Rehabilitation of the Ecological Functions of the Senegal River Delta

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1. Introduction

This report is an initial effort to evaluate the options for rehabilitating the Ndiaël. It is the result of a desk study carried out in November 2000 and of two month-long field mission held in May and August of 2001. The findings will serve in preparation for the Environmental Management Component of the Long Term Water Sector Project, which also includes a management plan for the Lac de Guiers and the rehabilitation of the Baie de Hann (Dakar). The work was researched in the context of two other World Bank projects: the Coastal and Marine Biodiversity Management GEF project and the Senegal River Basin GEF project.

Aims of Project

The initial report provided the scientific basis for further action. Case studies of the rehabilitation of wetlands worldwide were examined and the importance of estuaries for fisheries confirmed. Over 70 persons with relevant academic experience were contacted. Of these, ten experts were identified as highly relevant (see Recommended Resources below). The first field trip in May 2001 aimed to get a comprehensive lay of the land; an update of the situation as it has evolved over last two decades. The second trip focused on identifying physical rehabilitation channels. The information gathered included:

- cataloguing the activities in the delta (human and natural conditions),
- identifying the concerns and agendas of local participants,
- obtaining qualitative and quantitative field data,
- uncovering the opportunities for rehabilitation.

The study zone of this project is the entire ecosystem of the Ndiaël, from the coast to the Lac de Guiers, south of the Route Nationale 2 (RN2). Previous studies have concentrated on the central depression of the Ndiaël (the "Cuvette") or the Réserve Spéciale de Faune (special wildlife reserve). Many studies of the Senegal River only go down as far as Diama. There are few fisheries studies of the lower delta and estuarine zone. Given the zone of study, the aim of this project is not imperatively to rehabilitate the cuvette itself, but peripheral zones too.

Structure of This Paper

First, information is presented about the historic condition of the Ndiaël, its deterioration over time and current condition. The field results are collated into four regional reports, which are the main routes contemplated for reflooding the Ndiaël: northeast (Niety Yone), Coastal Zone / Marine Connection, southwest (Trois Marigots) and north (Tellel). A section is dedicated to discussion and analysis of the water routes. Information is provided about areas of interest in the delta, including Diama and the Djoudj. The Diawling in Mauritania is presented as a relevant case study. This is followed by notes from meetings with interested parties and relevant agencies.

General Observations

Desertification

The entire delta has not been made into a desert, but most of the Ndiaël has. The water routes into the Ndiaël have been severed and a gradual drying up has resulted although some parts remain humid. Much of the veg-

etation has disappeared and the *gonakier* forest (*Acacia nilotica*) has started disappearing.

Wind Erosion

The RN2 north of Ross-Béthio to Richard Toll is subject to a high crosswind, which carries small sand dunes onto the road; this sand is being transported directly to the Ndiaël, and is contributing to obstructing the waterways. Preventing this wind erosion and deposition is a priority and could be achieved by planting erosion-controlling plants e.g. *Euphorbia* and *Prosopis*. Such a program is done by the Eaux et Forêts.

Desire to Reflood

There is a strong desire to reflood by all villagers contacted. Some institutions complained of the degradation in the area, and the desire to redress the situation. However, they stated that although they had the will, they did not have the means.

Lack of Coordination / Communication

From almost all parties contacted, the need for greater communication and coordination was expressed. The delta has many interested parties / stakeholders who act without knowing the activities of the others.

Typha

The invasive reed *Typha australis* is one of the main problems in the region. This plant has experienced a population explosion in the disturbed environment of the delta. Problems associated with *Typha* are: it is an obstruction to navigation; it harbours the floating aquatic weed *Salvinia molesta* (another invasive) as well as the snail which carries bilharzia/schistosomiasis; it destroys fish habitat; and provides nesting sites to the destructive avian pest *Quelea quelea*, a crop parasite.

It is estimated that less than 1% of *Typha* is utilised (for making mats and thatch). It can be destroyed by uprooting, drying, burning, or cutting below the waterline, which are extremely labour intensive processes.

The discovery of a beneficial use for this reed would solve a problem. In Ross-Béthio in 1998 Pronatura, an NGO, started a factory to make charcoal from *Typha*. However, the organisers of the project demanded too great a subsidy from donor organisations, and the project became uneconomical and failed. Another potential solution could be to make paper out of *Typha*.

Potential to Resolve Two Issues with One Action

With every rainy season, the city of Saint Louis is flooded. This is an indication that the volume of water passing through Diama during the peak flood is excessive. The cost to the city of Saint Louis is considerable (construction of flood defences) and has limited effect (floodwaters go either above or around the embankments). A potential solution to both flooding in Saint Louis and to the drying-up of the Ndiaël is to divert some of the floodwaters to natural depressions such as the Ndiaël. This has successfully been implemented in the Diawling (Mauritania), and is accepted practice in the Thames River Valley (UK).

Technical vs. political solution

Re-establishing the original hydrology, from a technical point of view, is feasible (opening dams and deepening canals). However, the problem arises as to whether it is possible from a political point of view (national and international).

2. The Ndiaël

The Historical Condition

The Senegal River Delta has traditionally been a rich source of fisheries, grazing land, forests, wildlife, drinking water and fertile agricultural soil. Reminiscent of the Nile, the floodwaters of the Senegal would irrigate a wide expanse of land, and deposit silt in the delta. The flood would benefit some species of fish, which used the low-salinity, high water level to spawn in. The wide expanse of flooded land would also serve as nursery grounds to juvenile fish and shrimp. The fertile floodplain would support vast expanses of herbaceous and ligneous growth, on which the local herdsmen would graze their cattle, collect firewood and building material, and in which

certain bird species would nest. In the less accessible areas wildlife (antelopes, carnivores, warthogs, crocodiles, manatees, hippopotami and even elephants) would find refuge. The floodwaters would slowly permeate into the subsoil, recharging the underlying aquifers. Finally, as the flood receded, farmers in the upper delta would grow crops in the rich, wet soil, without the need for rain. Before it was disconnected from its water sources, the Ndiaël was biologically diverse in flora and fauna. Hundreds of species of birds, over 20 mammals, and over thirty species of grasses, trees and shrubs were found.

Deterioration of the Delta

However, over the years, the natural ecology of the delta was disrupted. It is currently degraded because of lack of water. The cause of this demise is primarily roads and dams that have obstructed natural water routes. Dams were built to store fresh water, cutting the water routes from the ecosystem. The construction of roads also acted as barriers to the passage of water. Lastly, the development of agriculture, fields, irrigation canals and contaminated runoff also contributed to the disturbance of the natural functioning of the delta.

One of the areas that was affected most was the "cuvette", or natural depression, of the Ndiaël. It has four water routes leading to it: from the northeast (Niety Yone), a marine connection, from the southwest (Trois Marigots), and north (Tellel). The northeastern route was cut when the Compagnie Sucrière Sénégalaise (CSS) closed off the Niety Yone to maintain a sufficient level of water in the Lac de Guiers for its irrigation needs. This was done without regard to the downstream inhabitants, who suddenly saw their water supply cut off. The marine connection and southwestern routes were barred very early on (1866) when a channel was dammed to act as a water reservoir for Saint Louis. The northern route (Tellel) was closed off by the construction of the Route Nationale 2 (RN2), and subsequently rehabilitated to accommodate agricultural runoff, which now drains into the Ndiaël. Although degraded, the area received some water over the years, from the creeks, as well as from rainwater. After the floods, water can stay in the cuvette 5 – 8 months depending on the floods (until February or May).

A small population still inhabits the region. There are stands of trees throughout the area, as well as some wildlife and fish.

