Irrigation Water Management and the Bundala National Park

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Proceedings of the Workshop on Water Quality of the Bundala Lagoons

Held in Colombo, Sri Lanka

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Yutaka Matsuno, Wim van der Hoek, and Mala Ranawake, Editors

IWMI

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Cover photograph, by Luxhmanan, showing flamingos over the Bundala lagoon.

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Foreword

Several important changes have taken place within the International Irrigation Management Institute (IIMI) since its establishment in 1984. From a focus on irrigation systems, IIMI has now developed a much broader view of irrigation within the context of integrated water resources management in river basins. As a reflection of this we are now in the process of changing our name to "International Water Management Institute."*

In IIMI's research it has become increasingly clear that all uses of water have to be taken into account in water resources policies. These include water for agriculture, domestic water supply, industrial water needs, and water to conserve the environment.

An environmental concern of global importance in integrated water resources management is the degradation and loss of wetlands. Conservation strategies have been proposed but have rarely considered the interlinkage between irrigation water management and the wetland systems. Sri Lanka has important wetlands and many governmental and nongovernmental agencies have done studies to describe the ecosystem and the problems they are facing under economic development and population growth. However, these studies have not been coordinated and many questions remain unanswered. It was therefore a timely decision to conduct this workshop.

The main objectives of the workshop were to discuss current insights into the water quality of the Bundala Lagoons, to set priorities for further research, and develop appropriate water management strategies that could improve and sustain the environment of the Bundala National Park. The workshop brought together a multidisciplinary group of 38 people from 22 governmental and nongovernmental organizations. After the workshop, a project protocol was finalized and now forms the basis for collaboration between several institutions involved in field-based activities in the Bundala National Park.

As a result of this workshop, new partnerships have been initiated among various government departments and between these departments and IIMI. We are pleased that the workshop has proven so successful, and anticipate future collaborative research will lead to new knowledge and informed actions to manage the lagoons in a sustainable and productive manner.

Douglas J. Merrey
Deputy Director General
International Irrigation Management Institute

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*The International Irrigation Management Institute, one of sixteen centers supported by the Consultative Group on International Agricultural Research (CGIAR), was incorporated by an Act of Parliament in Sri Lanka. The Act is currently under amendment to read as International Water Management Institute.

IIMI and the Bundala National Park

Wim van der Hoek

THE BUNDALA NATIONAL PARK

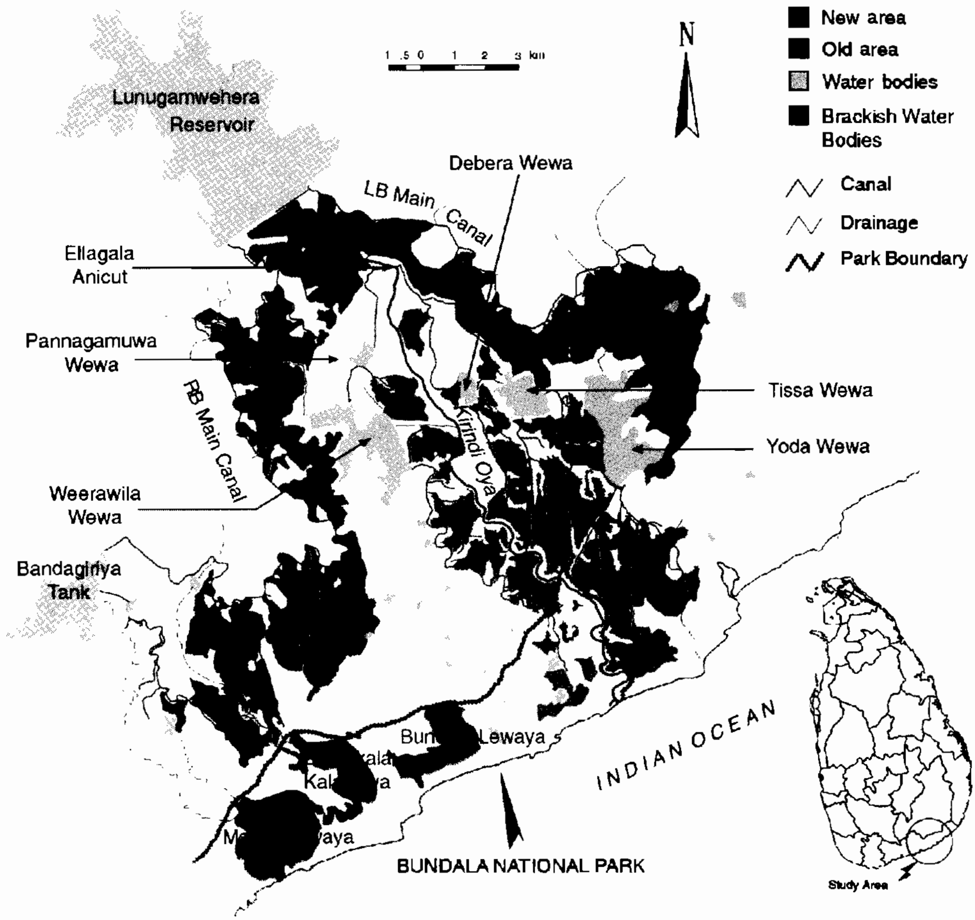
The Bundala National Park is located along the south coast of Sri Lanka in the Hambantota District (figure 1). It covers 6,216 hectares of lowland, including five shallow brackish water lagoons (Maha, Koholankala, Malala, Embilikala, and Bundala) with a total surface area of 2,250 hectares (figure 2). The park has important populations of water birds, elephants, turtles, and other wildlife. The brackish water lagoons serve as nurseries for shrimp, fish, and a variety of other marine organisms. It was declared a sanctuary in 1969 and upgraded to the status of National Park in 1992. The Department of Wildlife Conservation is responsible for overall management of the park. It is the only area in Sri Lanka listed under the International Convention on Wetlands (Ramsar Convention) as a wetland of international importance.

IMPACT OF IRRIGATION ON THE BUNDALA WETLAND ECOSYSTEM

There is an old irrigation scheme in this area, with a number of ancient tanks. After the construction of the large Lunugamwehera reservoir it became possible to irrigate the so-called new areas on the Left Bank and the Right Bank of the Kirindi Oya river. There is a separate irrigation scheme around the Badagiriya tank but with a connection to the Right Bank of the Kirindi Oya scheme.

The new ecosystems of the Malala and Embilikala lagoons have been severely affected by the drainage flow from the Kirindi Oya Irrigation and Settlement Project (KOISP) and the Badagiriya irrigation scheme. The drainage flow from the Badagiriya scheme goes to the Malala lagoon and water from Tracts 5, 6, and 7 of the Right Bank of the KOISP flows to the Embilikala lagoon. After the KOISP was implemented, salinity of the lagoons has dropped due to inflow of upstream irrigation water. This change in salinity levels has influenced the population of water birds as it has affected their food supply. Prawn fishing, which previously sustained several hundred families, has also been affected by this change and it has now almost disappeared from the area. Many other ecological changes have taken place and the two lagoons have now been converted into freshwater lakes. Eutrophication is an emerging problem in the lagoons. Water has a greenish color as a result of accumulation of nutrients and increase in filamentous green algae. The main cause is overgrazing with direct deposit of animal feces in surface water, along with high fertilizer runoff from the irrigated areas.

Figure 1. Study area.

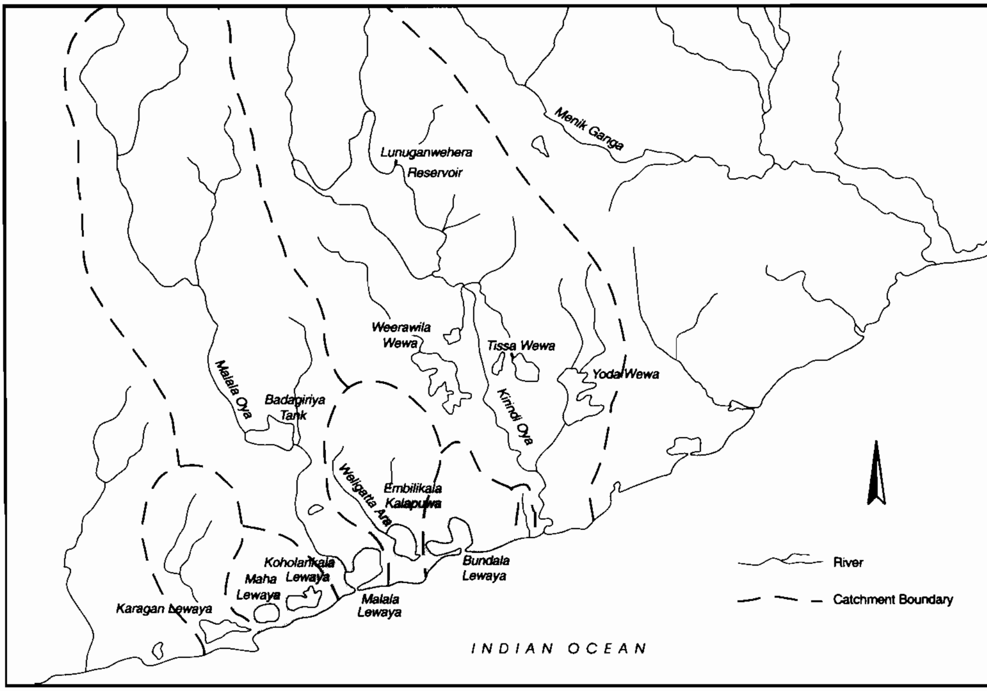


MULTIPLE USES OF WATER

IIMI has been working in the KOISP area for many years. In 1997, the Health and Environment Program started a new project to study the nonagricultural uses of irrigation water (SWIM Paper, forthcoming). This was a reflection of the broad view that IIMI has developed on irrigation within the context of integrated water resources management in river basins. While irrigation projects are designed to provide water for crop production, the water is used for many other purposes. It might be the only drinking water source for cattle; it is used for fishing; and people use water in canals or reservoirs for washing clothes, bathing, or even for drinking. There are also important environmental uses of water in irrigated areas. If we change the availability of water for irrigation it will also affect these unofficial uses.

