Case Study in Sri Lanka: Irrigation and Drainage Water Quality and Impacts of Human Activities on the Aquatic Environment in a Southeastern Part of Sri Lanka

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INTRODUCTION

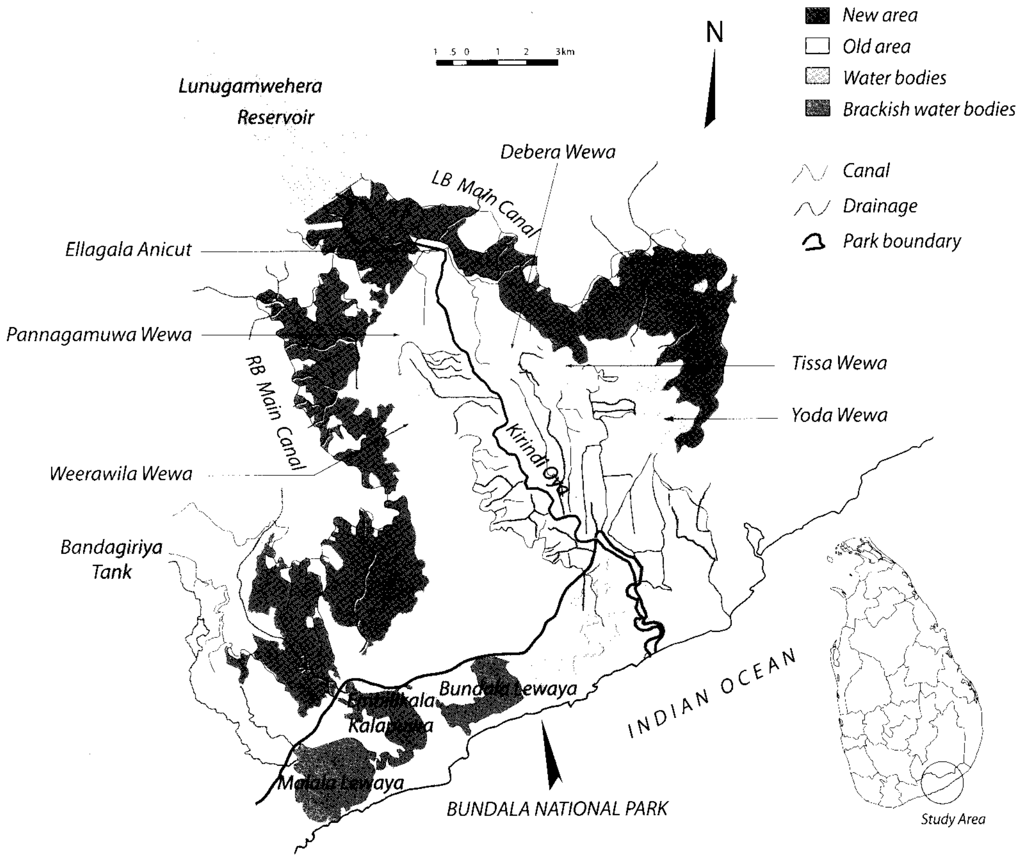
In Sri Lanka, irrigation water is used for many purposes other than irrigating field crops. Water from reservoirs and canals is used for livestock watering, fisheries, industries, and domestic purposes like drinking, bathing, and laundering. It also contributes to sustain the environment, like wildlife and wetland ecosystems (Bakker et al. 1999). The substantial environmental services of water have often been neglected in the environmental considerations in water allocation decisions, resulting in deterioration and depletion of ecosystems. This happens because many of these services go unrecognized and system managers only pay attention to the services and functions the system is designed for: irrigation and, sometimes, domestic uses of water.

Water is the primary resource controlling the ecosystem in wetland areas.[1] Wetlands are among the earth's most productive ecosystems and directly support millions of people and provide goods and services to the world outside the wetland as well. Direct and indirect human activities, especially related to irrigation development, have considerably changed wetland ecosystems (Barbier, Acreman, and Knowler 1997). Wetlands are also threatened by the increasing water scarcity and the wetland ecosystems have to compete with irrigation for freshwater.

The Bundala National Park is located along the south coast of Sri Lanka, 275 kilometers from Colombo (figure 1). The climate is generally hot and dry, with an annual rainfall of 1,074 mm and a mean temperature of 27 ^{0}C. The total area of the park is 6,216 hectares, including 5 shallow brackish water lagoons (Maha, Koholankala, Malala, Embilikala, and Bundala) with a total surface area of 2,250 hectares. The park has important populations of water birds, el-

[1]In this paper the broad definition of the International Convention on Wetlands (Ramsar Convention Manual 1997) is used. Wetlands are defined as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres. In addition, wetlands may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands.

Figure 1. Map of Study Area.



ephants, turtles, and other wildlife. The brackish water lagoons serve as nurseries for shrimp, fish, and a variety of other marine organisms (Matsuno, van der Hoek, and Ranawake 1998). It was declared a sanctuary in 1969 and upgraded to the status of a National Park in 1992. Due to the existing natural values the area was listed under the International Convention of Wetlands, the Ramsar Convention, in 1991, so far being the only one of its kind in Sri Lanka. The main reason for this establishment is that the area is regarded as an internationally important waterfowl habitat (CEA 1993).