More recently, as a result of the extended drought of the 1970s and early 1980s, the annual flood decreased in volume and saline water from the Atlantic Ocean penetrated deeper inland. This posed a threat to the drinking water supply of the riparian towns, and prevented agricultural use of the water during the dry season. Moreover, it was thought that if fresh water could be had year-round, two crops could be cultivated per year. This prompted the development of the Organisation pour la Mise en Valeur du fleuve Senegal (OMVS),[1] which reacted by building two dams: the Manantali, in the upper reaches of the Bafing, in Mali, a high dam with a holding capacity of 12 billion m^3, and Diama, a "salt wedge" dam 55 km from the mouth, with a capacity of 300 million m^3. A controlled release of water from Manantali throughout the year maintains the required water level for agriculture in Diama and its associated water bodies (Lac de Guiers, the marigots). Diama is managed at a preferred water level of 1.5 – 2.0 m ASL.[2]

Although this system is carefully managed as far as the river and main irrigated "perimeters" go, there have been considerable environmental impacts (e.g. proliferation of aquatic weeds, human health, drying up of the areas that were cut off from the system). It is in this context that the Ndiaël, which has been greatly affected, is to be rehabilitated.

Rehabilitation

The environmental degradation has se-

1 Organisation for the Development of the Senegal river

2 above sea level.

verely endangered the natural resources of the region (disappearance of vegetation cover, soil erosion, drying up of natural waterways, reduction in fauna, reduction in primary production). This has resulted in people migrating out of the area. All the villages have moved out of the zone, and have settled nearer to the road. The village of Bountou Dieugue, on the Niety Yone, is a typical example.

Rehabilitation is primarily in the form of re-inundation. A re-inundation would benefit:

- marine and continental fisheries,
- vegetation and tree growth for firewood and fodder,
- recession agriculture,
- biodiversity, including birdlife,
- tourism;
- hunting; and,
- halt desertification.

Furthermore, allowing water into the Ndiaël will help relieve the floods in Saint Louis. During the natural flood of the Senegal River, there is an excess of water. Normal flood prevention measures worldwide include diverting some of the flow to available lowlands, which is what this project aims to achieve. The cumulative economic effect of allowing pastoralists, fishermen, farmers, tourists and hunters back into the zone are considerable. A precise economic study of the benefits of rehabilitating the Ndiaël is not done in this study. Rather, a technical assessment of the water routes to get water back into the Ndiaël is made. In addition, the constraints on each of these routes are elaborated, as well as the stakeholders identified.

Réserve Spéciale de Faune du Ndiaël

The Réserve Spéciale de Faune (Special Wildlife Reserve) has been in existence since 1965. It was set up by parliamentary decree and is managed by the Département des Eaux et Forêts, Chasse et Conservation des Sols (DEFCCS) (Department of Water, Forestry, Hunting and Soil Conservation). The site is. 46,550 ha, and can be divided into two parts: north and south. The north is a natural depression, which is saline and practically devoid of vegetation. The drainage waters of Kassak and Grande Digue Tellel permanently inundate it. The south part has a more varied flora and is traversed by numerous small marigots. Geographically, it is the continuation of the Trois Marigots. In the field, the boundaries of the reserve are not clearly delineated. This lack of clarity has resulted in different map sources delineating the reserve inconsistently as illustrated in the map above.

The reserve is entirely within the Rural Community of Ross-Béthio. In 1977 it was registered as a Ramsar site (a wetland of international importance for migratory birds, per the Ramsar Convention). In 1987 it was included in the Montreux record of Ramsar sites, among the 29 most threatened wetland sites in the world.

Management Plan of the Ndiaël Special Wildlife Reserve – PADIN

The DEFCCS has a management plan for the reserve: the Plan d'Aménagement et de Développement Intégré du Ndiaël (PADIN) (Integrated Development and Management Plan for the Ndiaël). PADIN is a scientific management plan that includes environmental and socio-economic aspects. This plan was drawn up in association with Oiseaux Migrateurs du Paléarctique Occidental (OMPO) (Migratory Birds of the Western Palearctic). The delta of the Senegal River is an important refuge for European birds migrating south over the Sahara. OMPO therefore has an interest in preserving the Ndiaël.

As elsewhere in Senegal, if a wildlife reserve is situated on suitable agricultural land, local inhabitants typically ignore the reserve's boundaries and statutes and grow crops in it. This has happened on a limited scale in the northeast (at Bountou Dieugue), but encroachment into the reserve is likely to increase with re-inundation. In the past the DEFCCS has been instrumental in restricting access of agriculturists into the Ndiaël.

The global objective of PADIN / OMPO is to conserve the site for bird populations and

for traditional activities of the area (fishing, pastoralism, reforestation). Five operations are considered: (i) re-inundate via the Trois Marigots; (ii) study other options for re-inundation; (iii) plan traditional uses of the area; (iv) reforestation; and (v) improve knowledge of the site.

3. Northeastern Region / Niety Yone

The Niety Yone marigot is the principal inundation route to the Ndiaël. The marigot originates from the northern end of the Lac de Guiers; historically, during the annual floods, there was a direct water connection from this region to the Atlantic Ocean. The Lac de Guiers is the eastern edge of the Ndiaël biosphere.

The map below shows the main features of the region.

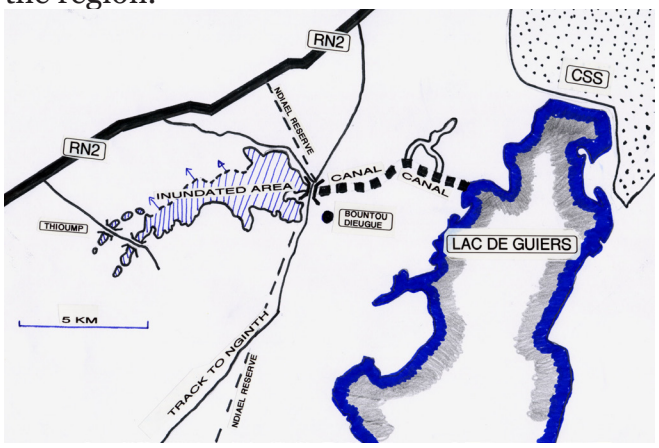

Fig. 1. Northern area of Ndiaël (boundary of Ndiaël shown as thin dotted line)

It lies to the south of the RN2, and is cut by numerous north-south tracks. The principal track runs along the Lac de Guiers to Ngnith. Around the northeast perimeter of the Lac de Guiers, industrial sugar cane production by the Compagnie Sucrière Sénégalaise (CSS) is the major regional activity. The Niety Yone canal, which is approximately 6 km long, brings water from the lake to the small village of Bountou Dieugue (population 50). This village, also known locally as Niety Yone, has high potential for sweet potato farming. Bountou Dieugue is at the eastern boundary of the Réserve Spéciale de Faune du Ndiaël (special wildlife reserve), created in 1965. The map shows the area west of Bountou Dieugue that has been newly re-inundated, the result of an initiative taken in April to dredge a canal. The quarry at Thioump, 12 km west, marks the extent in August of the water in the marigot. Continuing southwest from Thioump is the Ndiaël Cuvette.

The area north of the RN2 (not shown) is more densely populated due to extensive agricultural development and irrigation from the Senegal River.

History of the Niety Yone

Historically, the Niety Yone was the most important water route to the Ndiaël. Water was first cut off from the Niety Yone marigot in 1957 by the CSS. The CSS dammed it to maintain a sufficient water level in the lake to serve the needs of their sugar plantations and to settle in the newly dried up area. The drop down from the Lac de Guiers to the Niety Yone is. 3.5 m. The CSS dam contributed significantly to the drying up of the Ndiaël. In addition, villagers downstream became deprived of water and felt more immediate effects. In spite of continued protests by the villagers, the CSS did not respond. Over time the area declined with the emigration to nearby towns and villages. After continued protests and demonstrations by the few remaining villagers, in 1983 (almost 25 years later) under presidential decree, the CSS created a narrow canal connecting the lake to the relic bed of the Niety Yone ("canal" on map). This canal allowed water as far as the village of Bountou Dieugue. However, the canal was relatively narrow and water flow to the village was restricted, providing just enough to survive. Rapid colonisation by *Typha* in the canal further decreased the water supply to the area.