The aim of the research on multiple uses of water is to ensure that irrigation and water resources policies take into account all uses and users of water, so that water will be used in

Figure 2. Catchment areas associated with the Bundala National Park.



an efficient, equitable, and sustainable manner. That there is so little systematic document tion on the multiple uses of water is partly because every sector has its own objectives. Irr gation systems are designed to provide water for agriculture and rarely take domestic or e vironmental uses into account.

The environmental functions of water and the impact of irrigation on valuable ecosy tems came up as an important issue during the research. IIMI decided to explore possibiliti for the development of appropriate water management strategies that could improve and su tain the environment of the park. For the development of such management strategies, a be ter understanding of the cause-effect relationship between irrigation and the ecology of t lagoons is required. Much work has already been done by various governmental and nongo ernmental organizations. The present workshop was planned to assemble as many of the organizations as possible to further define the environmental problems in relation to the w ter management in the Bundala National Park and to identify research needs.

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Environment in the Bundala National Park

Chandra Jayawardene

The Bundala National Park was declared a sanctuary under the Fauna and Flora Protection Ordinance in 1969 and designated a Ramsar site in 1991. In 1992, the park was upgraded as a National Park under the Fauna and Flora Protection Ordinance.

The total area of the Bundala National Park is 6,216 hectares. The park is located 275 km from Colombo in the Hambantota district in the southern coast of Sri Lanka. The climate is generally hot and dry, with an annual rainfall of 1,074 mm and a mean temperature of 27 °C.

The Bundala National Park has five shallow lagoons: Maha lewaya (260 ha), Kohalankala lewaya (390 ha) the Bundala lewaya (520 ha), Malala kalapuwa (650 ha), and Embilikala kalapuwa (430 ha). The vegetation is dry evergreen scrub with around 48 species of flowering plants.

The breakdown of the fauna in the Bundala National Park could be as follows:

Bird Life: Excellent wintering habitat for 48 species of migratory waterfowl, totaling 149 species.

Mammals: Notable large mammals that could be found are elephant, rusty spotted cat and fishing cat, wild pig, mouse deer, barking deer, and spotted deer.

Reptiles: Estuarine and marsh crocodiles are found in the area and five species of turtles nest in the beaches of the park.

Tourism is the largest income generator to the park. Set out below are details of the number of tourists that visited the park and the income generated (in rupees):

	1996	1997
Foreign tourists	10, 931	17,366
Local tourists	11,367	15,726
Total revenue	421,675	659,700

A conservation program is currently being carried out in the park, which involves the stationing of staff, establishment of a visitor center, and development of a road network. Preparation of a management plan by the Global Environmental Facility for the Bundala National Park is under way.

The biggest threat faced by the Bundala National Park is the drain off from irrigation schemes such as the Kirindi Oya Project. This affects the salinity level of the lagoons that, in turn, influences the population of water birds as it affects their food supply. The drain off water from the proposed Mau Ara and Malala development schemes into the lagoons in the National Park would further add to this problem. Cattle grazing, shell mining, and poaching to a certain extent are also threats to the Bundala National Park.

Steps need to be taken to maintain the water regime of the lagoons by preventing drain off from irrigation schemes into the water bodies of the Bundala National Park.

Hydrology of KOISP and the Bundala National Park

C. R. Panabokke

INTRODUCTION

I propose to deal with some of the more significant *qualitative* aspects of the hydrology of the Kirindi Oya and adjacent river basins together with the various lagoon systems that are located within the Bundala National Park. These qualitative aspects that have not been highlighted in the past studies conducted by IIMI, have an important bearing on how we could better understand the hydrological behavior of the old and new systems and their interactions with the lagoon hydrology.

It is also considered useful to describe and analyze the modifications and interventions that have taken place at different periods over the last 50 years in respect of the macro-features of the hydrology of the Kirindi Oya and adjacent basins.

SITUATION PRIOR TO 1980—KIRINDI OYA

In the old Kirindi Oya irrigation system, water diverted from the main Kirindi Oya at the Ellegala anicut supplied Class I quality water to the Debarawewa, Tissa, and Yodawewa reservoirs in the left bank command area, and to the Pannegamuwa and Weerawila reservoirs in the right bank area. The rice lands under the command of these reservoirs are all located within the natural *flat alluvial plain* of the lower Kirindi Oya. The river course of the lower Kirindi Oya is sufficiently incised to provide good surface drainage to this flat alluvial plain.

Once the water table builds up within this flat alluvial plain during the early phase of the irrigation season, only the ET requirements of the rice crop have to be provided by irrigation issues, because there is very little seepage and percolation losses in this landscape. Hence, the reduced water duty experienced in this old system.

There was also sufficient provision for the riverbed below the Ellegala anicut to get scoured out during peak river flows in the *maha* (wet) season. Thus a natural flushing out of the whole system took place at frequent intervals when high river flows occurred during most maha seasons. The whole system had thereby attained a stable equilibrium over the period 1895–1980.

The Weerawila Ara brought in a very small quantity of sodium salts into the Weerawila reservoir, but it did not cause any salinity buildup because of subsequent dilution with Ellegala-derived Class I quality water. The peak floods experienced in maha 1969 disrupted some of

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MALALA OYA BASIN—BADAGIRIYA IRRIGATION SYSTEM

The Malala Oya river basin is located within one of the driest environments in Sri Lanka, namely the semiarid tropics. The ratio of discharge to rainfall is the lowest of all river basins of Sri Lanka which is a good index of its dryness. Sodic soils dominate the lower part of its catchment area.

As a consequence, severe salinization was experienced in the command area of the Badagiriya irrigation scheme in the years following 1960, soon after the completion of the headworks and the main delivery system. The water quality of the Malala Oya falls within Class II during the wet season and Class III during the dry season. The concentrated sodium salts in the soil had got leached out after 10 years of irrigation with Class II waters, and by 1970 there were only a few isolated locations of salinity in the drainage bottom lands.

There is no record of any adverse impact that had taken place on the Malala and Embilikala lagoons consequent to the completion of the Badagiriya irrigation scheme. Any adverse impact may have taken place in the initial years after 1960, and may have lasted only a few years.

LUNUGAMWEHERA RESERVOIR AND NEW KOISP

With the completion of the construction of the Lunugamwehera reservoir in 1986 and the provision of irrigation supply to the Right Bank (RB) and Left Bank (LB) Tracts 1 and 2, a drastic and major modification to the hydrology of the old irrigation system took place. The new irrigated lands in Tracts 1 and 2 of the RB traversed a significant extent of sodic soils (solodized solonetz). These soils are located on the residual, undulating mantled plain where the water table hydrology of the landscape is quite different to that of the flat alluvial plain. The seepage and percolation rates of the soil mantle on this residual plain landscape are also very high. Leaching and deposition of sodium salts from these newly irrigated areas to the old irrigated areas took place during the initial years, from 1987 to 1993.

Monitoring of the quality of irrigation water in the Lunugamwehera and the old reservoirs was carried out during the period 1990–1994. Monitoring of the quality of the drainage water at the four *basnawas* (outfalls) commenced in May 1993. The initial buildup and subsequent decline in the quality of reservoir water, irrigation water, and drainage water have been adequately documented (IIMI 1995). It could be observed that most of the salts that had got leached out of the newly developed lands have now got flushed out of the whole system and that a new equilibrium has been attained. The initial salinity hazards have also been greatly reduced and almost eliminated.

IMPACT OF RB TRACTS 5 AND 6 ON THE HYDROLOGY OF THE EMBILIKALA AND MALALA LAGOONS

The landscape of RB Tracts 5 and 6 is made up of a high proportion of sodic soils that occur in a very dry environment, which is also further enriched with atmospheric cyclic salts brought in by the strong southwesterly winds from May to September each year. Even though the water quality in the RB main canal was within Class II, the drainage outflows from Tracts 5 and 6 were enriched with the leached out salts. The drainage water that passed through the Weligatta Ara fell within Classes III and V.

The inflows of this highly enriched drainage water from Tracts 5 and 6 through the Weligatta Ara into the Embilikala and Malala lagoons have disrupted the water quality balance so essential for prawn and fish culture in these lagoons (See IIMI 1995, pp.234–238 for a more detailed analysis and conclusions)

GEOMORPHOLOGY AND HYDROLOGY OF LAGOON SYSTEMS AROUND BUNDALA

The principal coastline and shoreline classes of the south and southeast of Sri Lanka are well-described and discussed by Swan (1983). The stretch of coast between Hambantota and Kirindi Oya outfall is noteworthy for its extensive dunes and large lakes or lagoons, known locally as *lewayas*. These have been formed by the isolation of bays due to drowning and subsequent basin development across the bay mouth. The main shoreline type of this coast is the *bay and headland type with beaches and high dunes.* The beaches are often steep and dunes are high and plentiful.

One very notable feature of the tidal range in this area is the comparatively low difference between the spring tide 75 cm, and neap tide 25 cm. This makes it difficult to manipulate the entry of seawater into the lagoons because of the low head of 50 cm that is available.

