*Lonchura punctulata*	Least Concern	IV	Estrildidae	Resident
44	Orange bullfinch	*Pyrrhula aurantiaca*	Least Concern	IV	Fringillidae	Unconfirmed
45	Small pratincole	*Glareola lactea*	Least Concern	Not included	Glareolidae	Resident

46	Crested Tree swift	*Hemiprocne coronata*	Least Concern	Not included	Hemiprocnidae	Resident
47	Plain martin	*Riparia paludicola*	Least Concern	Not included	Hirundinidae	Unconfirmed
48	Red-rumped swallow	*Hirundo daurica*	Least Concern	Not included	Hirundinidae	Resident
49	Barn swallow	*Hirundo rustica*	Least Concern	Not included	Hirundinidae	Winter visitor
50	Common iora	*Aegithina tiphia*	Least Concern	IV	Irenidae	Resident
51	Golden-fronted leaf-bird	*Chloropsis aurifrons*	Least Concern	IV	Irenidae	Resident
52	Long-tailed shrike	*Lanius schach*	Least Concern	Not included	Laniidae	Winter visitor
53	Chestnut-headed bee-eater	*Merops leschenaulti*	Least Concern	Not included	Meropidae	Resident
54	Green bee-eater	*Merops orientalis*	Least Concern	Not included	Meropidae	Resident
55	Blue-tailed bee-eater	*Merops philippinus*	Least Concern	Not included	Meropidae	Winter visitor
56	White-browed wagtail	*Motacilla madaraspatensis*	Least Concern	IV	Motacillidae	Resident
57	Paddyfield pipit	*Anthus rufulus*	Least Concern	IV	Motacillidae	Winter visitor
58	Citrine wagtail	*Motacilla citreola*	Least Concern	IV	Motacillidae	Isolated records
59	Yellow wagtail	*Motacilla flava*	Least Concern	IV	Motacillidae	Winter visitor
60	White wagtail	*Motacilla alba*	Least Concern	IV	Motacillidae	Winter visitor
61	Asian brown flycatcher	*Muscicapa dauurica*	Least Concern	IV	Muscicapinae	Winter visitor
62	Blue-throated flycatcher	*Cyornis rubeculoides*	Least Concern	IV	Muscicapinae	Unconfirmed
63	Asian paradise flycatcher	*Terpsiphone paradisi*	Least Concern	IV	Muscicapinae	Summer visitor
64	Purple sunbird	*Nectarinia asiatica*	Least Concern	IV	Nectariniidae	Resident
65	Purple-rumped sunbird	*Nectarinia zeylonica*	Least Concern	IV	Nectariniidae	Resident
66	Eurasian golden oriole	*Oriolus oriolus*	Least Concern	IV	Oriolidae	Winter visitor
67	Black-hooded oriole	*Oriolus xanthornus*	Least Concern	IV	Oriolidae	Resident
68	Black-naped oriole	*Oriolus chinensis*	Least Concern	IV	Oriolidae	Unconfirmed
69	House sparrow	*Passer domesticus*	Least Concern	IV	Passerinae	Resident
70	Indian peafowl	*Pavo cristatus*	Least Concern	I	Phasianidae	Resident

71	Red junglefowl	*Gallus gallus*	Least Concern	IV	Phasianidae	Unconfirmed
72	Common flameback	*Dinopium javanense*	Least Concern	IV	Picidae	Unconfirmed
73	Baya weaver	*Ploceus philippinus*	Least Concern	IV	Ploceinae	Resident
74	Rose-ringed parakeet	*Psittacula krameri*	Least Concern	IV	Psittacidae	Resident
75	Plum-headed parakeet	*Psittacula cyanocephala*	Least Concern	IV	Psittacidae	Resident
76	Alexandrine parakeet	*Psittacula eupatria*	Least Concern	IV	Psittacidae	Resident
77	Red-vented bulbul	*Pycnonotus cafer*	Least Concern	IV	Pycnonotidae	Resident
78	Red-whiskered bulbul	*Pycnonotus jocosus*	Least Concern	IV	Pycnonotidae	Resident
79	Little stint	*Calidris minuta*	Least Concern	IV	Scolopacidae	Winter visitor
80	Common greenshank	*Tringa nebularia*	Least Concern	IV	Scolopacidae	Winter visitor
81	Spotted owlet	*Athene brama*	Least Concern	I	Strigidae	Resident
82	Common myna	*Acridotheres tristis*	Least Concern	IV	Sturnidae	Resident
83	Brahminy starling	*Sturnus pagodarum*	Least Concern	IV	Sturnidae	Resident
84	Warbler				Sylviinae	
85	Dusky warbler	*Phylloscopus fuscatus*	Least Concern	IV	Sylviinae	Unconfirmed
86	Red-naped ibis	*Pseudibis papillosa*	Least Concern	I	Threskiornithidae	Resident
87	Black-headed ibis	*Threskiornis melanocephalus*	Near Threatened	I	Threskiornithidae	Resident
88	Oriental magpie-robin	*Copsychus saularis*	Least Concern	IV	Turdinae	Resident
89	Indian robin	*Saxicoloides fulicata*	Least Concern	IV	Turdinae	Resident
90	White-rumped shama	*Copsychus malabaricus*	Least Concern	IV	Turdinae	Resident
91	Black redstart	*Phoenicurus ochruros*	Least Concern	IV	Turdinae	Winter visitor
92	Eurasian hoopoe	*Upupa epops*	Least Concern	Not included	Upupidae	Resident
93	Asian pied starling	*Sturnus contra*	Least Concern	IV	Sturnidae	
94	Yellow-footed green pigeon	*Treron phoenicopterus*	Least Concern	IV	Columbidae	
95	Pied bush chat	*Saxicola caprata*	Least Concern	IV	Muscicapinae	
96	Ashy prinia	*Prinia socialis*	Least	Not included	Cisticolidae	

			Concern			
97	Plain prinia	*Prinia inornata*	Least Concern	Not included	Cisticolidae	
98	Rufous-fronted prinia	*Prinia buchanani*	Least Concern	Not included	Cisticolidae	
99	Greater cormorant	*Phalacrocorax carbo*	Least Concern	IV	Phalacrocoridae	
100	Little cormorant	*Phalacrocorax niger*	Least Concern	IV	Phalacrocoridae	
101	Hill myna	*Gracula religiosa*	Least Concern	IV	Sturnidae	Resident

Annexure III

List of fish species recorded from the four zones in the lower reaches of the Godavari River