In the past, fishermen from the area of Niety Yone would sell their catch as far as Dakar. During the period when the canal was dry, fisheries practically disappeared. Now, with the return of water, fisheries are on the

increase in the area.

SAED Re-flooding Initiative

In April 2001 the Société d'Aménagement et d'Exploitation des Terres du Delta (SAED) dredged a 1.3 km length of the Niety Yone canal at a cost of CFA 28,000,000 ($40,000 or $31,000 / km). At the same time, at Bountou Dieugue, a passage for the Niety Yone marigot was built. This resulted in allowing water to flow beyond Bountou Dieugue towards the Ndiaël.

The objective of the SAED is to support the needs of the local population for agriculture. More recently the SAED also claims to support fishing, forestry, hunting, pastoralism and tourism. The SAED requires villagers to be organised into "user committees" responsible for the maintenance of infrastructure (canals / embankments). In response the village of Bountou Dieugue formed the Comité des Usagers du Chenal du Yetti Yone (CUCY) (the Niety Yone Canal User Committee). The aim of this organisation is to manage and exploit the Niety Yone. The villagers have expressed their desire to dam the marigot to maintain a high water level year-round. This could be problematic for rehabilitating the Niety Yone, will undoubtedly result in weed infestation and needs to be addressed.

This zone produces the highest quality of sweet potato of the Lac de Guiers. For this reason, the SAED chose this sector as a test zone for its diversification policy.

The initiative was viewed as experimental by the SAED, with a "wait and see" attitude as to how far the water would go during the floods. It was affirmed by the SAED that future discussions were needed with the Ministry of Hydraulics. No apparent coordination with the Eaux et Forêts is contemplated even though the location of the re-flooding initiative is within the area of the Special Reserve of the Ndiaël, which is managed by the Eaux et Forêts.

Field Observations

The Canal

The canal from the Lac de Guiers to the village is approximately 6 km long and about 4 to 5 metres wide. The SAED dredged and cleared 1.3 km (about 1/5 the canal) starting at the perimeter of the lake.

The Passage at Bountou Dieugue

At Bountou Dieugue a passage was built to allow the water to pass, under the track to Ngnith, to the Niety Yone marigot. It is approximately 1.5 metres wide and spans the length of the road (5 m). In August the opening shown was completely submerged under water, indicating that the water level had risen almost 1 m. This water is inadequate to let all the water from the Lac de Guiers to pass.

Flooding in the Niety Yone Marigot – May

In May, the extent of the flooded area was approximately 3.2 km^2). In some areas water levels were over 1 m deep. Newly watered areas, i.e. those under water for only a few days, were poor in fish (confirmed by experimental catches and by local fishermen). Areas under water for weeks seemed abundant with fish that originated from the Lac de Guiers. Fishing activity was evident with nets strung across newly created bays and lines with multiple hooks left out (catfish bite on unbaited hooks). One fisherman caught 30 catfish (commonly up to 50 cm in length) for the Dakar market, and was drying them in the sun. His price is CFA 1,500 per kg ($2 per kg) in Dakar.

Mosquito larvae were observed in the water here but never noticed before at any other site. It is speculated that they may provide a food source for the fish. Areas that had been under water for close to a month, however, had an abundance of fish, and no visible mosquito larvae. Dense flocks of ducks and other birds flying overhead were attributed to the re-flooding. There were geese, ducks, egrets, herons and plovers.

Niety Yone Marigot – August

By August the extent of the flood was. 2.5 times greater than in May (8 km^2 or 800 ha); the water originated from the Lac de Guiers

but was also supplemented by rainwater. The extent of the flooded area was plotted with GPS and had reached a point 12 km west of Bountou Dieugue (near Thioump). The estimated flood volume is. 3.25 million m^3 (average depth 40 cm).

Much of the soil in the area is clay, and does not allow water to permeate rapidly. At Thioump, the northern arm of the Niety Yone marigot is called the Lamougl. The Lamougl is a series of pools separated by marshland. If the water continues to rise, the pools will merge into a continuous marigot – this process typifies the progression of floodwaters in clay areas. Both the Lamougl and the Niety Yone are obstructed with sand in places.

Also at Thioump, a north-south road crosses over the inundation route. A few narrow plastic water pipes (about 20 cm diameter), partially blocked with sand, placed under the road are used to provide a channel for the water. The scarcity of such access channels prevents the water from advancing towards the Ndiaël. In order to increase the progress of the water existing access routes must be repaired and additional pipes installed.

In theory, during the flood, the Lac de Guiers overflows, and this water should flow to the Ndiaël. When the level in the Lac de Guiers falls, the waterway dries up. This would be a good time to do maintenance work on it.

Obstacle to Road Communication

Various north-south dirt tracks have been cut by water. This is one of the negative impacts of reflooding, confirmed by Mietton and Humbert (1991).

Fisheries

In August, fisheries in the re-flooded areas were abundant. Mature fish originated in the Lac de Guiers, and utilised the floodplain as feeding and reproduction grounds. Newly hatched fish used the floodplain as nursery grounds. The fishing methods were consistent with those observed in May. Setting nets across the entire marigot is illegal though frequently attempted by poachers. Fishermen in the reflooded area call on the Eaux et Forêts to remove nets that obstruct the entire waterway. Species caught are catfish, tilapia and *Polypterus*. Fish productivity is directly proportional to area under inundation, with productivity of 80 – 150 kg per hectare per year. To date, this would represent 13,000 – 40,000 kg of fish, or $26,000 – $80,000.

Wildlife

Wildlife in the area includes jackals, warthogs and Patas monkeys. In addition, a rich variety of waterbirds utilise the newly flooded area, including geese, ducks, egrets, herons and plovers. Non-aquatic birdlife is also plentiful and varied.

Hunting

Hunting is prohibited in the Special Reserve. The surrounding land has been broken down into hunting zones. Around Bountou Dieugue the zone is called the Zone de Chasse Amodiée de Niety Yone. The Président du Conseil Rural (PCR) grants licenses, renewable every five years. The decision to grant licences is made by the Eaux et Forêts in Dakar. The village of Bountou Dieugue does not receive any direct revenue from hunting and tourism, and the villagers consider the current situation inequitable.

Licence holders have contributed minimally to the development of the area. They have given small gifts (e.g. oil lamps) and promised clinics and schools, but few of these promises have been realised. To gather more widespread support for rehabilitation initiatives from local populations, a more equitable system of revenue distribution should be investigated, e.g. a "per vehicle per day" toll charged by villagers to the tourists, or a percentage of hunting licenses fees. In support of developing hunting and tourism, local infrastructure could be developed e.g. a shop or rest house for tourists in Bountou Dieugue.

Agriculture in the Niety Yone

SAED and Bountou Dieugue

The SAED is continually looking for new agricultural areas to develop; it has historically focused on the region north of the RN2.

Expansion south of the RN2 is seen as a significant move. The SAED dredged the canal of the Niety Yone in co-operation with the farmers of Bountou Dieugue to promote agriculture; neither the SAED nor the farmers showed particular interest in re-watering the Ndiaël. Farmers in Bountou Dieugue successfully grow sweet potatoes.

Compagnie Sucrière Sénégalaise (CSS)

The CSS is a private company founded in 1970 that leases. 12,500 ha from the Senegalese State, 8,500 ha of which are is used to grow sugar cane. It has a 99-year lease from the Senegalese state for CFA 200,000,000 ($285,000) per year. Part of the arrangement with the Senegalese government was to operate ten years tax-free. The CSS has. 6,500 employees (4,000 full-time, and 2,500 part-time) and runs a fully integrated operation from growing cane to manufacturing sugar (cubes and granulated). Sugar deliveries are free to anywhere in Senegal. It also provides free irrigation (3000 ha) to local villagers.