The Embilikala *kalapuwa* (lagoon) is an inland lagoon with no direct outfall to the sea, while the Malala lewaya has a direct link with the sea at Malala *modera* (mouth of the river). Inflows into these two lagoons fluctuate according to the amount of drainage water received through the Weligatta Ara and Malala Oya. Water levels in the lagoon vary between +1 m mean sea level (MSL) to about +2.2 m MSL according to inflow.

The Bundala lagoon is located within its own independent catchment and is not influenced by any drainage flow from Weligatta Ara. The western portion of the Bundala lagoon has been converted into a saltern. A greater part of the area covered by this lagoon in its present state could be considered a natural habitat for fish, birds, and other wildlife.

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Bundala: Social and Environmental Challenges

Chaminda Rajapakse

The wetland system in Bundala is of great ecological significance, especially due to the large variety and number of waterfowl that live and visit the area. Wetlands in the tropics ensure a rich biomass turnover and rich and diverse plant and animal communities. The importance of such wetlands to humans is also paramount, providing communities with food, building and utility materials, and an ideal recreational setting. The wetlands in the vicinity of Bundala are a prime example of this genre of habitat. The prominence of the wetland system in Bundala was acknowledged when on October 15, 1990, it was ratified as a "Wetland of International Importance" under Article 2 of the Convention on Wetlands of International Importance or the Ramsar Convention.

The main hydrology of ecological significance in the Bundala area wetland systems comprises five shallow brackish water lagoons covering an area of 2,250 hectares. They are fed by surface runoff, streams and rivers, inflow through drainage channels of upstream irrigation schemes, and inflow and seepage of water from the sea. Of the five lagoons in the system, the Maha lewaya and Koholankola lewaya are partially used for salt production.

FAUNA AND FLORA

The main significance of the Bundala area is the presence of diverse fauna, both migratory and resident. The biological productivity of the wetlands provides an ideal habitat for a variety of birds. This is the most important area for bird life outside the northern part of the country and supports significant populations of all species of waterbirds seen in Sri Lanka. The lagoon area is one of the major wintering areas for migratory birds, sometimes accommodating such rare and endangered species as the black-necked stork (*Ephippiorhynchus asiaticus)* and the white-bellied sea eagle (*Haliaeetus leucogaster*). The park is also a winter haven for the picturesque greater flamingo (*Phoenicopterus ruber*) large numbers of which have been reported. Of the 149 species of birds observed in the Bundala area 48 are migratory species, of which 9 are considered endangered. Also, the surrounding forest is a home of the jungle fowl (*Gallus lafayetti*) which is endemic to Sri Lanka.

The surrounding dry zone forest hosts some of the country's larger species of mammals. The most prominent of them is the Asian elephant. It is estimated that the park holds about 15-20 permanent, and 30-40 migratory elephants. The toque monkey and the golden palm cat are endemic species that can be seen in the Bundala National Park. A few leopards are believed to remain in the park.

The beaches within the National Park and the Bundala area serve as an important nesting ground for at least three species of endangered marine turtles; leatherback (*Dermochelys* *coriacea*), oliver ridley (*Lepidochelys olivacia*), and green turtle (*Chelonia mydas*) and two species of threatened marine turtles, the hawksbill and loggerhead. Two species of endangered crocodiles are also found in the area.

The lagoon systems are prime breeding grounds for fish and other brackish life, that are essential for the overall food cycle of the biological system and provide both animals and humans with a valuable source of nourishment.

A variety of dry zone vegetation is found in the Bundala area. The vegetation is classified into lagoon marsh vegetation (which consists of algae, grasses, and sedges); sand dune and beach front vegetation (adaptive to the relative high salinity in the soil, dry situations, and the strong winds); and cultivated homesteads. Mature forests with a relatively strong canopy would have covered the area at one time, but only patches of it remain at present. The remaining forests do provide some valuable indigenous medicines for a variety of illnesses. Out of the 48 vascular plants recorded in the conservation area, 40 percent were reported to be used for medicinal purposes. No endangered or threatened species of flora are to be found in the area.

HUMAN ACTIVITIES AFFECTING THE ENVIRONMENT

Human activity has affected the natural environment of the Bundala since the advent of civilization in the area. Today, approximately 171 families live in the ancient Bundala village that inherited its name from the ancient settlement of the dry zone kingdoms. It is one of the *purana* villages of the country having a history dating back to 2,400 years. The apex of the village is believed to have occurred in the era of the dry zone kingdoms. Ancient ruins in the vicinity of the village give evidence to the antiquity of the settlement.

Ancient irrigation practices probably affected the hydrology of the area but likely to a lesser extent than at present. Agriculture, irrigation, livestock grazing, fishing and aquaculture, industry, fuelwood collection, and poaching are the major concerns that have the potential of affecting the environment if mismanaged. Agriculture and irrigation have altered and are continuing to greatly alter the hydrology of the wetland systems. This, in turn, results in the alteration of the ecology of the aquatic life thus affecting the other reaches of the ecology such as the bird populations.

Livestock grazing within the conservation area tends to be problematic because it results in direct competition between livestock and other animals such as deer. The waste products excreted by animals also result in other effects such as eutrophication of the water bodies. Human activity such as poaching and destructive fishing methods also have direct repercussions on the fauna of the area. The collection of fuelwood is an example of an exaggerated traditional activity that is environmentally destructive. Fuelwood collection provides an artificial boost for the propagation of species of plants considered undesirable. The chief industry in the Bundala area is salt production and the same lagoons have been historically used for this practice. The effect of salterns is both positive and negative in relation to the wetland. While its presence provides a valuable feeding ground for wading birds, its overextension would cause an imbalance in the ecology.

The Government of Sri Lanka has encouraged development programs for the southern part of the country and is implementing them. Rapid development is envisaged in and around the Bundala area. Two projects are already planned that will have direct and indirect effects on the environment. They are a caustic soda project and an oil refinery that will be sited close to the conservation area. These developments have the potential to affect the environment directly through the industrial processes and by causing an increase in population through migration. This is likely to increase human activity with the inevitable burden on the environment.

AREAS FOR FURTHER STUDY

Impact and Control of Alien Invasive Species

Due to the introduction of nonindigenous species or due to selective felling, some species of plants are posing a threat to the ecology of the area by causing an imbalance or by suppression of native flora. Nonnative species that have been introduced are aggressively spreading and have impacted on the vegetation, fauna, and landscape. This, in turn, affects the ecology of the area encroaching on to grasslands and limiting the availability of pasture.

Only selected varieties of plants are deemed desirable for firewood. The extraction of firewood tends to favor the propagation of the undesirable species and limit the propagation of the more desirable species. The pressure of grazing by livestock has the tendency to create the same effect. These not only affect the ecology of the area and limit pastureland but also make it unsightly, decreasing the aesthetic value of the area. Beautiful pastureland, which would have sustained wildlife, has in some cases been converted to inhospitable barren land.

Invasive plants in the Bundala area are *Azima tetracantha, Opuntia dellenii,* and *Prosopis juliflore*. The latter two species are specially identified with the suppression of grasslands, thus causing a reduction in available pasture by invading the open area inside the forest and around the lagoons. This, subsequently, leads to increased pressure on the protected area, and its ecology.

Consequently, the research needs are:

- To determine the extent of the problem and to formulate solutions. The magnitude of the ecological pressure caused by these plants would be a major component of the research project.

- To propose and test an effective eradication method utilizing either physical or biological methods. Biological methods have been successful with *Opuntia dellenii* in other areas, but impact assessments should be carried out to determine its suitability before being applied.

Release of Cattle into the Protected Area

Livestock is second only to agriculture among the economic activities carried out by the residents of the Bundala area. Even though the law strictly prohibits the introduction of livestock into the conservation area, a large number of buffalo and cattle can be seen within the park, sometimes as many as 3,000. The carrying capacity of many areas of the park is believed to have been exceeded. These foraging animals compete directly with wildlife for food, especially with the elephant and spotted deer populations. In serious situations, this can even lead to disruptions in the breeding behavior of the animals. The domesticated animals destroy vegetation and stimulate the growth of invasive species. Elsewhere, overgrazing is suspected to have caused soil denudation, increased erosion, increased surface runoff, reduced soil permeability, and much reduced plant growth. The enrichment of the lagoon systems with nitrogen-rich effluent of the livestock results in algae blooms, which can lead to oxygen deprivation and which might eventually cause eutrophication of the water bodies.

The research objectives are:

- To ascertain the on-site effects of livestock grazing within the protected area. No data are available at present on the precise carrying capacity of the land or on the number of competing wildlife grazing within the park. A study to determine the carrying capacity of the park is urgently needed.
- To asses the nutrient influx into the wetlands, and to ascertain its impact.
- To propose a zoning concept for integrated activities or preventing the entry of excess animals into the park.
- To explore the possibility of upgrading the productivity of cattle or/and fodder, so as to reduce the necessity to graze in the protected area.
- To monitor the inflow of fresh water into the Embilikala and Malala lagoons, and its impact on the system.

The hydrology of the wetland systems has been adversely affected by irrigation activity conducted upstream and in the immediate vicinity. The influx of fresh water into the lagoon systems and the continuos outflow are the main concerns associated with irrigation projects. This affects the fluctuation of the salinity of the water which, in turn, has far-reaching ecological consequences. Other irrigation sector activities that greatly affect the ecology of the wetland system include the artificial intervention with natural periodic breaching of the sandbars that separate the lagoons from the sea.

The natural sandbar, which acts as a barrier between the sea and the lagoon, when seasonally breached causes fish and shrimp larvae to enter the lagoons. Once the opening has closed again in a natural process (due to wave action) the fish and shrimp can be harvested within about 2 months. This process occurs naturally when the water level rises or can be achieved artificially, by manually removing the sandbar. If the sandbar is not breached it will not allow fish and larvae to enter, or if breached at an inappropriate time the maturing fish will be washed out to sea. In such cases, the productivity of the lagoons will be considerably reduced thus adversely affecting the local fishing industry and other species that rely on it for food.