The 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, which are located upstream of the park (figure 1). Following the implementation of the KOISP in 1987, which increased the irrigated area from 4,200 hectares to 10,450 hectares, salinity levels of the lagoons have dropped due to inflow of upstream irrigation water. This change in salinity levels has decreased 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. This paper will concentrate on the irrigated areas of Badagiriya (850 ha), Right Bank tracts 5, 6, and 7 (1,760 ha) and three environmentally sensitive adjacent water lagoons: Malala (650 ha), Embilikala (430 ha), and Bundala (520 ha). The first two lagoons are most affected by the drainage water. The Bundala lagoon has its own small catchment, and is therefore not affected by the irrigation development.

Although drainage water is considered to be one of the major causes of the changes in the lagoon ecology, there is still a lack of knowledge about the impact of drainage water on the ecosystem of the park (Matsuno, van der Hoek, and Ranawake 1998). A thorough understanding of this relation to the activities taking place in and around the lagoons is essential for planning and selecting effective conservation measures for the park. Besides, characterization of water bodies is needed to understand and assess the environmental status and process in the wetland ecosystem. This is further important for making measurement and comparison of the various possible benefits of water and to assist as a tool in decision making on the management of the resource. Therefore, this chapter describes environmental concerns by human activities taking place around the park and also reports some results of primary monitoring of irrigation, drainage, and lagoon water quality over the 1-year period.

MATERIALS AND METHOD

To describe human activities and their impact on the environment, qualitative and quantitative information was collected from relevant government officers, NGOs, key informant interviews, and field observation. The primary and secondary data were stored in a database system and processed at the IWMI headquarters.

For water quality measurements, water samples were collected from irrigation (Lunugamvehera Reservoir) whose drainage water enters the Embilikala lagoon, and the water body of Embilikala lagoon. The samples were collected in the fourth week of every month from October 1997 to September 1998. Water and air temperatures, electrical conductivity (EC), and pH were measured at sampling sites using portable meters. Water samples were analyzed for their chemical concentrations at the National Water Supply and Drainage Board (NWSDB). The sampling procedure and analysis methods followed were those recommended by the NWSDB.

RESULTS AND DISCUSSION

The importance of the resources of the Bundala National Park is paramount for the communities in the vicinity of the Park. The irrigated areas upstream of the Park provide livelihood opportunities for 3,000 farmer families. Besides the contribution to the livelihoods of the families, either in cash or subsistence, these activities have some other impacts as well.

Institutional Impact

Before Bundala attained the status of a National Park (1992) people were allowed to retain land titles. Being a National Park, Bundala has far-reaching implications. First, a National Park is only state land and no private landownership is allowed. Boundaries of the Park are now under discussion in the Parliament to avoid private landholdings in the Park. Second, most of the human activities, except lagoon fishing and tourism, are prohibited by law (CEA 1993). Despite these regulations the resources in the Park are still used for a variety of purposes and most of the people involved in these activities are local villagers who have been forced into some illegal activity through lack of land for grazing, fuel, or income (CEA 1993).

The Bundala National Park covers 5 Grama Nilidari Divisions[2] with a total of approximately 1,100 families. The Department of Wildlife Conservation (DWLC) is responsible for the overall management of the Park and also for the enforcement of the aforementioned regulations. Strict enforcement of regulations is virtually impossible owing to lack of staff and transport (CEA 1993). During 1997, no patrolling or evidence of law enforcement was observed (Kularatne 1999). Besides a lack of enforcement from the DWLC, there was no compulsion to discontinue these illegal activities because the amounts of money fined were insignificant.

In addition to the problem of enforcement, another management problem of the Bundala National Park is that most of the institutional authorities are defined along sectoral or geographic lines that do not correspond to the range and types of environmental problems. The problems in this area cross these boundaries and authorities of a single department. Policies and decisions of one authority have an impact outside their geographical and sectoral lines. This problem becomes visible in the impact of the upstream irrigation system on the ecosystem of the Bundala National Park. The Irrigation Department is the responsible agency for the management of the upstream irrigation system but the protection of the Bundala National Park is not in its mandate. This shows the need to coordinate problems related to water management, preferably at basin level.

Agriculture

Within the park boundaries, agriculture itself does not appear to be an environmentally destructive activity. The most serious threat to the Park comes from the upstream KOISP. Efforts to clear and irrigate land and settle large numbers of people close to the Bundala National Park have led to wetland degradation, mainly because of impacts resulting from a range of activities these people carry out besides farming (CEA 1993). The irrigated agriculture, upstream of the Bundala National Park, generates important benefits. Apart from income and employment generation it contributes to food security and social consistency by decreasing the trend of migration from rural to urban areas (Bakker et al. 1999). However, irrigation delivers large quantities of freshwater to the lagoons in the Park and has significantly altered the salinity levels of the lagoon and thus changed the ecosystem of the Park. Table 1 shows the change in salinity level for the Malala lagoon following upstream irrigation development. In 1998, a comprehensive water balance study was performed in the area. For this study the drainage flow from RB tract 5 into the Bundala National Park was measured and quantified at 68 million cubic meters (MCM). The total net inflow in the system was 478 MCM, 14 percent of which drained into the Bundala National Park (Renault, Hemakumara, and Molden 1999).

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[2]Local level administrative unit in Sri Lanka.

Table 1. Average annual salinity level, Malala lagoon.

Year	Lowest	Highest
85/87	10 ppt*	41 ppt
91/92	5 ppt	10 ppt
95/97	0 ppt	7 ppt

Source: Kularatne 1999.

*Parts per thousand.