The CSS uses water from the river, which is either pumped or gravity-fed. Annually their production averages. 87,000 t of sugar (from 870,000 t of cane). In 2000 they produced 90,500 t of sugar, their highest ever. The Senegalese market is. 130,000 t; the shortfall of 40,000 – 50,000 t per year is imported.

Drainage and Discharge

There is a long history of controversy because of the environmental impacts of the CSS. They affirm that they discharge only 5% of their untreated wastewater into the Lac de Guiers or the river. The rest (95%) is treated and recycled in irrigation basins. Field observations found pump stations discharging large amounts of water into the lake and into the river, e.g. near the village of Bountou Baat on the Lac de Guiers and into the river at Mbagam (east of Richard Toll). A drainage canal filled with black mud probably contained waste from a factory.

The villagers of Bountou Dieugue claim that there is no pre-treatment of this wastewater and that it is a health hazard to people and livestock in the area (some fatalities are recorded in livestock). The wastewater from the CSS runs south along the shore of the lake, while the (less polluted) water from the river stays in the centre of the lake. For this reason, the water intake at Ngnith is in the centre of the lake. However, the villagers do not have access to this unpolluted, "central" water. Full investigation into the causes of disease of the people and livestock and the situation of toxic wastewater in the environment is needed. The Société pour la Gestion et la Planification des Ressources en Eau (SGPRE) (Organisation for Water Resource Planning and Management), part of the Ministry of Hydraulics, did a comprehensive review of the Lac de Guiers, and concluded that the CSS wastewater was highly polluted. A full report from the SGPRE was not available.

Pattern of Settlement

The population around the Niety Yone marigot is estimated at 500 inhabitants based on the number of elders in the region (30). Keur Momar Sarr is the most important city located at the southern portion of the lake with a population of 15,000.

The original course of the Niety Yone is the divider of the communes of Ross-Béthio and Rosso. However, the course of the waterway has been altered (straightened) and the current waterway is not exactly the divider any more. This is the cause of minor disputes.

In the centre of the Ndiaël, there are no inhabitants. All the villages have moved out of the centre towards the road: there are four inhabited villages (20 huts each) and two abandoned villages on the RN2 at the margin of the Ndiaël.

The initiative to re-flood the area in the Niety Yone marigot has brought a small migration back to the area. People have bought farms (up to 300 ha) along the projected route of the Niety Yone marigot. This is a typical pattern in this arid region: as soon as there is talk of re-inundation (as in the case of the

Vallées Fossiles), speculators purchase land adjacent to the potentially flooded area. If not carefully managed, local inhabitants, with ancestral rights to the land, can be the last to know what was decided at high level in Dakar or Saint Louis, and find themselves cheated of their land. Other immigrants are fishermen who are taking advantage of the re-inundation, and have set up temporary camps in the zone. This is one desired effect of re-inundation, although if badly managed, could lead to conflict over resource use.

Additional Points to be Addressed

Certain companies (e.g. road contractors) quarry for laterite and shells in the Thioump quarry, but pay no fee to the Rural Committee. Although small, the rural community does not benefit from its natural resources. A system of levies could be imposed on contractors using the resource.

The CSS supposedly discharges drainage water into the Lac de Guiers without treatment (this is denied by the CSS). This potentially causes disease in human beings and animals. The majority of the CSS lands are within the Rosso sector, although the Rural Community sees no revenue from this. In addition, the CSS took over natural marigots and made them into drainage canals without compensation. The legal right of local populations must be explored in cases like these, and steps taken to prevent future occurrences. Options for compensation must be studied. Lastly, an influx of people into the area may result from a re-inundation, which will be difficult to manage. A framework for settlement in the area should be set up prior to massive re-inundation.

4. Marine Connectivity

Importance of Coastal Zones for Fisheries

Significant scientific research supports the importance of coastal zones and estuaries for fisheries. Coastal zones are highly productive areas for fisheries. Inshore waters (above the continental shelf) account for 90% of world fish catches:

90% of global marine fish production is caught over the continental shelf. These fishing grounds are often associated with shallow waters where highly productive coastal ecosystems such as coastal lagoons, mangrove estuaries, seagrass meadows and coral reefs play an important role in the support systems provided by the fisheries (e.g. feeding, breeding, and nursery habitat).

The coastal zone does not have absolute boundaries and may include, depending on analytic requirements, upland watersheds, wetlands, estuaries, mangroves, shallow water embayments, coastal lagoons, beaches, seagrass meadows, coral reefs, and extend several hundred kilometres seaward.

Furthermore, estuaries are extremely productive by virtue of the nutrients that flow into them. They also offer calm areas, which are utilised as reproduction and nursery grounds. By contrast, the open sea (beyond the continental shelf), is practically devoid of life: low in nutrients, subject to rapid currents, unable to provide shelter and too deep to benefit from light penetration, it represents a "desert" in biological terms.

Estimates show that 98% of all fish caught in the Gulf of Mexico are estuarine dependent. The coral reef fishery of Northwest Sabah (Indonesia), with an annual estimated value of $ 1.25 million, accounts for approximately 30 percent of the total landings. Fisheries of the fringing coral reef and lagoon coastline bordering much of Tanzania, Kenya and Somalia are estimated to range from 5 to 17 times that of offshore Somalian waters of equivalent area.

The Senegal River Delta

The descriptions above of the coastal zone accurately describe the Senegal River Delta: it is a river that enters the sea via a vast floodplain, traversing areas of shallow water estuary, coastal lagoons, salt marsh, freshwater

marsh and mangroves. The region of Saint Louis is a busy fishing area, with the principal seaport on the Langue de Barbarie. Thousands of fishing pirogues operate out of this port. It is likely that most of the fisheries in this region are dependent on the estuary of the Senegal River for reproduction.

With the construction of dams and embankments on the Senegal River (starting in 1866 with Dakar-Bango), the area of estuary available to marine species in the Senegal River has been severely reduced. If the Ndiaël were reflooded via the river without a marine connection, only continental fisheries would benefit. An open connection between the sea and the Ndiaël would greatly benefit Senegalese marine fisheries, as it would increase the area of the estuary available.

Existing Connection

The Ndiaël is connected to the marine environment via Ndiaoudoune and Dakar Bango. These two dams constitute the water reservoir for Saint Louis and are managed by the Ministry of Hydraulics. The sole concern of the Ministry of Hydraulics is supplying water for Saint Louis. In theory opening these dams provides the most effective route for connecting the coast to the Ndiaël via the Ngalam and the Trois Marigots. However this is not a practical option. In order to use this water source freely, an alternative water supply for Saint Louis must be provided. This implies the construction of an expensive pipeline ($1 – $5 million) from Diama to Dakar-Bango (see section on Trois Marigots).

Alternative Marine Connection

Alternative marine connections were explored by surveying the coast from Saint Louis south to Moumbaye located approximately 7 km south of Gandiol. Water routes that could connect the coastal water to the Ngalam, Trois Marigots (and then on to the Ndiaël) were explored.

Flora

The vegetation at the summit of the dunes southeast of Ngalam is a forest of winterthorn trees (*Faidherbia albida*). The winterthorn loses its leaves in the rainy season, and is an important nitrogen fixer. The villagers indicate that gonakiers (*Acacia nilotica*) are found lower in the valley, where there is water. However, few gonakiers were observed. Around Bégaye at the summit of the dunes, the vegetation is mostly *Euphorbia balsamifera* (giant milkweed). Giant milkweed is of very little value to cattle. In the depressions, the vegetation is a mix of *Tamarix*, *Zygophylum*, and grasses. *Tamarix* and *Zygophylum* are low quality fodder plants that are eaten by camels when there is little else.