The main cause for the continued influx of fresh water to the lagoon systems is the KOISP. The drainage water from the project is channeled to the Embilikala *kalapuwa* and a permanent outflow to the sea has been constructed at the sea end of the Malala lagoon. The inflow of a continuos stream of freshwater and its outflow at a constant level have created a "freshwater lake" and the natural breach is prevented by the drainage channel.

The extensive destruction of forest cover upstream has affected the water retention capacity of the soil thus aggravating the above-mentioned effect, and also increasing seasonal flooding. The reduced salinity creates a salinity level that is not of optimal condition for the growth of brackish water life such as the prawn population which, in turn, directly affects the presence of other life.

Fertilizer and pesticide used upstream when washed down into the lagoons in the irrigation runoff, can also have considerable effect on the ecosystem. The gradual desalinization of the wetlands might eventually result in the disappearance of the natural brackish life which, in turn, will lead to the reduction of the birds that feed on it, and also disrupt the traditional lifestyle of the area's fish farmers.

The related research issues are:

- to study the specific effects of manipulation of the lagoon water level on the livelihood of the Bundala residents
- to monitor the hydrology of the region
- to monitor the inflow and its agrochemical content
- to monitor the water levels and the salinity gradients in the water bodies
- to study the impact of the new water composition on the flora and fauna
- to study the effects of deforestation and methods of mitigation

THE ECOLOGY AND BIOLOGY OF THE AVIFAUNA

Only two wetland systems in Sri Lanka feature a significant number of winter migratory waterfowl that can be observed in Sri Lanka. These are the Bundala system and the north of the country to which access is very limited due to the present security situation. The Bundala area features a significant number of all the migratory waterfowl that visit Sri Lanka and some of these species are considered globally endangered or threatened, mainly due to loss of habitat.

The avifauna in the area have received attention from many organizations and individuals and every year, since 1985, annual "winter waterfowl" counts are conducted in the area.

The issues which need to be addressed in respect to this topic are:

- the relative importance of the three different lagoon systems, Embilikala, Malala, and Bundala, for the avifauna in light of the new hydrological parameters
- the distribution and ecology of the threatened species: pelicans and open bill stork in the wetlands

- the food availability and resources partitioning of the migrant waders
- the use of the available brackish water, freshwater, and man-made (including proposed) water bodies by the avifauna and their significance to the overall composition and distribution of species
- the distribution and feeding ecologies of the major wetland species: painted stork, comerant, egret, ibis, spoon bill, red wattled lapwing, and so on

RESOLUTION OF ISSUES IN THE BUFFER ZONE

The impact of development around Bundala, its impact on the protected area, and the participation of the people in the conservation efforts will be a major concern in the conservation attempts at Bundala. The increasing human population in the area attributable to the development projects is invariably bound to affect the natural environment of the area. These impacts need to be studied to ensure sustainable development that is mutually beneficial to both humans and the natural environment.

Human-Elephant Conflict

The frequency of human-elephant conflicts is on the rise around the world due to the expanding human populations encroaching into lands used by elephants for foraging. Currently, the elephant population in Sri Lanka is dwindling at an annual rate of 6 percent while the regenerative rate is only 3-4 percent, which means that the overall number of elephants is rapidly decreasing. More than 57 percent of the elephants mortalities are estimated to be related to human-elephant conflicts of the nature of those occurring around Bundala.

The Bundala conservation area is presumed to have a semipermanent herd of 15-20 elephants and migratory visitations by about 30 elephants that roam a dwindling forested belt between the Yala National Park and Uda Walawe area. The extensive development schemes in progress in the area have effectively cramped the elephants out of their foraging lands and have limited the availability of their food. These animals are left with no alternative but to spend the day in isolated nonarable scrub forests and raid rice fields and other crops at night. This poses a major problem for the farmers who resort to mostly ineffective scare tactics to drive away the animals or to killing them as a last resort. Due to tourism some of these animals are accustomed to human presence that makes it even harder for the farmers to drive them away. The injuring of elephants with crude firearms has in many instances led to the agonizing deaths of some animals.

The human-elephant conflict in the area is a very pressing problem. These conflicts result in death and destruction of both humans and elephants. Since the economic loss associated with crop destruction is high and/or the killing of an endangered species is also of grave concern, this issue warrants a high priority study. To formulate solutions, a thorough study on the different aspects of behavior of these animals is essential. The report on the Bundala area compiled by the Wetlands Project mentions most of these concerns as well.

The proposed research programs are to meet these ends:

- determining the home ranges and the respective numbers of elephants present
- studying the daily and seasonal movements, herd structure, and dynamics
- studying the possibility of revenue generation by the presence of the animals (eco-tourism, etc.), which would fund the compensation for damage caused by elephants
- testing more effective methods of deterrence such as fences and scare tactics
- the possibility of reducing human-elephant conflict, through alternatives such as the establishment of corridors
- the effective use of radio-collared animals and regular observation

A Study on the Availability of Pasturelands and the Dairy Industry

As mentioned earlier, livestock (mainly cattle and buffalo) generate a prominent economic activity in and around Bundala. The animals are mainly used for milk, and to produce the curd for which the area is well known. The land available for grazing at present is seasonal, largely marginal, and often inside the National Park although using the area for such purposes is illegal. Serious soil degradation occurs due to the uncontrolled overgrazing of the areas within and outside the conservation area. Some government policies can be said to contribute to this problem because they artificially inflate the economic feasibility of owning cattle. Some of these policies are in the form of subsidies and low-interest loans for purchase of cattle aimed at promoting the livestock industry in the area. The use of common lands for grazing also inflates the profit margin since it does not convey the cost of depreciation of the input. These incentives have encouraged people who do not even live in the vicinity to graze their herds in the area. Recognizing the ownership of cattle as a status symbol further encourages the unproductive owning of cattle.

Overgrazing has led to a severe decrease in the carrying capacity of the soil thus affecting the wildlife and livestock alike. The "dung" nutrient flow into the wetland along with the changing character of the water is bound to create a serious eutrophication situation in the future, if no effective corrective steps are considered at an early stage.

To reduce the stress on the land of overgrazing, a wide array of options and modifications should be considered. Any advancement in the quality of pastureland and the reduction in grazing pressure in the buffer zone are bound to have the same effect within the conservation area as well.

Some areas that need immediate consideration would be:

- to study the current practices of the cattle industry with special attention to the subsidy schemes and mitigating adverse impacts on the protected area
- to study the grazing capacity of the protected area and the buffer zone
- to estimate the availability of grazing land and their productivity

- to estimate the nutrient input into the wetlands due to cattle dung and to asses its effect

Impact of Fuelwood Collection

Fuelwood collection in an unsustainable manner is seriously affecting the environment and thus the society and the ecology of the area. The dearth of fuelwood outside the protected area necessitates that the villagers use the protected area for this resource. If an alternative is explored, the pressure on the land within and outside the protected area can be relieved.

Studies to alleviate the problem and meet the needs of the people should consider:

- an estimate of the fuelwood needs of the people
- the feasibility of the establishment of fuelwood plantations in some areas that are of low value or along fences, and so on
- the use of alternative fuel that would be readily available and is efficient
- the promotion of fuel-efficient stove technology

The Impact of Conversion of Land for Agriculture

The intensive development envisaged to occur in the southern province is expected to rely heavily on the increase of agricultural output. This might entail the conversion of large tracts of land around the wetlands into farmland. Even though this might not be within the park itself, it would greatly increase the pressure on the conservation area through many other activities such as fuelwood collection and agrochemical runoff. On the other hand, a participatory rural appraisal done at the Bundala village indicated that the village youth aspired to engage themselves in agriculture. Accordingly, some abandoned tanks were rehabilitated. A few more such tanks exist allowing for more arable land to be brought under cultivation.

While efforts to minimize the negative effect of agricultural development should be considered, increased food production is essential to sustain an increasing population. The best approach would be to increase the productivity of the existing land and return to the farmer other arable land, without affecting the wetland.

These areas should be considered and researched into, and would involve:

- the introduction of better farming techniques to increase productivity
- the promotion of cheaper, eco-friendly integrated pest management that would benefit the farmer and the environment
- the increase of support services to farmers that would enable them to retain a larger part of their return (not incentives that would promote the non-cost-effective expansion)

CONCLUSION

The Bundala purana village, the wetland system, and the protected area are unique resources with immense cultural, environmental, and economic value. The unique cultural and biological environment of the area is extremely vulnerable to adverse impacts and may be lost if a conservation effort is not made. Any such attempt in this area should link the social and economical aspiration of the society with the aim of conservation. An integrated conservation and development model that pays special attention to the social and cultural structure of the village and the diversity of the environment has to be formulated.

The Impact of Domestic Cattle and Buffalo on the Status of the Bundala National Park

D. Bopitiya, P. N. Dayawansa, and S. W. Kotagama

The Bundala National Park is located between the town of Hambantota and Kirindi Oya covering 6,216 hectares (CEA/Euroconsult 1993). Since the rearing of livestock is one of the main occupations in this area, considerable numbers of domestic cattle and buffalo are found along the northern boarder of the National Park.

The main aim of the present survey was to investigate the impact of these domestic cattle and buffalo on the status of the National Park.

The period of study was from mid-June to early August 1997, during the *yala* (dry) season, which had very dry weather. Due to lack of rain, there was no cultivation and the livestock were restricted mostly to the fallow rice fields.

The number of domestic cattle and buffalo were counted using the sample head count technique (Caughely 1997). In addition, interview surveys were carried out along with the sample counting sessions.