Another potential source of ecosystem transformation is agrochemicals used for irrigated agriculture. At the moment, a survey is being conducted to estimate quantities and types of fertilizer and pesticides used in RB tracts 5, 6, and 7, and in Badagiriya, which are brought into the ecosystem of the Park through the drainage water. The excess drainage water results also in flooding of the agricultural and grazing lands around the Park. The lagoon area has increased at the cost of agricultural, grazing, and forest land. The maximum surface area of the Malala lagoon increased from 437 hectares in 1983 to 650 hectares in 1997 (Kularatne 1999). Further, the creation of the KOISP disrupted the livestock grazing system and wildlife habitat by converting grazing land and forest areas to paddy land. Many elephant migratory routes have been disrupted by farmlands and this has resulted in crop damage by elephants, leading to the human-elephant conflict in the area.

Fisheries

Prior to the implementation of the KOISP in 1987 and drainage inflow into the Bundala National Park, 400 families sustained themselves with prawn fishing in the Malala and Embilikala lagoons. At present, they have less income from fishing and people are forced to look for other income or subsistence-generating activities, in or near the Park (IIMI 1995; M.P. Gamage personal communication). Fishing is still continuing in these lagoons at a low intensity. Besides the change in the composition of the fish species, the fishermen have observed an increase in the number of fishermen, change in type of nets used (57% use prohibited small mesh gill nets), and a decrease in fish-breeding behavior after upstream irrigation development (Kularatne 1999). Despite these problems people continue fishing in the lagoons because the input costs are very low when they use a canoe without an engine.

At the present level of intensity and technology, fishing in the lagoons is not a serious environmental threat to the lagoon ecosystem. Removal of fish for human consumption may decrease the Park's carrying capacity of fish-eating birds, but there is no evidence of this being a problem at present (CEA 1993). The fishermen have been fishing in the lagoons for four generations and the officials of the DWLC do not see them as a threat to the Park ecosystem. Aquacultural techniques are not allowed to be used in the lagoons, for instance, to increase shrimp production. Table 2 shows the average fish and shrimp production over the years for the Malala lagoon. The table indicates that the lagoon is not suitable anymore for shrimp production but is favorable for the existence of other fish types, mainly cichlid. This is not surprising since the acceptable salinity range for shrimp culture is between 5 and 35 ppt, with an optimum range of 15 to 25 ppt while the current maximum salinity level of the lagoon is 7 ppt.

Table 2. Average fish and shrimp production per year (in kg/ha).

Before	1987	91–92	95–97
Average fish	Not available	120	60
Average shrimp	15.38–30.77	5.2–15	No shrimp production

Fuelwood Collection

The main source of energy for cooking in the area is fuelwood. It is collected by the local population for domestic as well as commercial purposes in the forest areas around the lagoons. They sell it to both shell burners who use it in their shell kilns and to people from the nearby towns (Kularatne 1999).

The forests around the lagoon are critically important to the area's ecosystem (CEA 1993). Fuelwood collection is an environment damaging activity that leads to the propagation of undesirable species of plants. For this reason, cutting of trees is banned within the boundaries of the Park but it is still practiced (ibid.). Collection of dead branches is also prohibited but this activity continues to take place. The demand for fuelwood has increased due to irrigation development and the human settlement close to the Park. Since this is an illegal activity quantitative data are lacking. However, it is clear that fuelwood collection is of high importance to the livelihoods of the families around the Park.

Livestock

Livestock, mainly buffalo and cattle, is an important subsistence and income-generating activity in the study area. The animals are mainly reared for milk, and to produce curd for which the area is well known. The livestock productivity is quite low because a large part of the herd is not used for milk production but as a capital asset. The ownership of livestock is recognized as a status symbol and the size of the herd is more important than the quality of the herd. Although it is illegal to allow domesticated animals to graze within the Park boundaries it happens quite often. Some large herds are owned by people outside the study area.

Before the start of the KOISP, livestock was one of the major livelihood activities of the communities in the study area. Lack of grazing land is now a major constraint in keeping livestock. In the planning of the KOISP, nobody took into account the livestock and their need for pasture area and the previous grazing grounds turned into irrigated rice fields. Livestock owners are to be blamed as well for the loss of grazing grounds under the KOISP because when the organizations sought data of the number of animals they owned, they did not provide the correct figures (Kularatne 1999).

The numbers of domestic cattle and buffalo that use the resources of the National Park vary according to the *yala* (dry) and *maha* (wet) seasons. During yala, livestock is mostly found along the northern boundary of the Park and the adjacent fallow rice fields in tracts 5, 6, and 7 and Badagiriya. In yala 1997, 4,000 domestic cattle and 1,700 buffalo were counted in this area (Bopitiya, Dayawansa, and Kotagama 1998). Livestock moves into the Park during maha when the rice fields are cultivated. The continuous supply of freshwater from the upstream irrigation systems encourage even more livestock to come to the Bundala National Park (ibid.). They compete directly with the wild animals, like the elephant and the spotted deer, for food in the park. All this leads to overgrazing of the area and to serious soil degradation. Further, dung and urine of livestock enrich the lagoon system and cause eutrophication.

Medicinal Plant Collection

So far, not much is known about medicinal plant collection and the role of medicinal plants in the livelihoods of the communities. A recent countrywide project to safeguard the wealth of medicinal plants, funded by the World Bank and the Global Environmental Facility, encountered a lot of opposition from local environmentalists. They objected to the collection of traditional knowledge without proper benefits to the local population (IPS 1999).