The forestry department of the Eaux et Forêts work together with rural communities to protect existing forests and plant new ones. The president of the rural communities (PCR) has to authorise tree cutting. The Eaux et Forêts sponsored a project (Progona) to plant gonakier (*Acacia nilotica*) and is introducing private forestry.

There is little *Typha* in the region, presumably because of salt, water level fluctuation or because the cattle eat the young shoots.

Conflict between Conservation and Development

The role of the Eaux et Forêts is long-term sustainable management to protect vegetation, fisheries, wildlife and to conserve soils. Individuals, however, are seen as seeking immediate returns. This was stated as a potential source of conflict. The rehabilitation of the Ndiaël, entrusted to the Eaux et Forêts, is not in contradiction to development, although it does prevent people from settling in the special reserve. Rehabilitation will also help develop micro-industries such as fishing, agriculture, pastoralism and tourism.

In the past the Eaux et Forêts was sometimes seen as repressive, although lately the Eaux et Forêts stressed a new positive participatory approach with the population while still being within the rule of law: “one step forward with the population is better than 100 steps forward without the population”.

5. Northern Region

The northern region is characterised by agricultural development and flat expanses of land, aqueducts, pumps, drainage canals and rice fields. North of the RN2 environmental considerations and the rehabilitation of wetlands are not priority issues. The area is relatively densely populated (e.g. Ross-Béthio: 3,000, Kassak: 1,700). Most of the agricultural development in the area is under the Société d'Aménagement et d'Exploitation des Terres du Delta (SAED), which is under the Ministry of Agriculture. Land south of the RN2 is seen speculatively for potential development, or considered "desert", consequently wastewater is allowed to drain into it.

In Ross-Béthio the local inhabitants refer to the Ndiaël as a "waterway without water". Because of the Ndiaël's deteriorated state, the population has moved out of the centre towards the road. The border of the Réserve Spéciale de Faune du Ndiaël is two kilometres north of Ross-Béthio along the RN2. Within the *Réserve* human habitation is only allowed within 1 km of the road. The Communauté Rurale of Ross-Béthio could benefit from a rehabilitation of the Ndiaël. The local population recognises this and is in favour of such an initiative.

The SAED utilises natural marigots as drains for its fields. The Tellel is a natural marigot that was appropriated by the SAED. It was transformed into a permanent drain, draining wastewater from the agricultural regions of Grande Digue Tellel and Kassak. The SAED refer to it as the "Drain du Ndiaël". The drainage water that enters the Drain du Ndiaël comes from hundreds of hectares of irrigated fields. The drain originates in the village of Kassak Nord, goes south underneath the Kassak marigot (through a siphon), then southwest for approximately 12 km through an area without fields or habitations. Closer to the RN2, it enters an agricultural zone, crosses the RN2, and continues south into the Ndiaël. In the Ndiaël, the water spreads out and inundates and area of approximately 3 km^2.

Water quality at the source of the Drain du Ndiaël (Kassak Nord) is very poor, the water is stagnant, dark, opaque and smells of nitrogen sulphide. There is a layer of oil on the water and the channel is choked with *Typha*. It is the worst water quality in the entire delta: 5-mg/l nitrate and 2-mg/l phosphate, 0.13 mg/l dissolved oxygen and 2.5‰ salinity. In this village the challenges facing the people as a consequence of poor water quality are bilharzia, gastro-enteritis, skin diseases, etc.

Typha as well as water lilies (*Nymphea lotus*) grow throughout the Drain du Ndiaël. Water quality improves with distance from its source. Oxygen increases progressively to 2.24 mg/l, salinity drops off to 0.3‰ and nitrates and phosphate drop to zero. *Typha* and water lilies presumably absorb the nitrates and phosphates as the water progresses down the canal. Throughout its length waterbirds utilise the canal. Aquatic species netted include shrimp and catfish. Jackals are seen south of the RN2.

The Tellel / Drain du Ndiaël could continue to be used in its current state. The advantages of using it in its current state are that it would require no work and no expense, and that water quality, by the time it reaches the Ndiaël, is adequate. The disadvantages are that the SAED has complete control of the water source. Furthermore, certain water quality parameters were not measured and could be of very low quality (pesticides, herbicides).

Given that the Tellel / Drain du Ndiaël passes directly underneath the Kassak, a short link (5 m) could be used to connect the two. This could dilute the wastewater in the Drain du Ndiaël and increase both quality and quantity of water.

Alternatively, if the "Emissaire Delta Branche A" (another drain) were constructed, this would free the Tellel from its role of draining wastewater altogether. It could then be connected to the Kassak marigot to transport unpolluted river water to the Ndiaël.

Other waterways to the North of the Ndiaël include the Lampsar to Bombol via Canal C3,

which utilises clean irrigation water (not drainage water). It would require the excavation of a 100-m channel to connect the Lampsar to the C3, and another 100-m channel to connect the C3 to the Bombol. Part of the Canal C3 follows the old bed of the Bombol marigot.

Alternatively, separate canals could be created to inundate the Ndiaël, however at high cost, for example from the Senegal River directly to the C3 and Bombol. This is expensive, but would ensure sufficient flows as well as autonomy to manage the canal.

6. Analysis of the Water Routes

There are three main regions from which the Ndiaël can be re-inundated: northeast (Niety Yone), southwest (coastal zone and Trois Marigots) and north. The Ndiaël is currently being inundated from all three directions to varying degrees but not at 100% potential capacity. There are a total of ten water routes that can be considered including those currently allowing water into the Ndiaël. Others are either semi-active or have potential but are currently not used.

Northeast

The Niety Yone is historically the most important water route into the Ndiaël. The focus is on the passage of water from the Lac de Guiers to Bountou Dieugue. Downstream of Bountou Dieugue, the options become one. There are three sub-options:

1. The active Canal of the Niety Yone, created by the CSS in 1983 and dredged by the SAED in 2001 (maintaining the status quo)

Advantages: it is an existing structure that can be dredged further to increase its current capacity; relatively low cost solution.

Disadvantages: the capacity is limited; do not have full control of waterway; need full co-operation of SAED and villages; connection at Bountou Dieugue needs to be widened and reinforced

2. Using the old Niety Yone Marigot

Advantages: the capacity of this section of the marigot is much greater then the existing CSS canal; restoration of an original waterway.

Disadvantages: the Korean Wall that separates the CSS wastewater needs to be reinforced; need co-operation of CSS to remove the original dam; need co-operation of SAED and villagers; connection at Bountou Dieugue needs to be widened and reinforced.

3. From the Lac de Guiers using large underground PVC pipes

Advantages: full control of water; low maintenance; no obstruction to roads; can be operated in addition to existing canal.

Disadvantages: Higher initial up front cost; much disruption during construction; potential for limited flow.

Southwest – Marine Connection – Trois Marigots

The Trois Marigots are important as they provide the potential for marine connectivity. The OMPO canals are an added advantage. The southwest has two sub-options:

4. Existing water route through Dakar-Bango and Ndiaoudoune

Advantages: establishes a marine connection; alleviates flood pressure on Saint Louis; utilises existing infrastructure; large capacity of water; existing flood route that is not fully maximised (additional flow could be realised without the need for a pipeline).

Disadvantages: need approval of the Ministry of Hydraulics; high cost to build a pipeline from Diama as an alternative water source for Saint Louis.

5. Through N'Del to the Canal du Gandiolé.

Advantages: connect the Ndiaël directly to the marine environment; lower cost alternative to the pipeline.

Disadvantages: many obstacles to the water route (blocked pipes, inadequate passages under roads, high tunnel thresholds); potential conflict with the proposed Canal du Gandiolé; planned dam at Al Bar.