Sl. no.	List of species	Zone I	Zone II	Zone III	Zone IV	Habitat	IUCN status
1	*Acanthocobius botia*	+	+			Stream	NA
2	*Amblypharyngodon mola*	+				Stream	NA
3	*Anabas olegolepis*		+	+		River	DD
4	*Aplocheilus punchax*	+				Stream	LC
5	*Bagarius yarrellii*	+	+	+		River	NT
6	*Bangana dero*	+				Stream	LC
7	*Barilius bendalisis*	+				Stream	LC
8	*Catla catla*	+	+	+	+	River	LC
9	*Channa marulias*		+	+		River	LC
10	*Channa gachua*		+			River/stream	LC
11	*Channa punctatus*		+	+		River/brackish	LC
12	*Channa striatus*	+	+	+		River	LC
13	*Chela laubuca*	+				River	LC
14	*Cirrhinus cirrhosus*	+	+	+		River/brackish	VU
15	*Cirrhinus fulungee*	+	+			River	LC
16	*Cirrhinus macrops*	+	+	+		River	NE
17	*Cirrhinus mrigale*	+	+			River	LC
18	*Cirrhinus reba*	+	+			River	LC
19	*Clarias gariepinus*		+	+		River	Exotic
20	*Ctenopharyngodon idella*		+			River	Exotic
21	*Cyprinus carpio*		+	+	+	River/brackish	Exotic

22	*Danio rerio*	+				Stream	LC
23	*Devario aequipinnatus*	+				Stream	LC
24	*Eleotris gusca*	+				River	LC
25	*Esomus dandrica*	+				Stream	LC
26	*Etroplus maculatus*		+				LC
27	*Etroplus suratensis*	+	+	+		Estuarine/river mouth	LC
28	*Eutropiichthys goongwaree*	+	+			River	NA
29	*Eutropiichthys murius*		+			River	LC
30	*Garra mullya*	+				Stream	LC
31	*Glossogobius giuris*	+	+	+		River/estuarine	LC
32	*Heteropneustes fossilis*	+	+		+	River	LC
33	*Hyporamphus limbatus*			+		River	LC
34	*Hypselobarbus kolus*	+	+			River	VU
35	*Johnius coitor*	+	+	+		Estuarine/river	LC
36	*Labeo angra*						LC
37	*Labeo bata*	+				River	LC
38	*Labeo calbasu*	+	+	+		River	LC
39	*Labeo dussumieri*		+			River	LC
40	*Labeo fimbriatus*	+	+	+		River	LC
41	*Labeo rohita*	+	+	+	+	River	LC
42	*Lates calcarifer*		+	+		Estuarine/coastal	NE
43	*Lepidocephalichthys guntea*	+				Stream	LC
44	*Liza parsia*		+	+		Marine/estuarine	NE
45	*Macrognathus aral*		+	+		River	NA
46	*Macrognathus pancalus*			+	+	River	LC
47	*Mastacembelus armatus*	+	+	+	+	River	LC

48	*Mugil cephalus*		+	+		Marine/estuarine	LC
49	*Mystus armatus*			+	+	River	LC
50	*Mystus bleekeri*			+		River	LC
51	*Mystus cavasius*	+	+			River	LC
52	*Mystus gulio*			+	+		LC
53	*Nematalosa nasus*		+			Marine/brackish	LC
54	*Notopterus notopterus*	+	+	+		River	LC
55	*Ompok bimacculatus*	+	+			River	NT
56	*Oreochromis mossambicus*	+	+	+	+	Brackish/river	Exotic
57	*Oreochromis niloticus*	+	+	+	+	Brackish/river	Exotic
58	*Osteobrama belangeeri*		+			River	NT
59	*Osteobrama cotio peninsularis*	+	+			River	DD
60	*Osteobrama godavariensis*	+	+			River	LC
61	*Osteobrama vigorsii*	+	+			River	LC
62	*Pangasius pangasius*	+		+		Estuarine/river	LC
63	*Parambassis ranga*	+	+			river	LC
64	*Parambassis thomassi*	+	+			River/possibly marine	LC
65	*Proeutropiichdhys taakree*	+	+			River	LC
66	*Pseudapocryptes lanceolatus*			+		River	LC
67	*Pseudosphromenus cupanus*	+				River/stream	LC
68	*Puntius chola*	+				River/stream	LC
69	*Puntius conchonius*	+				River	LC
70	*Puntius sarana*	+	+			Stream	LC
71	*Puntius sophore*	+	+			River/stream	LC
72	*Puntius ticto*	+				River/stream	LC
73	*Pygocentrus nattereri*	+	+			River/cultured	NE

74	*Rita kuturnee*		+	+		River	LC
75	*Roasbora daniconius*	+	+			River	LC
76	*Rohtee ogilbii*	+	+			River	LC
77	*Salmophasia clupeodus*		+			River	LC
78	*Salmophasia horai*	+	+			River/stream	VU
79	*Schistura denisonii*	+				Stream	LC
80	*Sperata aor*	+	+			River	LC
81	*Sperata seenghala*	+	+			River	LC
82	*Stigmatogobius minima*			+		River	NA
83	*Tenualosa ilisha*		+	+		Marine	NE
84	*Tenualosa kelee*		+	+		Marine	NE
85	*Terapon jarbua*			+		Marine/brackish	LC
86	*Tor khudree*	+				River	EN
87	*Toxotes chatareus*			+		River	NA
88	*Wallago attu*	+	+	+	+	River	NT
89	*Xenentodon cancila*	+	+	+		River	LC

Annexure IV

List of floral species encountered in the submersible areas within PNP in Khammam, West Godavari and East Godavari districts