Salt Farming

Since the Bundala lagoon has its own small catchment it has not been affected by irrigation development and therefore the water has maintained its natural salinity level. Though salt production is not directly linked to or affected by freshwater inflow we took it into account because it is an important employment-generating activity and is thus important to the livelihoods of the villagers. We also considered salt farming so as not to take the risk of overlooking an important ecological relationship that is unknown at the moment. The Salt Corporation operates 100 hectares of the Bundala Lagoon despite the fact that human activities and private landownership are not allowed within the Park boundaries. In 1978, the Salt Corporation became operative, first, under the ownership of the government and, subsequently, of a private company. As the salt farm creates a lot of employment for the villagers, the DWLC allows the salt farm to continue its operations but it cannot extend its area further than the existing 100 hectares.

Salt production is seasonal and limited to periods of low rainfall (July-October and February-May). The Bundala saltern produces 15,000 tonnes/year. In total, 70 permanent employees and 43 casual, and 250 seasonal laborers are employed in the salt farm. They all travel within a radius of 15 kilometers. The benefits of salt production are given in table 3.

The water inlet pond, where water from the ocean is pumped into the salt pans, is an important feeding place for birds. The water and salinity levels in this pond are controlled and this provides a valuable feeding ground, especially for flamingos and small wading birds. Since the salinity of the Embilikala and Malala lagoons is too low and water levels fluctuate too

Table 3. Benefits of salt farming in 1998 (in US$).

Total output	15,000 * US$37.42 = US$561,300
Total labor costs	US$269,559
Other costs	Unknown*
Total max. net value of output	US$291,741 (2,917 per ha)

*Not much machinery input is used in this salt farm; salt is sold in bulk, so no packaging, etc., takes place.

much this is the only place in the National Park where these birds could go to. Despite this important ecological function of the salt farm it is also argued that overextension causes an imbalance in the ecology (Rajapakse 1998).

Shell Mining

Apart from fuelwood collection, shell mining is another of the most environmentally destructive activities in the study area. It extracts fossil shells from beds, which can be found just beneath the ground surface. The shells are sifted, washed, and sold as shells or burned and sold as lime. This is a highly destructive activity because it disturbs the soil structure, destroys the vegetation cover, and leads to increased soil erosion (CEA 1993).

Shell mining, within the National Park and in nearby areas, is a major source of self-employment. Because of the environmental destructiveness it is prohibited by the DWLC but continues to take place. In 1998, it was estimated that there were 13 illegal shell mines inside the Park and 15 illegal mines outside the Park. There are also 12 permitted (legal) shell mines outside the park (Kularatne 1999). Usually permit holders allow others to mine the shells in their shell beds and they do not carry out any mining activity on their permit lands. They buy the shells for Rs 25 per 15 kg. Because it is possible to mine shells without a permit, people are not interested in obtaining a permit. The number of permit holders decreased from 1994 to 1997 while observations reveal that many people are still involved in this activity. As the total production of shell mining is unknown we cannot quantify the benefits derived from this activity.

Tourism

Tourism is a major income-generating activity of the Bundala National Park with only minor impacts on the economies of the nearby villages. While the activity generates a considerable amount of income for jeep drivers, guides, and guesthouses, it seems that no villagers from the vicinity receive benefits from the presence of tourists. The people involved come from villages and towns further away from the Park (CEA 1993).

The way tourism is practiced at present in the Park has a negative impact on its ecosystem. The main impact is on the habitat, which is being increasingly destroyed by four-wheel drive vehicles leaving the established roads in search of wildlife. This, in addition to harassment of animals, makes the Park less-attractive and less-habitable for wildlife (CEA 1993). Another adverse effect that tourism has had and of which villagers complain is that the animals, particularly elephants, are accustomed to human presence which makes it harder for the farmers to drive them away when they damage the crops. These conflicts result in death and destruction of both humans and elephants (Rajapakse 1998).

One of the possible impacts of drainage water inflow in the National Park could be a drop in the number of tourists visiting the area because of the changing ecosystem. So far, no clear relationship has been detected. The data in table 6 show the number of tourists visiting the area and the income derived from such visits. We have no explanation for the sudden decline of the number of tourist visits in 1996 and the increase in 1997 to the same level as 1995.

Table 4. Number of tourists and the total revenue of entrance fees for Bundala National Park.

	1995	1996	1997
Number of foreign tourists	16,350	11,301	16,448
Number of local tourists	16,824	11,024	17,300
Total	33,174	22,325	33,748
Total revenue in US dollars	91,022.76	62,790.87	91,644.90

Source: Personal communication with Mr. Liyanage, DWLC.

Irrigation, Drainage, and Lagoon Water Quality

Table 5 shows the average and standard deviation of major water quality parameters during the monitoring period. Additionally, heavy metal concentrations such as mercury, cadmium, and lead were tested for, but their presence was not detected. The irrigation water quality is within the acceptable limit of guideline values (table 6), except the Sodium Absorption Ratio (SAR), which is a concern with irrigation water having a given EC. This indicates the potential problem for infiltration and/or salinity and reduction of yield for sodium-sensitive crops. According to the South African Water Quality Guidelines (Volume 8, Department of Water Affairs and Forestry 1996), the values of turbidity, phosphorus, and ammonia of the lagoon water exceed the guideline values for either aquatic ecosystems or aquaculture. Higher concentrations were found in most of the quality parameters of drainage and lagoon water when compared with the irrigation water quality parameters. Higher concentration of lagoon water is due likely to excess fertilizer from the irrigated area and livestock urine and dung from the surroundings of the lagoon.