These surveys revealed that a majority of herds were from the neighboring regions and that the herds had lost their earlier grazing fields due to irrigation development projects such as the KOISP (Panditharatne and Nelson 1991). As their previous grazing grounds were converted to irrigated rice fields, the herd owners have led their herds into the present grazing fields, which are the temporary grasslands that have emerged due to the reduction of the water levels of the lagoons.

It was also found that the numbers of domestic cattle and buffalo that use the resources of the National Park vary according to the yala and maha seasons. During yala, which is the dry season, the livestock are mostly found along the northern boundary and the adjacent fallow rice fields of the northern buffer zone. Maha, which is the rainy season, causes these livestock to move into the interior of the park towards the Pathirajapitiya, which is located at a higher altitude, since the temporary grasslands fringing the lagoons submerge and the fallow rice fields are cultivated.

It was found that there are 4,009 ± 115 domestic cattle and 1,716 ± 79 buffalo along the northern boundary and the immediate buffer zone. The interview survey carried out along with the counting confirmed that these livestock utilize the resources of the National Park at least once a year.

The highest number of livestock, 2,073 ± 182 domestic cattle and 1,037 ± 86 buffalo, entered the park from the Weligatta region, and this is mainly because of the migrated herds. As a result, the highest numbers of livestock were found on the northern section of the Embilikala kalapuwa.

IMPACT OF THE LIVESTOCK ON THE BUNDALA NATIONAL PARK

The entire National Park was divided according to the number of livestock into two distinct zones, high density, the region west of the Embilikala kalapuwa and low density, in the east. The two major study sites, the western portion of Weligatta and Bundala, were chosen to represent the high and low density zones, respectively.

To investigate the impact of these livestock on the National Park, the degree of overgrazing was measured by grazing pressure (Milner and Hughes 1968) along with the percentage ground herbage cover of the grasslands utilized, and the rate of accumulation of fresh dung. These were measured on selected sampling sites of the two main study sites. Along with these main parameters, the degree of compacting of soil was noted by a rough estimate of the number of hoof marks on the ground.

Site	Average number of livestock	Grazing pressure*	Percentage ground herbage cover (%)	Degree of overgrazing	Degree of soil compacting
Weligatta	1,274 ± 134	0.92	33.3	Heavy	Heavy
Bundala	792 ± 23	0.73	88.1	Moderate	Low

*Grazing pressure = Rate of intake/Rate of herbage production.

The overgrazing of the available temporary grasslands and the compacting of soil and prolonged dry weather have caused the appearance of unproductive desert regions along the northern boundary, especially in the Weligatta region.

The rate of accumulation of fresh dung for Weligatta was 1,155 pats per day whereas in Bundala the rate was only 390 pats per day. This again showed a direct relationship with the number of livestock utilizing the respective sampling sites. As the numbers increased, the rate of accumulation also increased.

The dung accumulated tend to persist in the environment for longer periods as dry cow pats since the rate of decomposition is very slow.

It was also found that these animals fed on the fruits of the opportunistic species like *Opuntia dellenii* and *Prosopis jiliflora* and the dung is responsible for spreading the seeds, which have caused a change in the floral compositions in some of the areas of the National Park.

As the water levels rise during the rainy season, these grasslands submerge, thereby drawing down the dung into the lagoons causing an accumulation of nutrients in the water body. The absence of adequate rain to dilute the nutrient load and eventually to flush out the entire water body, has led to the concentration of nutrients in the static layers of the water body causing fecal pollution and eutrophication.

During the period of study it was observed that at Weligatta, herds used the fresh water of Weligatta Ara for drinking. The continuous supply of freshwater even during the dry periods may encourage other herd owners to migrate to this region. If this takes place the present status of the National Park may worsen.

In conclusion, it is possible to state that the large numbers of domestic cattle and buffalo that utilize the resources of the Bundala National Park have caused severe negative impacts.

Drastic and effective management measures are required to prevent the degradation of this important National Park and its Ramsar wetland site.

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Impact of Cattle Grazing on the Nutrient Levels in the Ramsar Wetland, Sri Lanka

M. S. De Silva, S. W. Kotagama, and W. D. Ratnasooriya

Eutrophication both in freshwater and marine water is one of the most serious water quality deterioration issues in the world. The presence of potentially high nutrient levels in the ecosystem accelerates this situation (Chiras 1991). Further, continued inflow contaminates the sediment and soil.

The aim of this study was to determine nutrient levels in water and sediment and to quantify the nutrient load in the water bodies. The study was conducted at the Ramsar wetland site, in five selected water bodies namely Benga Wewa, Bundala, Embilikala, Koholankala, and Malala (CEA/Euroconsult 1993).

Nutrients such as potassium, calcium, magnesium, phosphate, and nitrate were measured and analyzed in water (at two depths), in urine, in cow dung, and in grass. The grass was of two different growth stages at two different sties (Bundala and Embilikala). Apart from these, levels of ammonia, bicarbonate, dissolved oxygen, and biological oxygen demand and some physical parameters such as temperature, turbidity, surface velocity, wind velocity and light velocity, and the primary productivity were determined at selected sites in the water bodies. Sampling was done on a weekly basis continuously for the 6-week period from 27 June to 4 August 1997.

Some of the data obtained are given in tables 1 and 2. Both the water and sediments contained high concentrations of nutrients. According to this study, the nutrient input from cattle has an effect on the water bodies at the Ramsar wetland. The major nutrient input to the water body is due to the cattle and buffalo excreta. This waste runs off into the water bodies giving rise to high nutrient levels.

Nitrate concentration of sediments showed a positive correlation with urine nitrogen load input. A strong positive correlation ($p<0.05$ and $p<0.01$) is shown between the sediment magnesium and urine magnesium load input. Phosphate concentration of sediment shows a positive correlation ($p<0.05$) with cow dung phosphate load input to water bodies.

Nitrate in water shows a positive correlation ($p<0.05$) with urine nitrogen load input. The correlation ($p<0.05$ and $p<0.01$) between water calcium concentration and urine calcium load input is strong. Magnesium and potassium in water also show a positive correlation ($p<0.05$) with cow dung magnesium and potassium load input. Both layers of water studied contain a high concentration of nutrients.

The nitrate and phosphate of water sediment are higher than the levels reported for minimum algal stimulation (UNESCO 1988). This is mainly due to the nutrients added to the lagoons. Nitrate and phosphate which act as limiting nutrients for eutrophication are exceedingly high. Even the lowest nitrate and phosphate recordings are 35.29 and 0.44 ppm, respectively.

Table 1. Input of urine and cow dung nutrient load at the five different water bodies (in kg/day).

Location	Potassium		Calcium		Magnesium		Nitrogen		Phosphorous	
	Urine	Cow dung	Urine	Cow dung	Urine	Cow dung	Urine	Cow dung	Urine	Cow dung
Benga wewa	3.72	7.58	0.135	6.74	0.025	0.99	0.926	774.8	-	6.24
Bundala	1.76	2.203	0.064	194	0.011	0.27	0.438	225.06	-	1.814
Embilikala	30.01	77.07	1.09	6.84	0.201	9.66	7.46	7868.69	-	63.4
Malala	0.261	0.405	0.009	0.036	0.0017	0.051	0.06	41.69	-	0.33
Koholankala	0.654	0.75	0.023	0.0669	0.004	0.094	0.16	77.03	-	0.62

Table 2. Nutrient levels of water and sediment at the five different sites.

Location/ Parameter	Benga Wewa Sed.	Benga Wewa Water	Bundala Sed.	Bundala Water	Embilikala Sed.	Embilikala Water	CE1 Sed.	CE1 Water	CE2 Sed.	CE2 Water	Malala Sed.	Malala Water	Koholankala Sed.	Koholankala Water
Nitrate	414.45 ±10.95	**50.26 ±11.21	295.23 ±11.26	*83.092 ±19	485.22 ±65.8	*167.86 ±16.55	395.42 ±58.31	273.8 ±35.51	1077 ±33.4	401.35 ±64.43	257.6 ±77.43	136.13 ±32.28	267.53 ±76.51	220.48 ±63.69
Nitrite	2.95 ±1.01	**0.28 ±0.064	3.84 ±1.83	*1.38 ±0.49	*4.12 ±1.03	**11.83 ±2.24	3.85 ±1.5	13.84 ±2.78	5.39 ±3.38	20.77 ±1.68	4.15 ±0.42	1.47 ±0.33	*0.68 ±0.33	1.61 ±0.33
Phosphate	*43.05 ±4.7	0.555 ±0.07	52.08 ±4.24	16.49 ±1.33	*65.03 ±3.09	*4.75 ±0.75	72.48 ±3.14	3.86 ±0.505	65.98 ±15.98	4,62 ±1.62	36.34 ±4.8	1.59 ±0.02	52.08 ±4.24	2 ±0.34
Potassium	4.1 ±0.91	4.03 ±1.14	7.19 ±0.67	11.55 ±0.77	*6.34 ±2.55	14.09 ±2.28	2.86 ±1.41	14.35 ±1.53	4.51 ±0.98	17.77 ±3.46	3.73 ±1.22	8.08 ±2.62	3.36 ±1.44	6.625 ±2.07
Magnesium	1064.2 ±82.74	*289.81 ±60.9	1030.9 ±63.14	235.06 ±59.35	927.26 ±60.03	*434.65 ±52.11	972.8 ±50.02	397.46 ±60.61	1459 ±60.01	608 ±62.61	547.2 ±70.02	**287.28 ±45.55	526.6 ±61.31	313.69 ±26.56
Calcium	601.2 ±0	300.6 ±19.34	629.26 ±73.74	*416.83 ±20.49	1335.21 ±96.8	**428.60 ±30.29	2004.3 ±87.06	300.6 ±1.69	2405 ±98.24	400.8 ±36.38	450.9 ±13.4	**260.62 ±47.5	451 ±23.67	240.13 ±45.61
PH	8.68 ±0.33	9.71 ±0.4	8.66 ±0.31	8.34 ±0.42	8.59 ±0.27	8.86 ±0.3	8.21 ±0.11	8.55 ±0.23	8.56 ±0.43	8.61 ±0.21	7.99 ±0.67	9.77 ±0.44	7.91 ±0.41	8.65 ±0.32

Sed=sediment ±=Std. Error. Water=water concentrations in ppm(surface+bottom/2). CE1= Weligatta Ara before entering the Ramsar wetland. CE2=Weligatta Ara after entering the Ramsar wetland. * 1% to 5% * and ** 5% significantly differs with each other.