Sl. No.	Species	Family	WG	EG	KHM
1.	*Acacia caesia* (S)	Mimosaceae			✓
2.	*Acacia lebbeck* (T)	Mimosaceae		✓	
3.	*Acacia nilotica* (T)	Mimosaceae	✓	✓	✓
4.	*Acacia pennata* (T)	Mimosaceae			✓
5.	*Acanthus ilicifolius* (T)	Acanthaceae		✓	✓
6.	*Achyranthes aspera* (H)	Amaranthaceae	✓	✓	✓
7.	*Adina cordifolia* (T)	Rubiaceae	✓		✓
8.	*Aegle marmelos* (T)	Rutaceae			✓
9.	*Alangium salvifolium* (T)	Alangiaceae			✓
10.	*Anacardium occidentale* (T)	Anacardiaceae	✓	✓	
11.	*Annona squamosa* (T)	Annonaceae	✓	✓	✓
12.	*Anogeissus latifolia* (T)	Combretaceae			✓
13.	*Artocarpus altilis* (T)	Moraceae			✓
14.	*Azadirachta indica* (T)	Meliaceae	✓	✓	
15.	*Bambusa arundinacea* (T)	Poaceae	✓	✓	✓
16.	*Bauhinia purpurea* (T)	Caesalpiniaceae			✓
17.	*Bauhinia racemosa* (T)	Caesalpiniaceae			✓
18.	*Borassus flabellifer* (T)	Palmaceae	✓	✓	✓
19.	*Butea monosperma* (T)	Fabaceae	✓	✓	✓
20.	*Butea superba* (C)	Fabaceae		✓	
21.	*Cassia auriculata* (T)	Caesalpiniaceae			✓
22.	*Cassia fistula* (T)	Caesalpiniaceae	✓	✓	
23.	*Cassia sophera* (T)	Caesalpiniaceae			✓

Sl. No.	Species	Family	WG	EG	KHM
24.	*Catharanthes roseus* (H)	Apocynaceae	✓	✓	✓
25.	*Chloroxylon swietenia* (T)	Rutaceae		✓	✓
26.	*Chrozophora rottleri* (H)	Euphorbiaceae	✓	✓	✓
27.	*Cleistanthus collinus* (S)	Euphorbiaceae		✓	✓
28.	*Crotalaria junctia* (H)	Fabaceae	✓	✓	✓
29.	*Croton sparsiflorus* (H)	Euphorbiaceae		✓	✓
30.	*Datura metel* (H)	Solanaceae	✓	✓	✓
31.	*Dichrostachys cinerea* (T)	Fabaceae	✓	✓	✓
32.	*Diospyros melanoxylon* (T)	Ebenaceae		✓	✓
33.	*Ficus benghalensis* (T)	Moraceae	✓		
34.	*Ficus hispida* (T)	Moraceae	✓	✓	✓
35.	*Ficus racemosa* (T)	Moraceae	✓		✓
36.	*Heliotropium ovalifolium* (H)	Boraginaceae	✓	✓	✓
37.	*Holarrhena antidysenterica* (S)	Apocynaceae			✓
38.	*Indigofera tinctoria* (S)	Fabaceae	✓	✓	✓
39.	*Jatropha curcas* (S)	Euphorbiaceae	✓		✓
40.	*Lagerstroemia parviflora* (T)	Lythraceae			✓
41.	*Lannea coromandelica* (T)	Anacardiaceae		✓	
42.	*Lantana camara* (S)	Verbenaceae	✓	✓	✓
43.	*Mangifera indica* (T)	Anacardiaceae	✓	✓	
44.	*Mimosa pudica* (H)	Mimosaceae	✓	✓	✓
45.	*Mitrogyna parvifolia* (T)	Rubiaceae	✓		
46.	*Morinda tinctorea* (T)	Rubiaceae		✓	✓
47.	*Parthenium hysterophorus* (H)	Asteraceae	✓	✓	✓
48.	*Phoenix padulosa* (T)	Palmaceae	✓		
49.	*Phoenix sylvestris* (T)	Palmaceae	✓		✓
50.	*Pithecellobium dulce* (T)	Mimosaceae	✓		✓

Sl. No.	Species	Family	WG	EG	KHM
51.	*Punica granatum* (T)	Lythraceae	✓	✓	✓
52.	*Pongamia pinnata* (T)	Fabaceae	✓	✓	✓
53.	*Prosopis juliflora* (T)	Fabaceae	✓	✓	✓
54.	*Ricinus communis* (S)	Euphorbiaceae	✓		
55.	*Sida veronicaefolia* (H)	Malvaceae	✓	✓	✓
56.	*Solanum* spp. (H)	Solanaceae			✓
57.	*Soymida febrifuga* (T)	Meliaceae			✓
58.	*Sterculia urens* (S)	Sterculiaceae	✓	✓	✓
59.	*Stereospermum tetragonum* (T)	Bignoniaceae			✓
60.	*Strychnos nux-vomica* (S)	Loganiaceae	✓		✓
61.	*Sygizium cumini* (T)	Myrtaceae	✓	✓	✓
62.	*Tamarindus indica* (T)	Caesalpiniaceae	✓	✓	✓
63.	*Tectona grandis* (T)	Verbenaceae	✓	✓	✓
64.	*Terminalia tomentosa* (T)	Combretaceae	✓		✓
65.	*Thespesia populnea* (T)	Malvaceae		✓	
66.	*Trichodesma indicum* (H)	Boraginaceae	✓	✓	✓
67.	*Vitex negundo* (S)	Verbenaceae	✓	✓	
68.	*Wattakaka volubilis* (C)	Asclepiadaceae	✓	✓	✓
69.	*Ziziphus mauritiana* (S)	Rhamnaceae		✓	✓
70.	*Ziziphus oenoplia* (S)	Rhamnaceae	✓		✓