Figure 2 shows the irrigation water issue to the right bank main canal from Lunugamwehera, and figures 3 to 9 show the trend of concentrations in some parameters in the three water bodies. During the monitoring period, the peak inflow was at the beginning of two cultivation seasons in December and May. Figure 4 shows the same EC trends of the drainage water as the lagoon water EC, indicating that the salt content of lagoon water is subject to the drainage water quality. The trends of concentration in drainage water do not clearly show a correspondence with the inflow, and only NO_2 shows peak concentration in the months of high inflow, while the concentration of irrigation water is relatively stable. Further analysis including the loading estimate is required to clarify the relationship between the flow and water quality.

Table 5. Average and standard deviation (in parentheses) of major quality parameters in irrigation, drainage, and lagoon water.

	EC (mS/cm)	TDS* (mg/l)	Turbidity (NTU)**	Color (TCU)***	pH	PO_4 (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)	SO_4 (mg/l)
Irrigation (Lunugamwehera)	0.32	0.16	5.2	13.55	7.42	0.26	0.69	0.01	17.5
	(0.07)	(0.03)	(4.85)	(10.01)	(0.63)	(0.41)	(0.24)	(0.01)	(11.12)
Drainage	2.12	1.06	55.11	40.42	7.6	0.16	1.14	0.02	147.83
	(1.89)	(0.95)	(44.77)	(39.27)	(0.41)	(0.11)	(0.39)	(0.03)	(150.63)
Lagoon (Embilikala)	2.09	1.04	66.97	57.25	7.63	0.27	1.36	0.02	91.5
	(1.84)	(0.92)	(59.47)	(62.50)	(0.37)	(0.25)	(0.49)	(0.05)	(46.87)

*TDS = Total dissolved solids.

* NTU = Nephelometric turbidity unit.

** TCU = True color unit.

	NH_3 (mg/l)	Suspended solids	Total hardness	Alkalinity	Cl (mg/l)	F (mg/l)	Na (mg/l)	K (mg/l)	SAR
Irrigation (Lunugamwehera)	0.08	15.5	120.33	147.67	18	0.2	20.43	3.67	26.52
	(.06)	(7.69)	(24.92)	(32.07)	(7.34)	(0.06)	(4.79)	(0.58)	(5.77)
Drainage	0.53	127	540.5	211.67	447.83	0.36	155.35	6	110.42
	(.46)	(99.23)	(515.07)	(60.59)	(535.58)	(0.10)	(97.05)	(3.33)	(33.26)
Lagoon (Embilikala)	0.63	183.92	337.09	206.73	282.55	0.31	161.06	7.38	125.93
	(.61)	(149.12)	(96.26)	(30.10)	(147.06)	(0.05)	(78.56)	(4.50)	(40.97)

Table 6. WHO drinking water and FAO/national irrigation water quality guidelines.

Parameter	Unit	WHO[1] 1996[a]	FAO[2] 1985[b]	South Africa[4] 1996[d]	Taiwan[3] 1978[d]	USA[3] 1973[e]	Hungary[3] 1991[d]	Saudi Arabia[3] No date[d]	Tunisia[3] No date[d]
Aluminum Al	mg/l	0.2*	5*	5	5	5	5	5	
Ammonia NH_3	mg/l	1.5*							
Arsenic As	µg/l	10	100*	100	1,000	100	200	100	100
Barium Ba	mg/l	0.7					4		
Benzene	µg/l	10					2,500		
Beryllium Be	mg/l		0.1*	0.1	0.5	0.1		0.1	
BOD	mg/l							10	
Boron B	mg/l	0.03	0.5-15*	0.5	0.75	0.75	0.7	0.5	3
Cadmium Cd	µg/l	3	10*	10	10	10	20	10	10
Chloride Cl^-	mg/l	250*		100	175			280	2,000
Chromium Cr	µg/l		100*	100	100	100	5,000	100	100
Cobalt Co	µg/l		50*	50	50	50	50	50	100
COD	mg/l								90
Copper Cu	mg/l	1*	0.2*	0.2	0.2	0.2	2	0.4	0.5
Cyanide	mg/l	0.07							
Electric Conductivity	µmho/cm				750				700
Fluoride F	mg/l	1.5	1*	2			1	2	3
Iron Fe	mg/l	0.3*	5*	5			0.1	5	5
Lead Pb	mg/l	0.01	5*	0.2	0.1	5	1	0.1	1
Lithium Li	mg/l		2.5*	2.5					
Magnesium Mg	mg/l								
Manganese Mn	mg/l	0.5	0.2*	0.02	2	0.2	5	0.2	0.5
Mercury (total) Hg	µg/l	1			5		10	1	1
Molybdenum Mo	µg/l	70	10	10	10	10	0	100	
Nickel Ni	mg/l	0.02	0.2*	0.2	0.5	0.2	1	0.02	0.2
Nitrate (NO_3^-)	mg/l	50							
Nitrite (NO_2^-)	mg/l	3							
Selenium Se	µg/l		20*	20	20	20		20	50
Sodium Na	mg/l	200*		70					
Sulfate (SO_3^-)	mg/l	250*			200				
Total Dissolved Solids	g/l	1*		40					
Total nitrogen N	mg/l				1				
Vanadium V	mg/l		0.1*	0.1	10	0.1	5		
Zinc Zn	mg/l	3*	2*	1	2	2	5	4	5

[a] Drinking water. [b]Irrigation water use = max. 10,000 m^3/ha/year. [c]Industrial effluent used in irrigation. [d]All soils. [e]Sandy soils. *Recommended values.