The presence of a high nitrate level indicates that the pollution of Malala lagoon is due to fecal matter, which is not a recent occurrence but something continuing from an early period. Recent fecal pollution at the Bundala lagoon is evident from the high level of ammonia in water.

By comparing chemical and physical parameters of water and sediment it has become evident that, except Benga Wewa all other water bodies indicate conditions favorable for eutrophication. Therefore, the management of nutrients is of great importance for this ecosystem. Continued monitoring of the nutrient contents gives an indication of the function of the system, thus providing direction for management and conservation.

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Water Accounting and Drainage in the Bundala National Park

Anneke van Eijk

INTRODUCTION

Two points are highlighted in this section. First, the water quantity relations in the study area: the influence of irrigation in the Malala Oya and Embilikala Oya on drainage water to the lagoons. Second, the institutional relations between the interested groups.

WATER RELATIONS

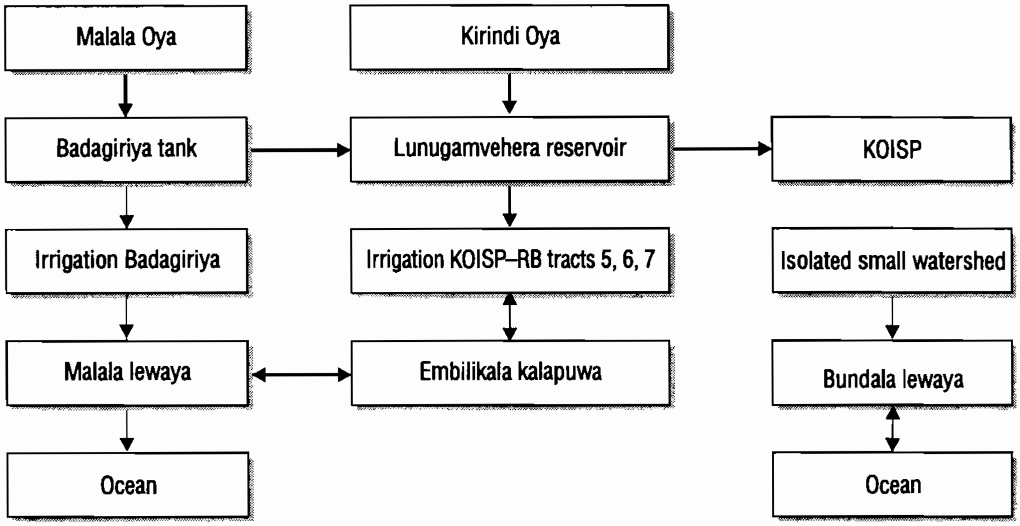
The Bundala National Park is located in two river basins, which means that activities and developments in the upstream part of the river basins affect the situation in the Bundala National Park. Figure 1 shows the water relations covering the Bundala National Park. Irrigation drainage water from Right Bank (RB) Tracts 5, 6, and 7 of the KOISP and Badagiriya irrigation scheme affects the Embilikala and Malala lagoons. The Bundala lewaya lies in an isolated river basin and is not affected by irrigation drainage water.

To study changes over the years in the Bundala National Park it is needed to study changes in the Embilikala Oya and Malala Oya river basins. Before 1989, the Embilikala Oya river basin did not have a trans-boundary river basin diversion, but was isolated from other river basins. The rainfall runoff of this river basin was drained to the Embilikala kalapuwa. In 1989, the KOISP changed this situation. RB Tracts 5, 6, and 7 from the KOISP are located in the Embilikala Oya river basin. Therefore, if these tracts are irrigated, supplementary water is supplied from the Kirindi Oya river basin to the Embilikala Oya river basin causing extra water to be drained to the Embilikala kalapuwa.

The KOISP has an indirect effect on the Malala Oya since it is connected with the Embilikala lagoon by a natural canal. The diversion from the Lunugamwehera reservoir to the Badagiriya tank is a relatively small quantity of 0.5 million cubic meters (MCM) per year when with the total water supply. At present there is a water diversion being constructed from the Walawe Ganga river basin to the Malala Oya through the Badagiriya tank. This diversion will affect the drainage outflow to the Malala lewaya, although it is agreed that this diversion will not increase the inflow to the Badagiriya tank.

In conclusion, it has to be stated that the Malala lewaya and Embilikala kalapuwa are mainly affected by supplementary water supply from the Kirindi Oya river basin to the

Figure 1. Bundala lagoons' water relation.



Embilikala Oya river basin causing an increase in drainage water to the Embilikala kalapuwa. Another effect of irrigation on the lagoons is that irrigation changes the water quality; water of a different quality is drained to the Embilikala kalapuwa.

DRAINAGE OUTFLOW

The Embilikala Oya river basin has a catchment of 6,000 hectares of which 30 percent of RB Tracts 5, 6, and 7, can be irrigated. The Malala Oya river basin has a catchment of 40,400 hectares while the Badagiriya scheme has a command area of 850 hectares. These irrigated areas influence the lagoons in the Bundala National Park, but are not always irrigated. Of the 16 seasons (from 1989 to 1996) RB Tracts 5, 6, and 7 were completely irrigated eight times. In the same period the Badagiriya scheme was irrigated eleven times. During the seasons of cultivation, supplementary water is supplied to the river basins draining into the lagoons.

A water accounting study in the KOISP has been performed to estimate the water budget of this area. The calculation is based on assumptions and secondary information, so the outcomes should be considered as an approximation of the water consumption and drainage outflow. The water balance is calculated for 1995/1996, a relatively wet year, and for 1996/1997, a relatively dry year. Figures 2a and 2b give the outcome of the first order estimate.

Assuming that the distribution of water use in the Embilikala Oya river basin is comparable with the Kirindi Oya river basin, the percentage of water drained to the ocean is used for calculating the drainage outflow to the Embilikala lagoon. The outcome is shown in table 1.

Figure 2a. Distribution of water use in KOISP in 1995/1996.

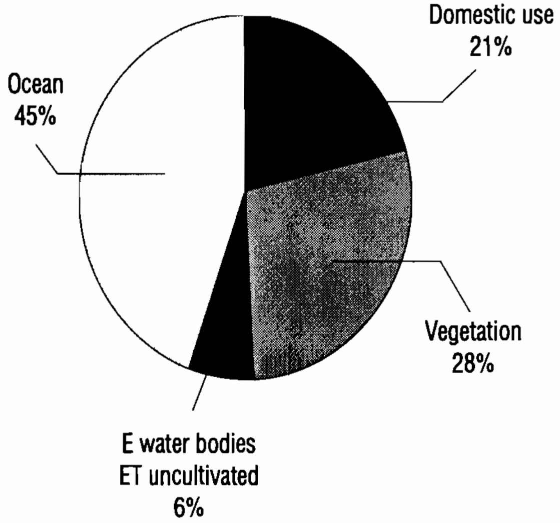


Figure 2b. Distribution of water use in KOISP in 1996/1997.

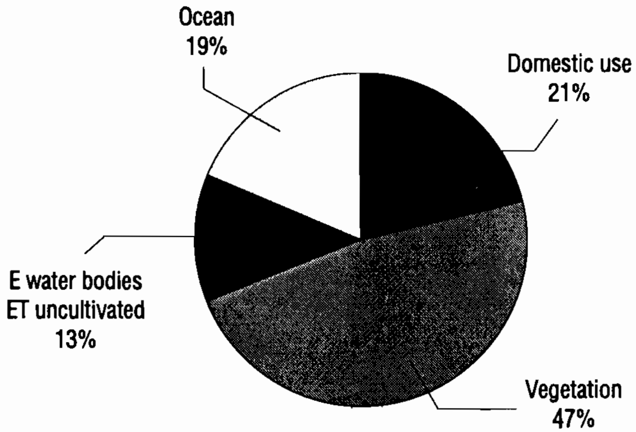


Table 1. Inflow to Embilikala Oya river basin and drainage to the Embilikala kalapuwa (in MCM).

	1995/96	1996/97
Supplementary irrigation inflow from Lunugamwehera reservoir	77	36
Rainfall	68	42
Water drained to the Embilikala lagoon	55	15

INSTITUTIONAL RELATIONS

In practice, often no formal arrangements are made concerning drainage flows between the different government departments that are responsible for irrigation and for conservation of the environment.

RECOMMENDATIONS

It is important to know the range of permissible outflow into the lagoons in the maha and yala seasons. Irrigation should be practiced according to this range. To study the consequences of irrigation in the area influencing the lagoons, the amount of water supplementarily diverted to these river basins should be known. This would require that the water supply from the Lunugamwehera reservoir to RB Tracts 5, 6, 7, and to Badagiriya tank be measured; the expected diversion from the Walawe Ganga river basin to the Malala Oya river basin should be measured as well. The relation between the extra water supplied to the river basins and the increase of drainage outflow to the lagoons, should also be studied.