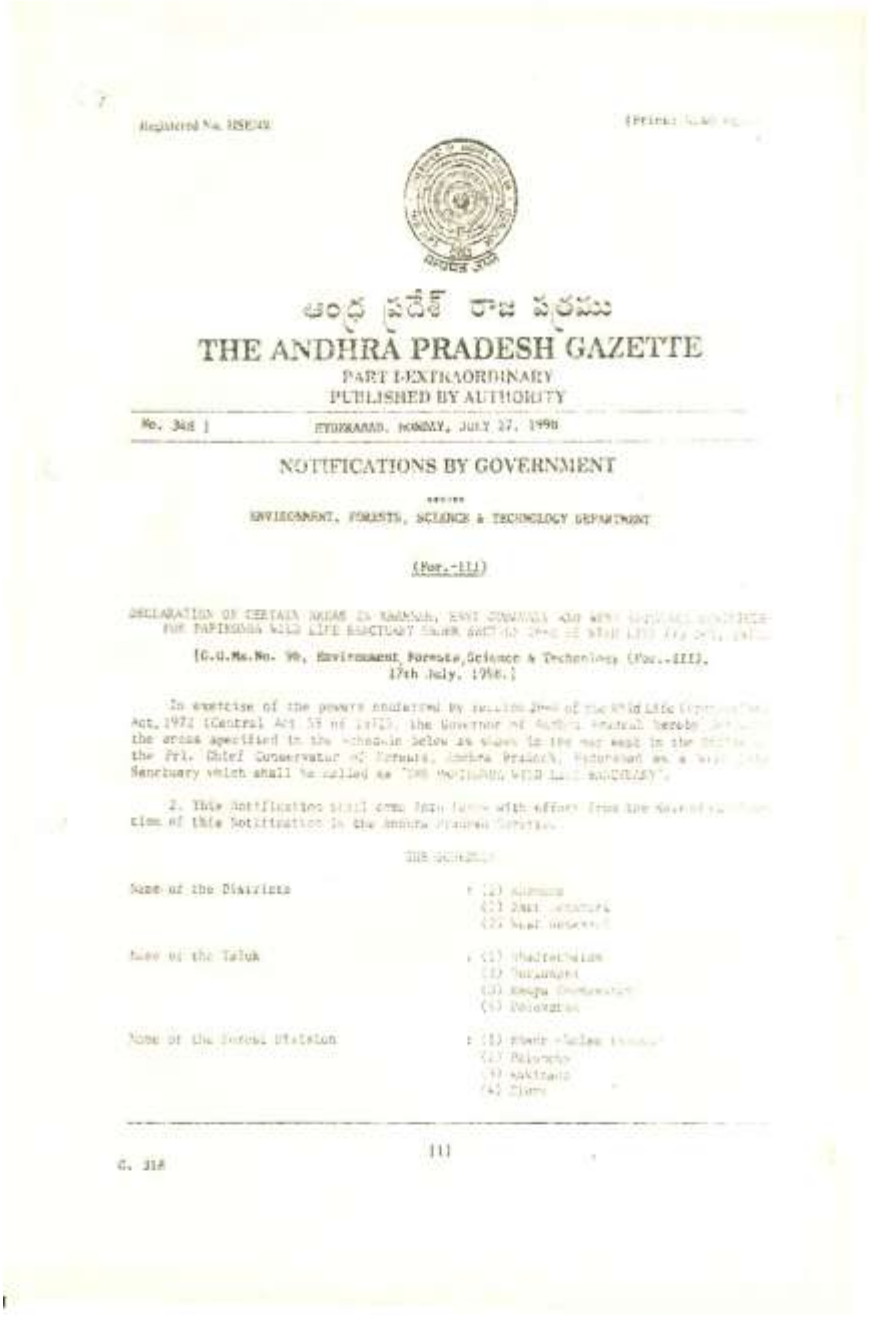
T, tree; S, shrub; H, herb; C, climber.

WG, West Godavari; EG, East Godavari; KHM, Khammam.

✓ Present in the respective district.

ANNEXURE – V

GAZETTE NOTIFICATIONS OF PAPIKONDA WILDLIFE SANCTUARY AND NATIONAL PARK DECLARATION



Registered No. HSE/49 [illegible]

[Price: [illegible]

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THE ANDHRA PRADESH GAZETTE

PART I-EXTRAORDINARY

PUBLISHED BY AUTHORITY

No. 348] HYDERABAD, MONDAY, JULY 27, 1998

NOTIFICATIONS BY GOVERNMENT

ENVIRONMENT, FORESTS, SCIENCE & TECHNOLOGY DEPARTMENT

(For.-III)

DECLARATION OF CERTAIN AREAS IN KHAMMAM, EAST GODAVARI AND WEST [illegible] FOR PAPIKONDA WILD LIFE SANCTUARY UNDER SECTION [illegible]

[G.O.Ms.No. 98, Environment Forests, Science & Technology (For.-III), 17th July, 1998.]

In exercise of the powers conferred by section [illegible] of the Wild Life [illegible] Act, 1972 (Central Act 53 of 1972), the Governor of Andhra Pradesh hereby [illegible] the areas specified in the schedule below as shown in the map kept in the [illegible] the Prl. Chief Conservator of Forests, Andhra Pradesh, Hyderabad as a [illegible] Sanctuary which shall be called as "THE PAPIKONDA WILD LIFE SANCTUARY".

2. This Notification shall come into force with effect from the date of [illegible] tion of this Notification in the Andhra Pradesh Gazette.

THE SCHEDULE

Name of the Districts	: (1) Khammam (2) East Godavari (3) West Godavari
Name of the Taluk	: (1) Bhadrachalam (2) [illegible] (3) [illegible] (4) Polavaram
Name of the Forest Division	: (1) [illegible] (2) [illegible] (3) Kakinada (4) Eluru

[1]

G. 318

Name of the Ranges : (1) V.R. Puram
(2) Rudramkote
(3) Gokavaram
(4) Polavaram

Name of the Wild Life Division : Wild Life Management Division, Rajahmundry.

Name of the Sanctuary : PAPIKONDA WILD LIFE SANCTUARY

Area of the Sanctuary : 59,068 Ha. or 591 Sq. Kms.

AREA STATEMENT

Sl. No.	Name of the District.	Name of the Taluk.	Name of the Forest Division.	Name of the Range.	Area of the Sanctuary in Sq. Kms.
(1)	(2)	(3)	(4)	(5)	(6)
1.	Khammam	1. Bhadra-chalam.	Bhadrachalam (S).	V.R. Puram	98.56
		2. Burgumpadu	Paloncha	Rudramkota	129.95
2.	East Godavari	Rampachodavaram	Kakinada	Gokavaram	196.26
3.	West Godavari	Polavaram	Eluru	Polavaram	148.38
4.	Godavari River bed.	-	-	-	15.53
					59,068 Ha. or 591 Sq. Kms.

BOUNDARY DESCRIPTION

The boundaries of the Sanctuary as delineated in the map kept in the Office of the Pri. Chief Conservator of Forests, A.P., Hyderabad are as follows:

North (A To B).–The boundary of the sanctuary starts from the station 'A' denoted on the map and on the field by the construction of Masonary Pillar which is also North West corner of the Sanctuary. On the Southern enclosure line of village Somanamalla in Rekhapally hill Reserve Forest of Bhadrachalam South Division. The line runs in Easterly direction along the Foot path Somanamalla to Kakarlava village upto Gonderu and crosses the Gonderu vagu near Akuluru village and further runs in Easterly direction along the foot path to Kakarlava through Akuru Reserve Forest and joins the station 'B' denoted on the map, which is located on the Eastern bank of Pamuleru river.