[1]WHO (1993),[2] FAO (1992), [3]Chang et al.(1996), [4]Department of Water Affairs and Forestry (1996).

Figure 2. Monthly irrigation issue to the Right Bank from October 1997 to September 1998.

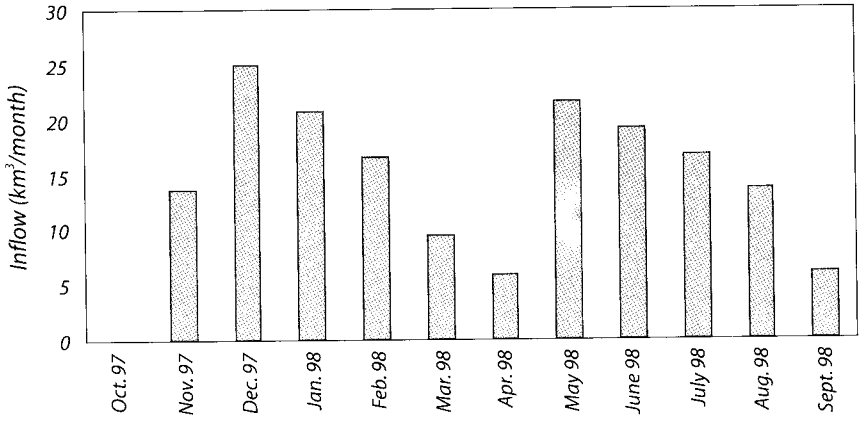


Figure 3. pH in the irrigation, drainage, and lagoon water.

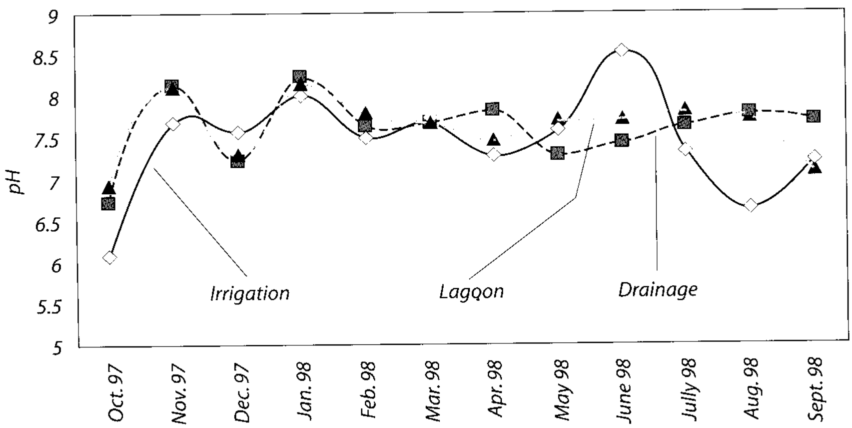


Figure 4. Electrical Conductivity (EC) values in the irrigation, drainage, and lagoon water.

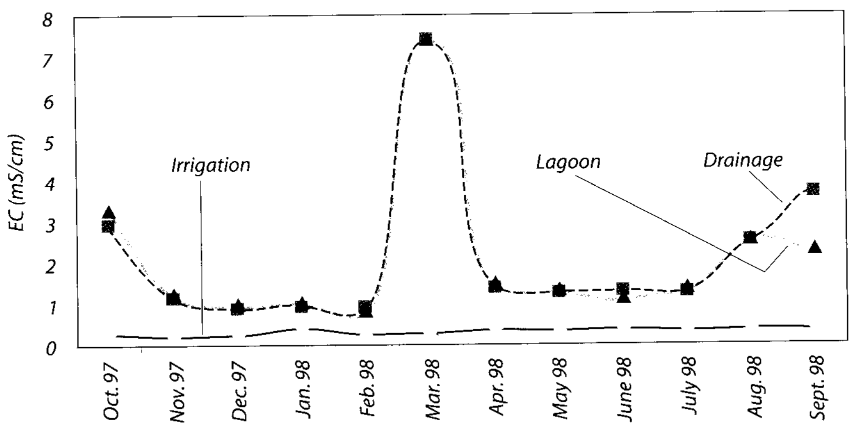


Figure 5. Total Phosphorus (PO_4) concentrations in the irrigation, drainage, and lagoon water.

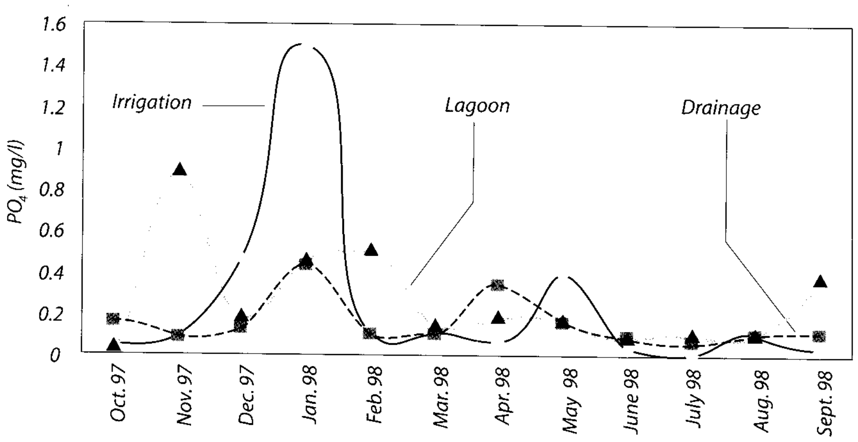


Figure 6. Potassium (K) concentrations in the irrigation, drainage, and lagoon water.