North

The construction of the RN2 caused this in-

undation route to be severed. In addition the development of agriculture north of the RN2 has contributed to disrupting the natural water routes. There are five sub-options to inundate from the north:

6. The active Drain du Ndiaël wastewater from the agricultural perimeters of Grande Digue Tellel and Kassak (i.e. maintain status quo)

Advantages: uses existing channel; regular flow; recently dredged by SAED; can continue to be used; brunt of excavation costs borne by SAED

Disadvantages: low or unknown water quality; limited flow; no control over the flow.

7. Using the Canal C3 by connecting it to the Lampsar and to the Bombol.

Advantages: Lampsar is unpolluted; low cost to connect to the water source (200m only needs to be dredged); C3 canal currently operational with capacity for more water

Disadvantages: limited flow; no control over the flow, need authorisation from SAED to use the C3 canal.

8. Diluting wastewater from the Drain du Ndiaël with unpolluted water from the Kassak Marigot.

Advantages: increase the flow in an existing canal; improve water quality; low connection costs (5 metres need to be excavated).

Disadvantages: need authorisation from SAED to use the Kassak marigot.

9. Redirecting drainage water to "Emissaire A" and using unpolluted water from the Kassak marigot in the Drain du Ndiaël

Advantages: improved water quality; use of existing infrastructure

Disadvantages: need to wait for SAED to build Emissaire "A"; need authorisation from SAED to use the Kassak marigot.

10. Creating a canal from the river (Deby-Tiguet) directly to the Bombol

Advantages: virtually unlimited water supply; control over flow; helping decrease chance of flood in Saint Louis.

Disadvantages: high cost to build; need OMVS approval; disruption during construction.

Ranking of Water Routes

A quantitative analysis was attempted to rank each of the water routes. Nine factors were taken into consideration and were ranked from 1 – 10 (0 = worst, 10 = best). The most

Option	Northeast			North					Southwest	
	1 CSS Canal	2 N Yone Marigot	3 PVC pipes	4 Drain du Ndiaël	5 Canal C3	6 dilute from Kassak	7 from Kassak only	8 from River	9 Dakar Bango	10 N'Del
Factor										
Directness	10	10	10	10	9	9	9	0	8	8
Cost*	10	5	0	10	3	9	5	0	0	5
Control over waterway	0	1	10	0	0	5	5	10	0	9
Water Volume*	5	10	3	3	5	5	5	10	10	7
Time to operation	10	2	0	10	2	5	4	0	2	8
Maintenance cost	5	5	9	5	5	6	5	2	5	5
Water quality	9	9	9	5	10	7	9	10	10	10
Biodiversity*	5	7	3	0	3	5	2	5	10	10
Contribution to marine fisheries	1	1	1	1	1	1	1	1	8	10
Weight Adjusted Total	75	72	51	57	49	71	57	53	73	94

important factors have been indicated with and asterisk and were weighted by a factor of 2. A high score therefore represents a better option.

The analysis yielded the following four routes, with their required actions:

1. N'Del – remove the failed dam under the Al Bar bridge, install additional passes at Rao Peul, lower the thresholds of the two tunnels under the RN2 for the Gandiolé Canal, level the sand obstructions in the Gandiolé.

2. CSS Canal – continue the dredging of the existing canal, expand the capacity of the passage Bountou Dieugue or create additional ones, clear all the blocked pipes at Thioump and install additional pipes, level the sand obstructions in the Niety Yone.

3. Dakar Bango – lobby the Ministry of Hydraulics for as much water release as possible for the longest period. Investigate the possibility to settle the sediment faster at Dakar Bango. Investigate the costs of building a new water pipeline from Diama to Dakar-Bango.

4. Dilute the Drain du Ndiaël from Kassak – negotiate with the SAED to optimise use of this existing infrastructure; hire engineer to design and build short connection.

It also points to exploring the use of the Old Niety Yone marigot instead of the CSS canal. It is recommended to use a two step approach for any proposed re-inundation.

Recommendations

The first step is to optimise existing routes with a modest capital expenditure for an enhanced inundation, specifically for the four routes identified. During this "enhanced inundation" period it is important to establish monitoring programs to track water levels, inundation routes, fisheries, settlement, reactions of interested parties and any political ramifications. The value of a socio-economic study and awareness campaign cannot be stressed enough, as one of the biggest threats to the re-inundation is the uncontrolled influx of people. The use of remote sensing (satellite photos) is recommended to track the progress of the enhanced inundation. The SAED is the biggest player and a plan is needed as to how to approach it. It controls much of the infrastructure and is very powerful in the delta. Alliances need to be formed with groups who have similar interests (Eaux et Forêts, OMPO, IUCN, DPN, Wetlands International) so as not to duplicate efforts and maximise available investment dollars as well as human capital.

Additional practical issues that will provide significant benefit at little cost are: (i) on the ground re-stake out the Réserve de Faune du Ndiaël, with visible markers and signs; (ii) put road signs especially in the Gandiolé; and (iii) mandate that future road construction in the area should provide for adequate water passage.

The second step involves a full re-inundation effort. Much preparation is required for this. The results of the first step will provide some guidance but a full socio-economic analysis needs to be done. The co-operation of many parties will be required in particular: the Ministry of the Environment, Ministry of Hydraulics, SAED and OMVS.

7. Water Quality Results

The water quality results obtained in the two field missions can be used as a baseline to measure any future improvements in water quality when the project is under way.

Dissolved Oxygen (DO)

DO is a basic indicator of water quality, and is an important factor in determining habitability by fish and other biota (measured in mg/l (milligrams per litre) or % saturation). Water in contact with air is at 100 % saturation. DO can rise above 100 % if the water is aerated.

In waters polluted with organic waste e.g. sewage or fertiliser, microbes decompose the organic molecules, and use up oxygen in the process. Low oxygen can therefore be an indication of organic pollution. The results of the dissolved oxygen in this study range from 0.13 mg/l to 9.80 mg/l, with an average of 4.43

Dissolved Oxygen	Consequences
> 5.0 mg / l	Meets NYS Standard for dissolved oxygen – few adverse effects on marine life
4.0 mg / l	Reduce survival of crab and lobster larvae by 30 %
3.0 mg / l	Hypoxia – affect the growth of crabs and lobster. Fish avoid the area.
2.5 mg / l	Growth reduced in grass shrimp, summer flounder and lobster.
2.0 mg / l	Sharply reduced growth. Lowest safe dissolved oxygen level for many juvenile organisms.
1.5 mg / l	Very high lethal effects on shrimp, fish and lobster.
0.0 mg / l	Anoxia – Intolerable environment for nearly all marine organisms.

mg/l. From the table below, it can be seen that levels below 3 mg/l have a negative effect on aquatic life. Most values in the delta were around 7 mg/l, which indicates high water quality. The few low figures indicate areas for further study, as they could indicate eutrophication or other forms of disturbance. Consequences of low dissolved oxygen are tabulated below:

Temperature

Temperature is a basic determinant and limiting factor for many aquatic species (measured in °C). It determines primary productivity and metabolic rate of plants and cold-blooded organisms, and therefore controls growth. It also affects levels of dissolved oxygen in water. The temperature range in the study area is from 21.2°C to 33.9°C, with an average of 28.5°C, which is expected given the tropical environment and the shallow water. There is little variation in temperature readings throughout the region. The highest temperatures (33.9 °C) were recorded in shallow pools of evaporating water in the Niety Yone, and the lowest temperature (21.2 °C) was recorded was at the tip of the Langue de Barbarie, where the river meets the sea.

Conductivity

Conductivity is a measure of all dissolved ions together e.g. sodium, potassium, iron, calcium, etc. It gives an indication of the total load of ions in the water. Marine waters have much higher conductivity than fresh waters because of the natural salt load (sodium ions). Conductivity also gives an indication of pollution (high conductivity indicates pollution). It is measured in µS/cm (micro Siemens per centimetre).

Conductivity varies greatly between fresh water and seawater. It is best to separate the two results in the delta:

Fresh water: range: 0.0 – 5,260 µS/cm, average: 888 µS/cm.