EAST (B to C).–The Sanctuary line starts from Station 'B' and runs in Southernly direction about 5 to 6 Kms. along the Eastern Bank of river Pamuleru upto a point where another vagu joins the Pamuleru river. Then the line runs in easterly direction along the vagu for about 3 kms. and turns in South Westerly direction and runs along the ridge of the hill upto Kudumuru village and runs in South Easterly direction in a zig zag manner upto a point on Akuru Reserve Forest near Akuru village, then the line runs along the Akuru Reserve Forest for about 2 Kms. and joins the Eastern boundary line of Kondamodalu Reserve Forest. Then the line runs in Southernly direction along Kondamodalu Reserve Forest upto a point where Thunnuru Reserve Forest joins the Kundamudelu R.F. Then the line runs along Tunuru R.F. in Easterly direction in a zig zag manner along the Thunnuru Reserve Land and joins the Eastern boundary line of Manturu Reserve Land in South Westerly and northernly direction upto a Masonary Pillar constructed on the Eastern bank of river Godavari near Kat[illegible]luru village. Then the line crosses the river Godavari and joins the [illegible] Pillar constructed on the Western banks of river Godavari near Tutigunta village and then proceeds further and joins Eastern boundary line of Geddapalli R.L. and runs along the Geddapalli R.L. in Southernly direction in a zig zag manner upto the point where Singannapalli R.L. join the Geddapalli R.L. near Godavari river. Then the line runs along the northern line of Singannapalli R.L. and joins Paidipaka R.L. and runs in Southernly direction along the Paidipaka R.L. upto station (C) denoted on the map.

South (C to D).-The Sanctuary line starts from station (C) which is also the southern point of Paidipaka R.L. and runs in North Westerly direction along Paidipaka R.L. and Singannapalli R.L. and joins South Eastern Corner of Geddapalli, R.L. and includes Singannapalli and Paidipak R.L. Then the line runs along the Southern boundary line of Geddapalli R.L. in North Westernly direction upto the place where Gaddapalli line joins Kavaa R.L. which is a station (C-1) enoted on the map. Then the line runs in Northerly direction along the common line of Kovada and Geddapalli R.L. upto the village Geddapally where it joins Papikonda R.F. boundary line and thence the line runs further in westerly direction along Chikaluru, Dharwada and Katrapally enclosure line and joins the common line of Kavada and Papikonda R.Fs. Thence the line runs along the Southern boundary of Papikonda R.F. and joins at the common point of Parentapally and Papikonda R.F's. Then the line runs along the southern boundary of Parantapalli R.F. in Westerly direction upto a point where Eastern boundary of Katkuru R.F. joins the Parentapalli near Gogulapalli village which is Station (D) denoted on the map.

West (D to A).-The Sanctuary line starts from Station (D) and runs in northernly direction along the common boundry line of Parentapalli R.F. and Katkur R.F. upto the common junction point where Perantapalli Extention (I) joins and thence the line runs in the Zig zag manner and joins the masonary pillar constructed on Southern Bank of river Godavari near the village Kohidal. Then the line crosses the river Godavari and joins the masonary pillar constructed on Northern Banks of River Godavari at a place on the south west corner of Rakapalli Hill Reserve Forest in Northernly direction upto the village Bheemavaram and turns in North Easterly direction to a distance of about 1/2 K. Mtrs. and joins the southern boundary of enclosures line of Maredubudi village. Thence the line runs along the Maredubudi enclosure line in North Easterly direction along the foot path 'Bheemavaram to Gonderu' upto the river Peddavagu. Then the line runs in Northerly direction along the Peddavagu. Then the line runs in Northerly direction along the Peddavagu through Rekhapalli Hill Reserve Forests upto the State (A) which is the starting point of the sanctuary line near Soman Malla village denoted on the map as Station (A) on the Banks of Peddavagu.

All the enclosures within the Reserve Forest and villages, private lands covered in the above specified limits shall stand included for the purpose of this notification. The Conservator of Forests (Wild Life Management), Hyderabad who is authorised to perform the functions of the District Collector vide G.O. Ms. No. 39, EFS & T (For. III) Department, dated 17-4-97 has determined the existence, the nature and the extent of the rights of the persons in the Papikonda Wild Life Sanctuary vide his Proc. No. 2450/97/W6, dated 1-6-1998 as follows:

"The local communities are entitled to the rights and concession as admitted at the time of settlement of Forest Blocks".

a zig zag manner upto a point on Akuru Reserve Forest near Akuru village, then the line runs along the Akuru Reserve Forest for about 2 Kms. and joins the Eastern boundary line of Kondamodalu Reserve Forest. Then the line runs in Southernly direction along Kondamodalu Reserve Forest upto a point where Thunnuru Reserve Forest joins the Kundamudelu R.F. Then the line runs along Tunuru R.F. in Easterly direction in a zig zag manner along the Thunnuru Reserve Land and joins the Eastern boundary line of Manturu Reserve Land in South Westerly and northernly direction upto a Masonary Pillar constructed on the Eastern bank of river Godavari near Kat[illegible]luru village. Then the line crosses the river Godavari and joins the Mas[illegible] Pillar constructed on the Western banks of river Godavari near Tutigunta village and then proceeds further and joins Eastern boundary line of Geddapalli R.L. and runs along the Geddapalli R.L. in Southernly direction in a zig zag manner upto the point where Singannapalli R.L. join the Geddapalli R.L. near Godavari river. Then the line runs along the northern line of Singannapalli R.L. and joins Paidipaka R.L. and runs in Southernly direction along the Paidipaka R.L. upto station (C) denoted on the map.

South (C to D).-The Sanctuary line starts from station (C) which is also the southern point of Paidipaka R.L. and runs in North Westerly direction along Paidipaka R.L. and Singannapalli R.L. and joins South Eastern Corner of Geddapalli, R.L. and includes Singannapalli and Paidipak R.L. Then the line runs along the Southern boundary line of Geddapalli R.L. in North Westernly direction upto the place where Gaddapalli line joins Kavaa R.L. which is a station (C-1) enoted on the map. Then the line runs in Northerly direction along the common line of Kovada and Geddapalli R.L. upto the village Geddapally where it joins Papikonda R.F. boundary line and thence the line runs further in westerly direction along Chikaluru, Dharwada and Katrapally enclosure line and joins the common line of Kavada and Papikonda R.Fs. Thence the line runs along the Southern boundary of Papikonda R.F. and joins at the common point of Parentapally and Papikonda R.F's. Then the line runs along the southern boundary of Parantapalli R.F. in Westerly direction upto a point where Eastern boundary of Katkuru R.F. joins the Parentapalli near Gogulapalli village which is Station (D) denoted on the map.