As another point of attention, a formal arrangement should be made to control the quantity and quality of water flowing into the Bundala National Park. Towards this end, it is worth forming a committee consisting of all water interests groups in Malala Oya, Embilikala Oya, and the Kirindi Oya river basin that can make planning decisions regarding water resources aspects.

Valuing the Multiple Uses of Water

Margaretha Bakker

INTRODUCTION

As water scarcity intensifies, there will be an increasing pressure to transfer water from agricultural uses into municipal and industrial uses. A large part of this argument is based on the relatively low output per unit of water in irrigated agriculture, especially grain production, while irrigated agriculture is the biggest consumer of world's fresh water resources.[1] However, irrigation water is used for many purposes other than irrigating field crops. Often, the importance and value of multiple uses of irrigation water are underestimated. According to Bhatia 1997, direct economic benefits to the farmer (from crop output) reflect only a small proportion of the total benefits to the community using water in irrigated agriculture. An irrigation infrastructure provides nonirrigation benefits to other user sectors; ignoring these benefits will result in a serious underestimation of benefits available from the volume of water that is diverted for irrigation. The valuing of water for multiple uses should ensure that the full range of values placed on water in competing uses is observed (Pigram 1997), and taken into account when water allocation decisions are made.

MULTIPLE USES OF WATER

A study on the multiple uses of water took place in the Kirindi Oya irrigation system. There are two services taking water from the Lunugamwehera reservoir: the irrigation service (Irrigation Department) and the domestic service (National Water Supply and Drainage Board). Water from the irrigation service is used, of course, for irrigated crop production. Besides this, water is also issued for domestic purposes (bathing and washing clothes) when no irrigation is taking place. Indirectly, irrigation water contributes to domestic purposes by recharging the wells (groundwater). Further, when water is issued, either for irrigation or for domestic uses, water is used by livestock for drinking and bathing, by fish to breed and live, for small-scale industries (brick and curd pot making), and for other activities. The domestic service provides the water via a piped system. Besides drinking, this water is also used for bathing, washing, and other domestic uses and for home garden cultivation.

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[1]In terms of all countries, irrigation comprises 72 percent of the average per capita diversions with the industrial and domestic sectors accounting for 19 percent and 9 percent of the average, respectively (Seckler et al. 1998).

The water flowing into each use is put to a beneficial use, for instance, drinking water for people and livestock, for crop consumptive use, and as a habitat for fish. In the case of the Bundala National Park, water can also be non-beneficial or even destructive for the eco-system. As a result of the diversion to use, the water is either depleted from the system, or returns to the system (non-depletive use) where there is a chance that it may get used again.

VALUE OF WATER

In economics, the term "value" refers to monetary measures of changes in economic welfare. The value of water (desirability and scarcity) varies considerably across regions and seasons. Therefore, information on economic values of water must always be indicative rather than absolute (Pigram 1997). Besides the economic value of water, it is also important to take some other values into account when making water allocation decisions. Irrigation water has a social value, in the sense that it creates lots of opportunities for development. Irrigated agriculture generates employment and through this social consistency (less migration from rural to urban areas). Further, it contributes to food security and can also generate health benefits.

THE VALUE OF PRODUCTIVE USES OF WATER

To value the productive uses of water, like crop production, livestock, fisheries, and industries, the value added per m^3 of water should be calculated. This is the so-called factor productivity of water and is defined in box 1.

Box 1. Formula to calculate the value added per m^3 of water

The value added of water is defined as: $$\frac{\Sigma\,(PjQj - CjIj)}{m^3}$$

where,

Pj = Price of output; Qj = Quantity of output; Cj = Cost of inputs necessary to produce output j; Ij = Quantity of inputs necessary to produce output j; j = Output like rice, livestock, etc.

This is one way to measure the productivity of water for different productive uses of water. The value added for water can be calculated for three different levels:

1. *Private farmers' viewpoint*: shows the impact of water uses on the farm level and uses financial prices.

2. *National viewpoint*: shows the impact of different water uses from a national point of view and uses economic prices. It is useful to include environmental externali-

ties like damage to wetlands. Shadow prices have to be used when externalities are included.

3. *Global viewpoint*: shows the impact from a global (international) point of view. For instance, impact of water uses on maintenance of biodiversity, migratory birds, etc. It is hard to value these impacts.

Going from 1 to 3, it is necessary to make more assumptions related to prices and impacts.

In table 1 the results of value added calculations for productive uses of water in Kirindi Oya are given. The gross and net value added per m^3 are both calculated from farmers' point of view. Therefore, no cost is imputed for the used land along with family labor. Primary and secondary data were used for these calculations. To look for differences between wet and dry years the calculations were made for 1995/1996 (wet) and 1996/1997 (dry). The values are all expressed in constant 1997 Sri Lankan rupees (US$1.00 = Rs 58.80 in 1997) to make comparison possible. The values presented in the table are based on first order estimates and should be seen as a first indication rather than absolute values.

Table 1. Value added (gross and net) per m^3 for different productive water uses (in 1997 Sri Lankan rupees).

		1995/1996		1996/1997	
Productive use		Gross value (Rs/ m^3)	Net value (Rs/ m^3)	Gross value (Rs/ m^3)	Net value (Rs/ m^3)
Rice	*div. m^3	3.3	1.6	3.0	1.5
	**depl. m^3	7.2	3.7	7.1	3.6
OFC***	div. m^3	27.9	22.2	23	18.2
	depl. m^3	30.3	24.0	28.7	22.8
Livestock		19.0	7.6	19.0	7.6
Curd pot making		1,333.0	982.4	1,333.0	982.4

*div. = Diverted water

**depl. = Depleted water

***Other field crops, in this case a mixed cropping system of chili, onion, greengram, okra, soybean, longbean, tomato, and peanut.

For rice and OFC a distinction is made between diverted (div.) and depleted (depl.) water. The depleted amount of water reflects the ET by crops, which is less than the m^3 of water diverted to rice and OFC. Therefore, the value added per m^3 depleted water is higher than the value added per m^3 diverted water fort both rice and OFC. The m^3 of water for livestock and curd pot making reflects the amount of water taken by these uses. However, water used by livestock for drinking and bathing flows back into the system. Since there are no scheduled diversions of water for fish, which is also a productive use of water, it is not possible to calculate the value added per m^3 used by fish.

As expected, rice shows as a high water-consuming crop with the lowest gross and net value added per m^3. The mixed OFC cropping system generates a high gross and net value added. The value added for curd pot making is from another order of magnitude than the crop and livestock value added. With a very small amount of water, a high value can be generated with curd pot making. The differences between the values of a dry and a wet year are almost negligible.

BUNDALA NATIONAL PARK

With this value-added method we are only able to calculate the value of water for productive uses that consume water. Environmental and domestic uses of water stay out of the picture. To value these kinds of uses other methodologies are needed. At this moment it is not possible to value the water for the Bundala National Park. This is not only because there is no suitable methodology available but also because we do not know the exact impacts of the drainage water on the ecosystem of the Bundala National Park.

The perceived impacts of drainage water from Tracts 5, 6, and 7 and the Badagiriya irrigation scheme are:

- decline in shrimp and fish population
- eutrophication
- reduction in eco-tourism
- extinction of species and habitat diversity
- loss of genetic stock

One option to reduce the drainage inflow in the Bundala National Park is to cultivate less rice and more OFCs in Tracts 5, 6, and 7. Less water has to be diverted to Tracts 5, 6, and 7 because OFCs do not need as much water as rice.

However, to do a real impact analysis and valuing exercise, the following research is needed:

- How much water is flowing into the lagoons (not only quantity of water but also quality of inflowing water is important) ?
- How much inflow is needed to create or sustain a healthy lagoon ecosystem? It may be possible to find a minimum and maximum level of water flowing into the system and to define quality criteria.
- Identify the users of the different functions of the Bundala National Park; this can serve as input for valuing the environmental use of water.
- Design water management scenarios based on the results of the above issues to create or sustain a healthy lagoon ecosystem.

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Potential Impact of Agriculture and Irrigation on the Bundala National Park and Plans for Monitoring

Y. Matsuno

INTRODUCTION

The ecology of lagoon systems in the Bundala National Park has been influenced by the quality and quantity of drainage water flowing from the Kirindi Oya Irrigation System. Drainage water is considered to be one of the major causes of changes in the ecology of lagoons. Nevertheless, there is still a lack of knowledge about the impact of drainage water on the ecosystem of the park. A thorough understanding of this in relation to activities taking place in and around the lagoons is essential for planning and selecting effective conservation measures in the park.

This section explains the background of the study that IIMI and its collaborators are carrying out and describes the project plan. The methodology developed in this study will be generalized and would be applicable to other systems in Sri Lanka and elsewhere.

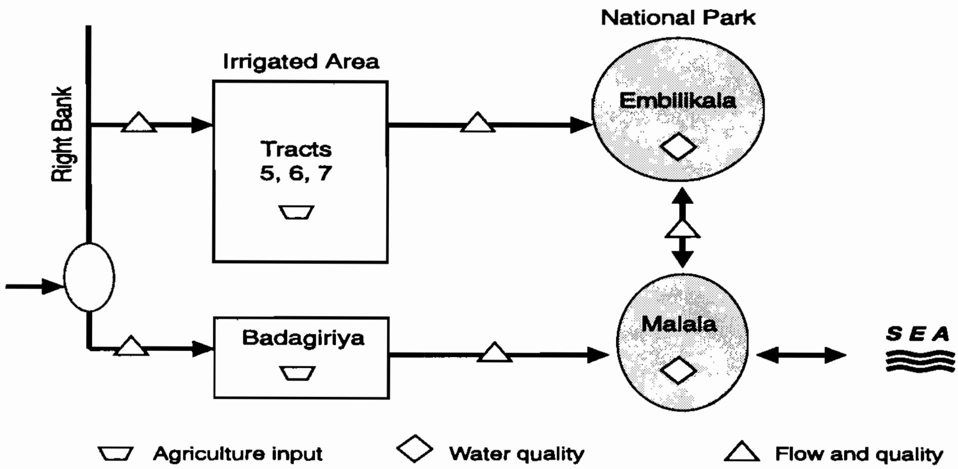
BACKGROUND

Part of the irrigation water of the total 1,760 hectares in Tracts 5, 6, and 7 of KOISP and the 850 hectares of the Badagiriya scheme drains into the Embilikala and Malala lagoons. The two lagoons are interconnected through a natural canal (see figure 1).