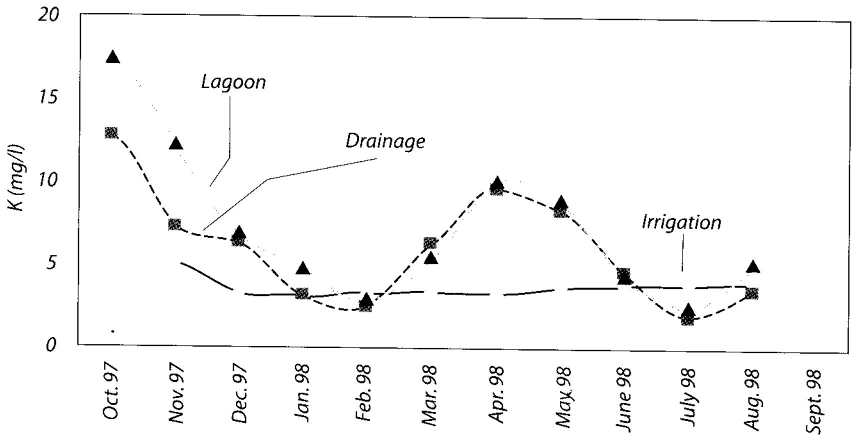


Figure 7. Nitrate (NO_3) concentrations in the irrigation, drainage, and lagoon water.

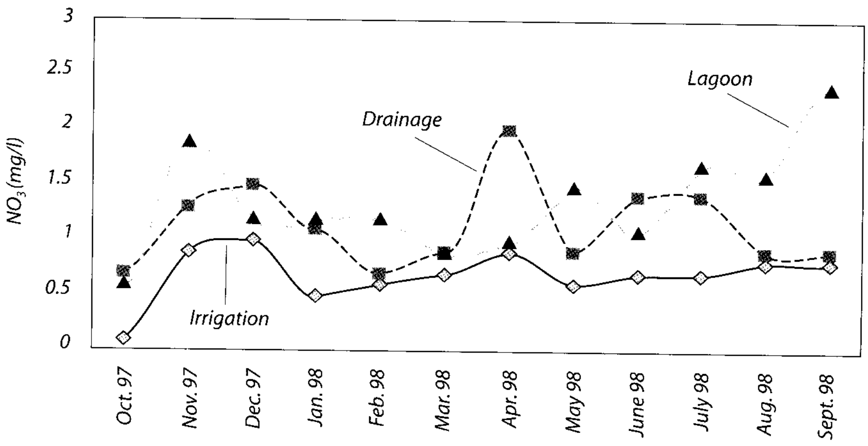


Figure 8. Nitrite (NO_2) concentrations in the irrigation, drainage, and lagoon water.

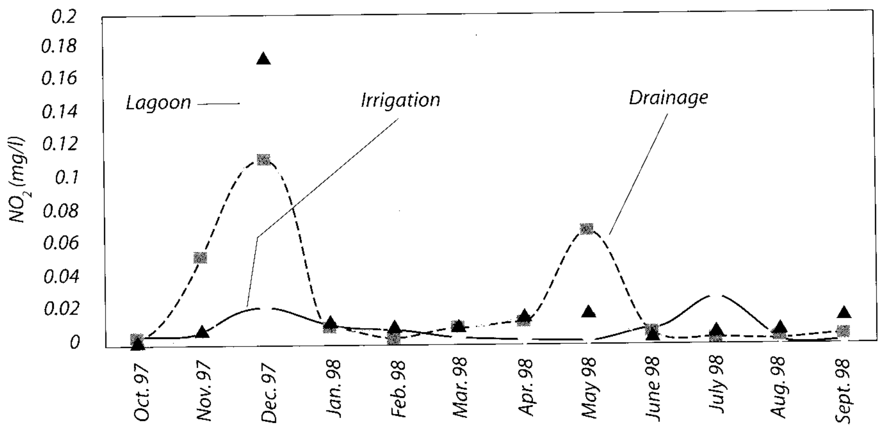
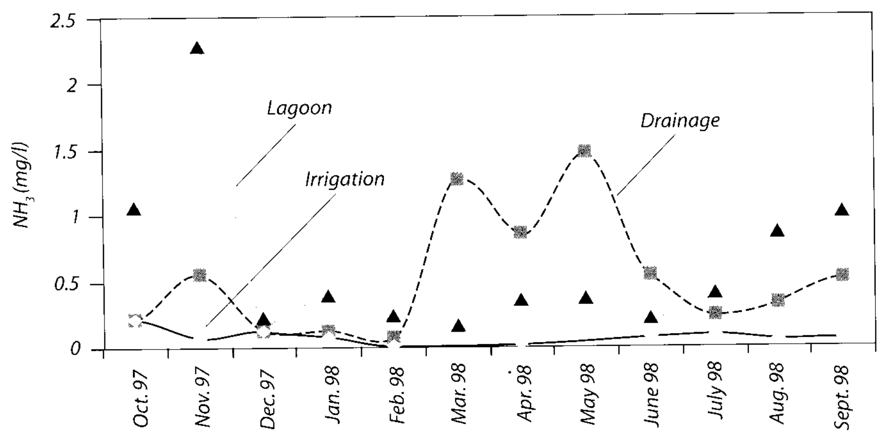


Figure 9. Ammonia (NH^3) concentrations in the irrigation, drainage, and lagoon water.