West (D to A).-The Sanctuary line starts from Station (D) and runs in northernly direction along the common boundry line of Parentapalli R.F. and Katkur R.F. upto the common junction point where Perantapalli Extention (I) joins and thence the line runs in the Zig zag manner and joins the masonary pillar constructed on Southern Bank of river Godavari near the village Kohidal. Then the line crosses the river Godavari and joins the masonary pillar constructed on Northern Banks of River Godavari at a place on the south west corner of Rakapalli Hill Reserve Forest in Northernly direction upto the village Bheemavaram and turns in North Easterly direction to a distance of about 1/2 K. Mtrs. and joins the southern boundary of enclosures line of Maredubudi village. Thence the line runs along the Maredubudi enclosure line in North Easterly direction along the foot path 'Bheemavaram to Gonderu' upto the river Peddavagu. Then the line runs in Northerly direction along the Peddavagu. Then the line runs in Northerly direction along the Peddavagu through Rekhapalli Hill Reserve Forests upto the State (A) which is the starting point of the sanctuary line near Soman Malla village denoted on the map as Station (A) on the Banks of Peddavagu.

All the enclosures within the Reserve Forest and villages, private lands covered in the above specified limits shall stand included for the purpose of this notification. The Conservator of Forests (Wild Life Management), Hyderabad who is authorised to perform the functions of the District Collector vide G.O. Ms. No. 39, EFS & T (For. III) Department, dated 17-4-97 has determined the existence, the nature and the extent of the rights of the persons in the Papikonda Wild Life Sanctuary vide his Proc. No. 2450/97/W6, dated 1-6-1998 as follows:

"The local communities are entitled to the rights and concession as admitted at the time of settlement of Forest Blocks".

ANDHRA PRADESH GAZETTE EXTRAORDINARY [Part I

DECLARATION OF CERTAIN AREAS IN CUDDAPAH DISTRICT FOR "Sri LANKAMALLESWARA WILD LIFE SANCTUARY" UNDER SECTION 26-A, WILD LIFE (P) ACT, 1972.

[G.O. Ms. No. 97, Environment, Forests, Science and Technology (For.-III), 17th July, 1998.]

In exercise of the powers conferred by Sub-Section (1) of Section 26-A of the Wild Life (Protection) Act, 1972 (Central Act 53 of 1972), the Government of Andhra Pradesh hereby declares the area specified in the Schedule below as shown in the map kept in the Office of the Prl. Chief Conservator of Forests, Andhra Pradesh, Hyderabad as a Wild Life Sanctuary which shall be called as "SRI LANKA MALLESWARA WILD LIFE SANCTUARY".

2. This Notification shall come into force with effect from the date of publication of the Notification in the Andhra Pradesh Gazette.

THE SCHEDULE

Name of the District	: Cuddapah
Name of the Mandals	: (1) Cuddapah (2) Badvel (3) Siddavatam
Name of the Forest Division	: (1) Cuddapah (2) Proddatur
Name of the Ranges	: (1) Siddavatam (2) Badvel (3) Proddatur
Name of the Wild Life Division	: Deputy Conservator of Forests, Sri Venkateswara National Park, Tirupathi.
Name of the Sanctuary	: Sri Lankamalleswara Wild Life Sanctuary
Area of the Sanctuary	: 46,442.82 Ha. or 464.42 Sq. Kms.

AREA STATEMENT

Sl. No.	Name of the District.	Name of the Division.	Name of the Range	Name of the Forest Block.	Total area of the Forest Block (in Ha)	Area included in the Sanctuary (in Ha)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Cuddapah.	Cuddapah.	Siddavatam.	Lankamalai R.F. (Part)	14963.37	14963.37
				Lankamalai Ext. R.F. (Part)	11429.38	11429.38

(1)	(2)	(3)	(4)	(5)	(6)	(7)
2.	Cuddapah.	Proddatur.	Badvel.	Lankamalai R.F. (Part)	6320.00	6320.00
				Lankamalai Ext. R.F. (Part)	3466.00	3466.00
			Proddatur.	Lankamalai R.F. and Lankamalai Ext. R.F.	9689.07	9689.07
				Chennamukkapalli R.F.	575.00	575.00
					46442.82	46442.82
				Total:	464.42 Sq. Kms.	

BOUNDARY DESCRIPTION

The boundaries of the Sanctuary as delineated in the map kept in the Office of the Pri. Chief Conservator of Forests, A.P. Hyderabad are as follows:

NORTH (A To B): The Boundary of the Sanctuary starts from Station 'A' which is marked on the map and which is a meeting point of the Reserve Forest line with the bifurcation point of Badvel metal road to Mydukuru and Khajipeta (which is permanent feature from where the Sanctuary boundary starts). The line then runs along the boundary line and incidentally all along with road to Badvel in the Eastern direction till it meets the point 'B'.

EAST (B To C): From point (B), the Sanctuary boundary runs all along the external boundary line of Lankamalai Extension Reserve Forest, in the Southern direction till it meets points 'C' which is the crossing point of Lankamalai Extension Reserve Forest boundary line and the public works Department Road from Badvel to Siddavatam.

SOUTH (C To D): From point 'c' the Sanctuary boundary run all along the external boundary line of Lankamalai Extension Reserve Forest in the South Eastern, Southern and Western direction till it meets Public Works Department Road from Badvel to Siddavatam, which is the point 'D' as shown in the map.

WEST (D To A): From point 'D' the Sanctuary boundary runs all along the external boundary line of Lankamalai Extension Reserve Forest in the North Western direction in a Zig-Zag manner till it meets point 'D' which is the south-western corner of Chennamukkapalli Reserve Forest (as shown in the map) then follows external boundary line Chennamukkapalli Reserve Forest and Lankamalai Reserve Forest in a North-Western, North - Eastern and Northern direction in a Zig Zag manner till it meets point 'A'.

All the enclosures within the Reserve Forest and Villages, private lands covered in the above specified limits shall stand included for the purpose of this notification. The Conservator of Forests, Kurnool who is authorised to perform the functions of the District Collector vide G.O.Ms.No. 39 EFS&T (For.III) Dept. Dated: 17-4-1997 has determined the existence, the Nature and the extent of the rights of the persons in the Sri Lankamalleswara Wild Life Sanctuary vide his Proc. No. 10344/97/M-5, Dated: 23-5-98 as follows:

"The local communities are entitled to the rights and concession as admitted at the time of settlement of Forest Blocks".