Drainage water flowing into the lagoons is categorized as surface and subsurface flows that receive and carry agricultural non-point source pollutants through the water course. The quantity of drainage water influences water levels in the lagoons, which affect the habitats of fish and wildlife. It has been observed that the drainage water causes a decrease in the salinity level of the Malala and Embilikala lagoons resulting in the disappearance of shrimps that live in a brackish water environment. The acceptable salinity range of shrimp culture is between 5 and 35 part per thousand (ppt) with an optimum range of 15 to 25 ppt (Jayasinghe 1997), while the drainage water salinity is well below this range. The other concerns of drainage water quality into the lagoons are with nutrients, pesticide residues, and sediments from the irrigated area.

Nitrogen, phosphorus, and potassium are the major components of fertilizer. Nitrate is easily converted from nitrogen and is mobile in soil. In general, the agricultural drainage of

Figure 1. Hydrological setting and proposed sampling points in the study area.



both surface and subsurface water contains more nitrate than phosphorus and potassium (Madramootoo, Johnston, and Wilardson 1996). Nitrogen and phosphrous are thought to be the primary nutrients controlling the rate of eutrophication. If sufficient phosphorus is available in a water body, a high nitrogen concentration may lead to significant increases of algae and aquatic plant production in the system. Sediments change the capacity of lagoons and influence biological activities by increasing the turbidity, and pesticides may be found in waterbodies or absorbed in sediments that result in bio-accumulation of toxic compounds in fish and other aquatic organisms.

FRAMEWORK OF THE PROJECT

Primary activities for conservation of the lagoon ecosystem related to drainage water should attempt to answer the following questions:

1. What is the current ecological status of the lagoon?
2. What are the problems facing the lagoon eco-systems?
3. What quantity and quality of water are necessary to sustain the ecology in the lagoons?

4. Are the current agricultural and irrigation practices causing the problem?

5. If so, of what quality and quantity should the drainage water be?

6. If not, what are the factors causing the problem?

7. What measures could be taken?

Measuring and monitoring of environmental parameters are important to identify the ecological status and evaluate its trends and changes. The results of monitoring should be linked to observed patterns and lead to specific actions and provide information to redirect and refocus actions.

Furthermore, the results of monitoring can be used to estimate the water quantity and quality (mass) balances of both irrigation and lagoon systems that help identify relationships between the ecological status and the activities. The box below shows the simplified water and mass balances in the Embilikala lagoon.

Chemical concentration (unit: mass [m]/volume[v])

$C_{Embilikala} = M_{Embilikala} / V_{Embilikala}$

Increase salinity: $\uparrow M_{Embilikala}$ *or* $\downarrow V_{Embilikala}$

Water balance (unit: volume)

$\Delta V_{Embilikala} = V_{Drainage} + V_{Rain} - V_{Evaporation} - V_{Seepage} \pm V_{Malala}$

Quality (mass) balance (unit: mass)

$\Delta M_{Embilikala} = M_{Drainage} + M_{Rain} - M_{Seepage} \pm M_{Malala} \pm$ source/sink

OBJECTIVES, ACTIVITIES, AND OUTPUT

IIMI and the national collaborators started the research project in 1998.

Objectives

- to assess the impact of upstream irrigation water management on the ecology of the Bundala National Park

- to identify water management options that improve the ecosystem of the National Park

- to value the environmental functions of water in the project area in economic terms and relate this to the value of other uses of water

- to identify, through partnership, the water use options that will best serve the interests of the different users, especially those of poor rural communities

- to guide policy makers in the relevant agencies in decision making and in the implementation of the conservation measures by providing technical assistance and disseminating research findings

The project will collect information on ecology, hydrology, agriculture, and irrigation of the study area to characterize, evaluate, and then predict the status of lagoon ecosystems in relation to the irrigation management and other activities.

Activities

1. Flow measurements in the irrigated areas: Inflow to Tracts 5, 6, and 7. Outflow to the Badagiriya tank. Drainage to the Embilikala and Malala lagoons.

2. Assessment of the hydrological and geomorphological conditions of the lagoon system: land use, geometry (area and capacity), catchment area of the lagoons, and inflow and drainage conditions. Hydrological monitoring in the lagoons: water levels in the lagoons, flow between the two lagoons, outflow to the ocean, and inflow from the ocean.

3. A rainfall gauge will be installed in the Bundala National Park area and rainfall will be monitored throughout the study period.

4. Nitrogen pathways and balances will be performed on the catchments of the lagoons with special emphasis on the role of cattle and fertilizer.

5. A water quality monitoring system will be set up in the three lagoons and the Right Bank area of the KOISP, focusing on salinity and nutrients. Sampling will take place at the same points as the flow measurements and in the three lagoons. Samples will be analyzed for electrical conductivity, total suspended solids, pH, phosphate, nitrate, temperature, and dissolved oxygen. In addition to the chemical analyses, phytoplankton and zooplankton will be analyzed in the samples. Salinity of seawater has to be tested at the same time as salinity in the Malala lagoon around November, when there will be an open connection.

6. The ecology of flora and fauna in the immediate catchment of the Malala, Embilikala, and Bundala lagoons will be related to the nutrient statuses of those lagoons.

7. A survey will take place among farmers in Tracts 5, 6, and 7 and Badagiriya. This will include information on irrigation schedules, fertilizer, and pesticides.

8. A survey will take place among the users of the different functions of the Bundala National Park. This will serve as input to value the environmental function of water.

9. The pesticide usage survey will serve to assess potential environmental hazards based on existing international databases. The pesticide usage survey will make it possible to set up a focused sampling scheme for pesticide residues in water and aquatic organisms at a later stage and subject to availability of funds.

10. The ecological statuses of the lagoons will be surveyed twice using indicator species:

    - aquatic vegetation: algae and macrophytes
    - shrimp
    - fish species
    - amphibian species
    - avian species

In addition to the surveys, the aquatic vegetation will be monitored throughout the study period.

11. Water balances will be performed on the four watersheds that are of importance to the National Park lagoons: lower Kirindi Oya subbasin, Embilikala, Malala Oya, and Bundala.

12. Salinity in the lagoons will be related to the amount of water released into the Right Bank Main Canal, the amount of water measured at drainage sites, and to the rainfall.

13. Salinity of the lagoons will be modeled under different water management scenarios and the range of permissible flows to the lagoons, to keep salinity at a permissible level, will be estimated.

Outputs

1. Report(s) containing

    - the ecological status of the Bundala Park.
    - the impact of upstream uses of water on the ecology of the Bundala Park.
    - valuation of the environmental functions of water in the project area.
    - present water management arrangements.
    - technical specifications of cost-effective monitoring systems that could be useful for integrated management of lagoons and irrigation.

2. Water management options for improving and sustaining the ecology of Bundala are identified and evaluated. Possible solutions to the problem of ecological degradation are identified and evaluated in terms of cost-effectiveness, technical soundness, and acceptability by the community.

3. Capacity building of the local community, water professionals, and students by engaging them in the research activities.

4. Important research output documented in research reports, including areas on methodology development for valuation of water for ecological uses, methodology to study interaction between irrigation and environment, and others.

5. An action plan for follow-up to implement the findings of the study.

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Appendix A

Workshop on "Water Quality of the Bundala Lagoons"
Held on 3rd April 1998

AGENDA

Time	Topic	Speaker
09:30 to 09:40	Opening Remarks	Douglas J. Merrey
09:40 to 10:00	Introduction and Purpose of the Workshop	Wim van der Hoek
10:00 to 10:20	Lagoon Ecosystem Management	J. Samarakoon
10:20 to 10:40	Environment in the Bundala National Park	Chandra Jayawardene
10:40 to 11:00	*Tea Break*	
11:00 to 11:20	Impact of Cattle Grazing on the Nutrient Levels at the Ramsar Wetland Site	Shamali de Silva
11:20 to 11:40	The Study of the Populations of Domestic Cattle and Buffalo for the Resolution of Management Conflict at the Bundala National Park	Deepanee Bopitiya
11:40 to 12:00	Bundala: Social and Environmental Challenges	Chaminda Rajapakse
12:00 to 13:00	*Lunch*	
13:00 to 13:20	Irrigation Management in the Kirindi Oya and Badagiriya Schemes	U.S. Wijesekera
13:20 to 13:40	Hydrology of KOISP and the Bundala National Park	Chris Panabokke
13:40 to 14:00	Water Accounting and Drainage in the Bundala National Park	Anneke van Eijk
14:00 to 14:20	Value of Multiple Uses of Water	Margaretha Bakker
14:20 to 14:40	Potential Effect of Agriculture and Irrigation on the Park and Plans for Monitoring	Yutaka Matsuno
14:40 to 15:15	Open Discussion	All Participants
15:15 to 15:30	*Tea Break*	
15:30 to 16:00	Discussion on the Need for Further Studies	Wim van der Hoek

Appendix B

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