Conductivity follows salinity to a large extent in all our results. Salinity (not only sodium, but other salts as well e.g. potassium and calcium) is a problem in the delta for agriculture. Certain freshwater sites e.g. Djeuss, Bas-Ferlo, Ngalam, Ndiaoudoune-downstream and Bombol (up to 5,000 µS/cm), have a much higher conductivity than average, which indicates high ion load, and perhaps pollution. This remains to be determined with further tests, specific to metals, pesticides etc.

Salt water: range: 32,450 – 71,400 µS/cm, average: 41,774 µS/cm.

Sodium accounts for most of the conductivity. There is little variation in these figures in May, but in August, with the advancing flood, and precipitation, some waters are slightly diluted, while others are supersaline and therefore have extreme conductivity (e.g. Gandiolé). By September freshwater has reached all saline sites.

Salinity

Salinity refers to sodium chloride ions only. It is a basic biological factor that determines what species can survive in an aquatic environment (measured in parts per thousand, ppt or ‰). Seawater is typically at 35 ppt. It is important for both plants and animals. Low

salinity is lethal for fully marine species, and likewise high salinity is lethal for freshwater species. Certain species can inhabit either environment. Furthermore, the ubiquitous freshwater reed *Typha australis* proliferates in freshwater habitats, but is absent when even low salinity is found (as low as. $^{1}/_{-}$ $^{1}/$ that of seawater). Given that the delta is a vast zone of saline and freshwater interaction, this is a very important parameter to study. Again, salinity varies greatly between fresh and seawater. It is best to separate the two results:

Fresh water: the range is from 0 to 2.8 ‰ with an average of.0.7 ‰. These values are altogether low, even in the Ferlo, which is said to be saline (average of 0.4 ‰).

Salt water: the range is from 28.9 to 43 ‰ with an average of 26.8 ‰.

The variations in salinity reflect fresh water input into sea water (releases from the dams). As expected, in the Langue de Barbarie, salinity increases as one approaches the open sea (from Saint Louis: 30.8 ‰ to 34.6 ‰) in May.

In August, salinity in the entire delta is very low (2‰ or less), except for the Leybar, which is around 20‰, and in the N'Del, which is supersaline (43‰). Supersalinity is achieved when saline water is subject to massive evaporation without inflow of fresh water. Surprisingly, certain tilapia were found in the supersaline water.

Biota (overall)

In addition to physico-chemical parameters, it is important to get an idea of the presence and abundance of living species for two reasons: their economic importance and the fact that they are indicators of water quality e.g. the catfish and tilapia are known to be extremely rustic, surviving in the harshest environment. An abundance of these species and little else indicates a stressed environment. The greater the number of species (= biodiversity), the less stressed an environment. Furthermore, biodiversity can serve as a baseline against which to measure future water quality. Lastly, physico-chemical readings alone can be deceptive: for example certain species will disappear even if DO drops for a short period. If DO then comes back to normal, the water quality could be assumed to be normal. However, species that are sensitive to low oxygen will be missing.

Sampling was done with a beach seine. The beach seine requires a beach to be effective (to prevent fish from escaping). In ideal conditions (such as a landing beach) it is very effective, even over a small area (10 m^2).

The most common fish species caught was tilapia, followed by catfish. The total number of aquatic species caught (including shellfish and molluscs) was. 42. The most common was a small white bivalve (*Caelatura lacoini*) and tilapia (*Oreochromis niloticus niloticus*) (over 1000 each in a single haul), followed by shrimp (270 total). The marine environment was more diverse than the freshwater environment (Dakar-Bango and Diama). Areas isolated from the rest of the aquatic network (Trois Marigots) were least diverse. Abdoulaye Djiba, aquaculture and marine mammal expert, and professor at IFAN and UCAD identified species.

Observations

Taken in the field by all members of the team, and supported by photographs, these included weather, vegetation, depth, turbidity, wildlife, birdlife, desertification, and human activity e.g. agriculture, fishing, settlement and grazing.

Without doubt the most common observation is of the over-abundant and invasive bulrush, *Typha australis*. The ground in some areas was covered by a carpet of *Typha* spores, making it white, giving an idea of the abundance of this reed. At times the spores floated through the air, making it uncomfortable to breathe. Other aquatic weeds were less widespread. Mamadou Sylla (Eaux et Forêts) says that there are 30,000 ha in the delta infested with a mix of *Typha* / *Salvinia*. It has already invaded the Lac de Guiers. Under the *Salvinia*, only "yess" (Claridae) and "wass" (*Tilapia*)

exist (both are very rustic fish).

The second most common observation is the presence of birds, most of them water birds. These included pelicans, plovers, ducks, herons and cormorants.

Wherever there was human habitation near water, there would be (usually young) people fishing. It was common to see gill nets drawn across the water – these are left in the water permanently, and the owners pick their catch off them regularly. Also near habitations it was common to observe children swimming, either unaware or unconcerned about the aquatic parasite bilharzia. Lastly, canoes were present wherever a village was near water. Whether or not near water, herds of cattle were present, herded by a minder.

In most aquatic environments visited, monitor lizards were seen. Other wildlife seen in the area included warthogs, monkeys and jackals.

Vegetation was varied: some regions had no vegetation. Others, e.g. the Trois Marigots had a mix of grasses, shrubs, trees and reeds. There are tree stands in the Ndiaël, although at the centre (in the cuvette), there are only grasses.

Other Regional Features

Features that are important in the region but do not have a bearing directly on rehabilitating the Ndiaël are described here.

Diawling National Park

The Diawling National Park is a precursor to the Ndiaël project. It has the same aims, is based on the same principles of re-inundation and is in the same river system. It has had significant success. Lessons learnt in the management of the Diawling can serve in the Ndiaël. Because of the importance and success of the Diawling, a report by Hamerlynck et al on the Diawling in included as Appendix 6.

The OMVS at first reluctantly allowed river water to flood the Diawling. It took the management team in the Diawling extensive effort to convince the OMVS that floodwaters could, instead of causing floods in Saint Louis, be diverted into natural depressions like the Diawling. Now the OMVS readily allows water into the Diawling during the flood. The Ndiaël project must use the same rationale to obtain water from the OMVS.

The embankment along the right bank of the Senegal River from Rosso to Diama (Rive Droite) was completed in 1988. There are eight floodgates along the Rive Droite. The Diawling National Park is situated directly along the embankment, and covers. 16,000 ha. Initially two inundations per year were planned, to accommodate waterbirds. However, *Typha* infestations soon developed, and the park management decided to inundate only once per year (July-March). This decision therefore sacrifices bird numbers in favour of overall ecosystem health.

There are two migrations of birds that use the waters of the Diawling: the Palearctic and the Afro-Tropical. The Afro-Tropical include the white-faced tree duck (which appear in the hundreds of thousands in January-March) and the spur-winged goose (which appear by the hundreds). However, as a result of the decision to let the lake dry up in winter, some Afro-Tropical species have had to migrate elsewhere.

In early August the water in the south of the park is clear, but nearer the sluice gates it is loaded with sediment (indicating floodwater). Two sluice gates are open (Cheyal and Lemer) and letting water in by gravity. None of the floodgates in the Rive Droite are equipped with pumps. At Cheyal an opening of 20 cm allows. $20 m^3/s$ through, an opening of 1.0 m allows. 40 – 50 m^3/s through. The latter rate sustained over a long period of time would allow water into the Aftout-es-Sahel and to Nouakchott.

The mouth of the Senegal River used to be located further north than it is now. Over the years it has been pushed further and further south by the Langue de Barbarie, which is a sand dune created by marine currents. The Chatt Boul and the Ntiallakh were former

mouths of the Senegal River. Currently, the Chatt Boul is a natural reserve. The Ntiallakh is a marigot running from south to north: it is the secondary inundation route for the Diawling.