DECLARATION OF CERTAIN AREAS IN KURNOOL DISTRICT IN "ROLLAPADU WILD LIFE SANCTUARY" UNDER SECTION 26-A OF WILD LIFE (P) ACT, 1972.

[G.O.Ms.No. 98, Environment, Forests, Science & Technology (FOR-III), 17th July, 1998.]

In exercise of the powers conferred by Section 26-A of the Wild Life (Protection) Act, 1972 (Central Act 53 of 1972), the Governor of Andhra Pradesh hereby declares the areas specified in the Schedule below as show in the map kept in the Office of the Prl. Chief Coservator of Forests, Andhra Pradesh, Hyderabad as a Wild Life Sanctuary which shall be called as "ROLLAPADU WILD LIFE SANCTUARY".

This notification shall come into force with effect from the date of publication of this notification in the Andhra Pradesh Gazette.

THE SCHEDULE

Name of the District	:	Kurnool.
Name of the Mandal	:	Midthur.
Name of the Wild Life Division	:	Assistant Director, (Project Tiger) Atmakur.
Name of the Sanctuary	:	Rollapadu Wild Life Sanctuary.
Area of the Sanctuary	:	1517.66 Acres or 614.19 Ha.

BOUNDARY DISCRIPTION

NORTH (A To E): The Sanctuary boundary starts at station (A) on the North-West side, which is a permanent mark on the ground (Masonry Pillar with Sanctuary mark). Thence it runs along the Northern boundaries of Survey Numbers, 280/A, 280/B, 289/A, 289/B upto Station (B) and thence along the Western boundaries of 294, 295 and thence along North - West and Northern boundary of Survey No. 295. Thence crossing the Rollapadu to Cherukucherla cart tract to the Northern boundary of Survey Nos. 313, 314A, 318 upto Station (C). Thence the bondary follows the Western boundary of Survey No. 330/A, 330/B, 331, 332, 211/B, 211/A, 210/C, 210/B, 210/A upto Station (D). Thence the boundary follows the Northern boundary of Survey Numbers 210/A, 209, 188/B, and the Western boundary of Survey No. 189 and thence the Northern and Eastern boundaries of Survey No. 198 thence along the general Northern Boundary of Survey No. 184/A, the Western boundary of Survey Numbers 179/B, 176, 175 and thence the Northern boundary of Survey Numbers 174, 173, 172, 171/B, 171/A, 158, 157/B, 157/A, 147 and 146 upto Station (E).

EAST (from Station E to F: From Station E on the North-East corner the Sanctuary Boundary follows the Eastern boundary of the Survey No. 146, 145, 144, 143, 142/C, 142/B, 142/A, 138/C, 138/B, 138/A and 135 which is the common village Boundary of Rollapadu and Alaganur villages, upto Station (F).

SOUTH (from Station F to L: From Station 'F' on the South-Eastern corner of the Sanctuary, the Boundary follows the Southern Boundaries of Survey Numbers 135, 136/A, 136/B and 131 upto Station (C). Thence it follows the western boundary of Sy.No. 131 also the right bank of Mogili vagu upto Station (M), thence along the Southern Boundary of Survey No. 130, thence along the Southern Boundary of Survey Nos. 128/A, 128/B and thence along the Southern Boundary of Survey Numbers 128/B, 128/C, 107, 108, 99, 110 and 363, crossing the Rollapadu - Parumanchala track, thence along the Western Boundary of Survey No. 326 the Southern boundary of 360/B, 342 thence along the Western Boundary of 342. 343, thence along the Southern boundary of 345, 346/A, 346/B upto station (I). Thence along the Southern Boundary of Survey Numbers 336, 329 thence along the Eastern boundary of 320, thence along the Southern Boundary of 321, 322 and 294 upto station (J). Thence the boundary runs along the Eastern Boundary of 290/A, 291, 443, thence crossing the Nandikotkur Nandyal Road, thence along the Eastern Boundary of Survey Numbers. 449/B, 449/A, 452/A, 452/B, 452/C 459/B upto station (K). Thence along the Southern boundary of Survey Numbers 459/B, 459/A, 458, 454, Eastern Boundary of Survey Numbers 472, 471, the Southern Boundary of Survey Nos. 471, 487, 486, 485 and 484 upto Station (L) (a permanent masonry pillar on ground).

From Station (L) the Sanctuary Boundary follows the Western Boundary of Survey Nos. 484, 483, 482, 481, 479, 478, 477, 476, 284, 283, 281/B, 281/A, 280/A upto Station (A). This is also the common village boundary of Rollapadu - Sunkesula and Rollapadu - Cherakucherla villages.

For the purpose of Wild Life Sanctuary, all the lands within the above description shall be enclosed in the Sanctuary.

The Conservator of Forests, Kurnool who is authorised to perform the functions of the District Collector vide G.O.Ms.No. 39 EFS&T (For.III) Department, Dated: 17-4-1997 has determined the existance, the Nature and the extent of the rights of the persons in the Rollapadu Wild Life Sanctuary vide his proceedings No. 10344/93-M2, Dated: 23-5-1998 as follows:

(1) Rights to use cart track from Parumanchala to Sanjeevarayudu temple (in South direction of the temple to north direction.)

(2) Rights to use cart track along North boundary of Rollapadu Wild Life Sanctuary and from Sanjeevarayudu temple to Alaganur (village).

(3) Right to use cart track from Rollapadu to Cherukucherla (V).

(4) Right to use Road from Nandikotkur to Nandyal.

(5) Right to use flow of water from Rollapadu cart track to Parumanchala (Village).

The Survey Number wise area included in the Wild Life Sanctuary are appended in the Annexure.

C. S. RANGA CHARI,
Special Chief Secretary to Government.

Registered No. HSE-49/2006-2008 [Price: Re. 0-75 Paise.

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THE ANDHRA PRADESH GAZETTE

PART–I EXTRAORDINARY

PUBLISHED BY AUTHORITY

No. 678] HYDERABAD, WEDNEDAY, NOVEMBER 26, 2008.

NOTIFICATIONS BY GOVERNMENT

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ENVIRONMENT, FOREST, SCIENCE & TECHNOLOGY DEPARTMENT

(FOR.II)

PAPIKONDA WILDLIFE SANCTUARY NOTIFIED UNDER SECTION 26-A OF WILDLIFE (PROTECTION) ACT,1972 - CONSOLIDATION AND UPGRADATION - REVISED NOTIFICATION.