CONCLUSIONS

Environmental services and functions of water often go unrecognized because they are not part of the primary functions of the man-made water allocation systems, like irrigation systems. Moreover, environmental considerations have often been ignored in water allocation decisions, resulting in deterioration of the ecosystem.

Listing and describing all the uses and nonuses, particularly the direct uses, assist us in obtaining a better picture of what is happening in the area. Further, it reveals linkages and interactions of people and institutions in a certain ecosystem and the impacts of their activities as well.

It is obvious that substantial conflicts exist between direct uses of the resources by the local community and sustainable development of the ecosystem. The biggest conflict in the area (between ecosystem and livelihoods of the local people) is caused by drainage water from irrigated rice fields, which enter the lagoon ecosystem. In this context, it is important to evaluate the output of irrigated agriculture in relation to the loss of ecological value of the Bundala National Park from an economic point of view.

It is too early to conclude if the people in the area would have been better off in terms of livelihood opportunities with or without the irrigated rice cultivation. In the first instance, it provided them with a plot of land to cultivate their staple crop and a source to draw water for domestic purposes but, on the other hand, it has extremely affected the opportunities for livestock keeping and fisheries. We are however sure that it has negatively affected the ecosystem in the area not only by draining freshwater into the lagoons but also by increasing population and pressure on natural resources in the area (e.g., fuelwood, pastureland).

Strict conservation of the Bundala National Park, which the DWLC is aiming for through restricting all human activities in the Park, will improve its ecological character and this is bound to increase the number of tourists visiting the area. To have a chance of success, the local people should receive more benefits from tourism than is currently the case. In other words, they should also get benefits from conservation otherwise it is not a viable option for them. Further, opportunities should be created to satisfy their resource needs, for instance fuelwood, from another area or an alternative source.

REFERENCES

Bakker, M.; R. Barker; R. Meinzen-Dick; and F. Konradsen, eds. 1999. *Multiple uses of water in irrigated areas. A case study from Sri Lanka*. SWIM Paper 8. Colombo, Sri Lanka: International Water Management Institute.

Barbier, E. B.; M. Acreman; and D. Knowler. 1997. *Economic valuation of wetlands. A guideline for policy makers and planners*. Gland, Switzerland: Ramsar Convention Bureau.

Bopitiya, D.; P. N. Dayawansa; and S. W. Kotagama. 1998. The impact of domestic cattle and buffalo on the status of the Bundala National Park. In *Irrigation water management and the Bundala National Park*, eds. Y. Matsuno, W. van der Hoek, and M. Ranawake.

CEA (Central Environmental Authority). 1993. *Bundala national park*. Wetland site report and conservation management plan. Sri Lanka: Central Environmental Authority/Euroconsult. Ministry of Environment and Parliamentary Affairs.

Chang A. C; A. L. Page; T. Asano; and I. Hespanhol. 1996. Developing human health related chemical guidelines for reclaimed wastewater irrigation. *Water Science and Technology*, 33(10-11):463-472.

Department of Water Affairs and Forestry. 1996. *South African Water Quality Guidelines. Volume 8, Field guide*. First Edition. Department of water affairs and forestry. Private bag X313, Pretoria, South Africa.

FAO. 1992. *Wastewater treatment and use in agriculture*. FAO irrigation and drainage paper no.47. Rome: FAO.

IIMI. 1995. *Kirindi Oya Irrigation and Settlement Project. Project Impact Evaluation Study*. Volume II: Annexes (final report). Colombo, Sri Lanka: International Irrigation Management Institute.

IPS (Inter Press Service). 1999. *Sri Lanka: Conservation plan threatens ancient remedies*. *http://customnews.cnn.com/cnews/pn...p_subcat=Sri+Lanka&p_category=Asia;*

Kularatne, M. G. 1999. Fishermen without fish. The effects of productivity decline in lagoon fisheries on a fishing and farming community and its use of natural resources. A case study of Malala lagoon, Hambantota, Sri Lanka. M.Sc. thesis. Enschede, The Netherlands: International Institute for Aerospace Survey and Earth Sciences.

Matsuno, Y.; W. van der Hoek; and M. Ranawake, eds. 1998. *Irrigation water management and the Bundala National Park. Proceedings of the workshop on water quality of the Bundala lagoons.* International Water Management Institute, Colombo, Sri Lanka.

Rajapakse, C. 1998. Bundala: Social and environmental challenges. In *Irrigation water management and the Bundala National Park*, eds. Y. Matsuno, W. van der Hoek, and M. Ranawake. Colombo, Sri Lanka: International Water Management Institute.

Ramsar Convention Manual. 1997. *A guide to the convention on wetlands (Ramsar, Iran 1971).* 2nd edition. Gland, Switzerland: Ramsar Convention Bureau.

Renault, D.; M. Hemakumara; and D. Molden. 1999. *Importance of evaporative depletion by non-crop vegetation in the irrigated areas of the humid tropics.* Internal Paper. Colombo, Sri Lanka: International Water Management Institute.

WHO. 1993. *Guidelines for drinking water quality, volume1 recommendation.* Geneva: WHO.