[G.O.Ms.No. 144, Environment, Forests, Science & Technology (FOR.II), 4th November, 2008]

In exercise of the powers conferred by sub section (4) of section 35 of the Wildlife (Protection) Act, 1972 (Central Act 53 of 1972), the Government of Andhra Pradesh hereby declares the entire area of Papikonda Wildlife Sanctuary (Notified vide G.O.Ms.No.96, Environment, Forests, Science & Technology (For.III) Department, dated 17.07.1998) and additional areas adjacent to the sanctuary that are free from habitations as specified in the Schedule below, as shown in the map kept in the office of the Principal Chief Conservator of Forests, Andhra Pradesh, Hyderabad as a National Park which may be in future called as **"THE PAPIKONDA NATIONAL PARK".**

The notification shall come into force with effect form the date of publication of this notification in the Andhra Pradesh Gazette.

THE SCHEDULE

Name of the Districts	:	1). Khammam 2). East Godavari 3). West Godavari
Name of the Forest Division	:	1). Bhadrachalam (South) 2). Paloncha 3). Kakinada 4). Eluru

[1]

G. 972.

Name of the Ranges	:	1). V.R.Puram 2). Kukunoor 3). Gokavaram 4). Polavaram 5). Rampachodavaram. 6). Chinturu.
Name of the Wildlife Division	:	Wildlife Management Division, Rajahmundry.
Name of the National Park	:	PAPIKONDA NATIONAL PARK
Area of the proposed Papikonda National Park	:	101285.88 Ha.

AREA STATEMENT

Sl. No	Name of the District	Name of the Mandal	Name of the Forest Division	Name of the Range	RF area above HFL	Area In Sq. Kms		Total Papikonda National Park Area
						Deemed Forest Area above HFL	RF, Deemed Forest, River bed, Private land & Revenue Poramboku Area under submergence	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Khammam	V.R.Puram	Bhadrachalam (South)	V.R.Puram	187.9600	2.5492	16.8957	207.4049
		Chinturu		Chinturu	65.9239	0.0000	3.2570	69.1809
		Valairpad	Paloncha	Kukunoor	148.8467	4,7000	10.2773	163.8240
2	East Godavari	Maredumilli		R C Varam	68.2657	3.9408	7.8700	80.0765
		R C Varam Devipatnam.	Kakinada	Gokavaram	201.5800	8.0527	20.9118	230 5445
3	West Godavari	Polavaram	Eluru	Polavararm	198.6805	7.7134	55.4341	261.8280
				Total :	871.2568	26.9561	114.6459	1012.8588

Boundary Description:

1. NORTH WEST:- (From A To H):

Station "A" (81° 21 '57.36" E, 17° 31' 33.46" N) is denoted on the map where 3 roads from Rekhapalli, Dharapalli and Bhimavaram villages join on the northern side of Bhimavaram village. From this point the line runs north westerly and northerly direction along the western boundary of Compartment 175 of Rekhapalli Hill extn. RF then runs in easterly direction along the northern boundary of Compartment 175 of Rekhapalli hill extn. RF and joins the road from Dharapalli to Buruguwada. This point is denoted as "B" on the map.

<u>B.To.C:-</u>

From station "B" (81° 22' 16.23" E, 17° 32' 44.09" N), the line runs in northerly direction all along the road from Dharapalli to Buruguwada till north west corner of compartment No.45 of Rekhapalli hill RF. This point is denoted as "C" on the map.

C To D:-

From the station "C" (81° 22' 22.74" E, 17° 33' 40.13" N), the line runs in north easterly, north westerly and northern directions along the western boundary of Rekhapalli Hill RF and meets the southern boundary of Pulusumamidi RF then runs in north easterly direction along the common boundary of Pulusumamidi RF and Rekhapalli Hill RF untill it joins the north eastern boundary of Pulusumamidi R.F. The point is denoted as "D" on the map.

D To E:-

From the station "D" (81° 24' 53.75" E, 17° 37'26.11" N), the line runs in south easterly, then north eastern, then north and north eastern, then south eastern and north east directions all along the northern boundary of Rekhapailli Hill RF upto a pointed portion to the north of hillock (474 MSL) i.e. north east of Tekuluru village. This point is denoted as "E" on the map.

E To F:-

From the station "E" (81° 26' 43.33" E, 17° 39' 04.86" N), the line runs in south easterly direction along the northern boundary of Compartment No.36 up to north west corner of Compartment No.53. Then the line ru north easterly and along the northern boundary of Compartment No.53 upto to a point denoted as "F" on the map.

F To G:-

From the station "F" (81° 30' 00.85" E, 17° 39' 17.29" N), the line runs easterly direction along the northern boundary of Compartment No.53 of Rekhapailli Hill RF up to point where it touches the common boundary of Khammam and East Godavari districts. This point is denoted as "G" on the map.

G To H:-

From the station "G" (81° 33' 15.23" E, 17° 38' 52.13" N), the line runs north easterly along the common boundary of Khammam and East Godavari districts upto where the line touches the road from Chinturu to Maredumilli. This point is denoted as "H" on the map.

2. EAST

H To I:-

From the station "H" (81° 34' 53.26" E, 17° 41' 26.42" N), the line runs in south easterly direction along the road from Chinturu to Maredumilli and touches the common boundary of Kundada and Valamuru RFs near 10th km stone. Then runs south easterly along the common boundary of Kundada and Valamuru RFs upto Pamuleru river near Valamuru. This point is denoted as "I" on the map.

I To J:-

From the station "I" (81° 38' 15.56" E, 17° 37' 26.72" N), the line runs south westerly along the common boundary of Kundada and Valamuru RFs along Pamuleru vagu upto a point where the Pamuleru vagu deviates from the common boundary. This point is denotes as "J" on the map.

J To K:-

From the station "J" (81° 35' 05.59" E, 17° 36' 12.10" N), the line runs south westerly and south easterly along the eastern bank of Pamuleru river upto a point where Kondetivagu joins Pamuleru. This point is denoted as "K" on the map.

K To L:-

From the station "K" (81° 35' 44.25" E, 17° 33' 32.81" N) , the line runs north easternly, then south easterly and again north easterly , then south easterly along Kondetivagu and northern boundary of Compartment No.365 of Akuru RF. about 3 Kmts, where the point is denoted as "L" on the map.