Water from the Diawling makes its way northwards towards the Chatt Boul. In early August, the water is still south of the Chatt Boul. In early August the Ntiallakh it is completely inundated and covers a vast floodplain. The soil in the area has salt depositions, and the dominant vegetation is *Tamarix* and *Zygophylum*. There are some acacias on the dunes (*Acacia niloticus adamsoni*).

Djoudj National Bird Park

The Djoudj is a bird park of international significance, and has biological connectivity with the Ndiaël (birds feeding in the Djoudj overnight in the Ndiaël). The Djoudj has been well studied. The DPN, which manages the Djoudj, tries to replicate the natural flood regime. The park is supported in part by Germany (Westphalia), who share migratory bird species with the Djoudj. Lessons learnt in the management of the Djoudj can serve in the Ndiaël. The sluice gate of the Gorom (which links the river to the Djoudj National Park) is operated by the DPN. It runs its water budget without consulting the OMVS.

The Djoudj harbours. 3 million birds, consisting of 366 species: 2000 nesting pelicans, 20,000 flamingos and 200,000 ducks. The ducks keep the numbers of snails that transmit bilharzia down. 3000 people live around the Djoudj, living off agriculture (rice and horticulture), fishing and pastoralism. They are Peuls, Moors and Wolofs, grouped in seven villages.

Fisheries

There are 30 species of fish in the Djoudj, and catches are controlled. Most catches occur near the sluice gates where they are more abundant. The more common species are "thiof", "mérou", catfish and tilapia. Fish are caught using nets, and are either consumed fresh, sun-dried for later consumption, or sold.

Agriculture

There are some 30,000 ha of rice around the Djoudj, and two harvests per year. Growing rice is the main economic activity of the local populations, who are supported by the SAED. There are smaller fields in the villages for horticulture for home consumption. Cash crops are also being developed e.g. tomatoes and salad.

Pastoralism

Traditionally, in the Djoudj, cattle herding is the main economic activity after fishing. During the dry season, the search for pasture can force the herds to travel great distances. Within the villages, smaller livestock (goats and poultry) is found, tended principally by the women. For the Peuls, cattle is capital – they never eat their cattle. For the Moors, it is a source of revenue. For the Wolofs, it is a secondary activity. Large herds (up to 50 head) of cattle are observed in the area in August.

Degradation of Environment

As elsewhere in the delta, invasive aquatic weeds are a major concern. They reduce water quality, affect fish life and offer barriers to navigation. They can be controlled physically (removed by hand, by current, fenced off or dredged up), chemically (using herbicides) and biologically (using insect parasites). There are 30,000 ha of mixed *Typha* and *Salvinia* in the delta. Catfish and tilapia are the only species that can utilise this habitat.

Salade d'Eau (Pistia stratiotes)

In the Djoudj there was a programme against the water lettuce (*Pistia stratiotes*) using insects (*Neohydronomus affinis*), which was fully successful: no *Pistia* survives.

Water cabbage (Salvinia molesta)

There is a programme in the Djoudj to eradicate *Salvinia molesta*, the water cabbage. *Salvinia* was introduced inadvertently into Senegal by a researcher looking to produce poultry feed from it. A campaign using the weevil *Cyrtobagous salviniae* has shown some success. The question remains as to whether it will be possible to breed the *Cyrtobagous* quickly enough to meet the increasing

areas of *Salvinia*. *Salvinia* can also be washed away with the current. To prevent the spread of *Salvinia*, wire mesh is placed at critical points, with reasonable success.

Bulrush / Cattail (Typha australis)

The banks of the river from Diama to Richard Toll are solidly lined with *Typha*. Smaller marigots (the Djeuss, Lampsar, Kassak, and Gorom) are also lined with *Typha*. The Djoudj has a programme to destroy it: it is cut mechanically below the water level and picked up by hand. Elsewhere in the delta, large excavators dredge up the bottom silt and uproot the *Typha* at the same time. In French Guinea the rhizomes of *Typha* are used as a famine relief food, and the immature spikes are consumed in Nigeria.

Facilities

The facilities of the Djoudj include a library and laboratory (DO and salinity meter, microscopes, species collection in formaldehyde).

The Bas Ferlo – Vallée Fossile

The Bas Ferlo is a "vallée fossile" (ancient or dry riverbed) 100 km long. It was part of the project "Projet de Revitalisation des Vallées Fossiles", which aimed to re-inundate many of the dry riverbeds present across Senegal. The "Revitalisation" project was not carried out for technical and political reasons. Technically, the energy requirement to pump water into the ancient riverbeds was too high, and politically Mauritania opposed large-scale water abstraction from the Senegal River.

Although the Bas Ferlo is said to be saline, salinity readings show otherwise. Furthermore, the production of crops (melons, watermelons, peppers and saplings) on the Israeli farm supports the assertion that agriculture is possible using Ferlo water.

Keur Momar Sarr

Keur Momar Sarr is the main town at the south of the Lac de Guiers. It is situated near the Lac de Guiers and the Bas Ferlo. The "Ferme Pilote" in Keur Momar Sarr is a model farm established in 1998 in cooperation with the Israeli government with the objective of pioneering a successful farm. It was started after the first 100 km of the valley was re-inundated. The local population as well as international partners have begun to follow the farm's example e.g. Greenland (an Arab / German / Dutch consortium) farming 60 ha; A Malian / Swiss cotton consortium (2,000 ha); and two ASPRODEP / World Bank sites (20 ha each).

Diama

Diama is not in direct contact with the Ndiaël, but is important because it is the biggest dam in the region, and controls the level of the water. Maintenance costs of Diama are very high e.g. the cost of repainting the dam is CFA 190 million ($270,000). These costs, in addition to the costs of construction, are useful in drawing the balance sheet of the dam.

In August water is released from Diama in anticipation of the coming flood. As a result, salinity in the river is very low (2‰ or less). Although the gates are partially open, there is a difference in the water level of 1.41 m between Diama upstream and downstream. The gates are open by three "paliers" (stages). There are 23 stages in total. When the gates are open to seven stages, there are floods in Saint Louis.

Floodwater is recognisable by its high silt load (opaque brown colour). Most of the year, the river water is clear. When the rains start in Guinea and Mali, soil is washed into the river, turning it brown. This brown water makes its appearance before the water level in the delta rises significantly. In 2001 brown water reached Diawar and Ronkh by the end of July. It reached Saint Louis on 4 August. The only area around Saint Louis that had clear water up to the end of August was the Gandiolé, hence its high salinity. However, by end September, brown water had displaced the clear, saline water. If brown water is immobilised e.g. in a pond, the silt deposits after approximately three days, and the water becomes clear again.

8. Conclusion

The Ndiaël, and the entire region stand to benefit greatly from a re-inundation. What is observed on a small scale in the Niety Yone

will be reproduced on a larger scale throughout the delta. Each individual brought back into employment through the exploitation of one of the natural resources of the delta (fisheries, pastoralism, tourism) means less unemployment in the country. This is the premise that the project is based on.

Strong support for the project was found among the inhabitants of the zone. Isolated families living at the fringes of the Ndiaël expressed their gratitude and hope that the project succeeds. They realise that the Ndiaël is a desert because of lack of water, and that it can become fertile again by allowing water back in.

A group that is generally silent, but that will benefit from a re-inundation, is the pastoralists. More difficult to reach because of their gregarious nature, they are direct beneficiaries of the project. The land will however have to be managed to avoid conflicts over resource use.

The first phase of the project can start immediately, by "micro-adjusting" and improving the current situation, while planning for the future. The greatest problem in similar projects has been of a socio-economic rather than a technical nature, whereby too many people compete for a limited resource.

Lastly water, a scarce resource in Senegal, is over-abundant during the flood months, and needs to be diverted away from where it damages infrastructure. Fortunately this concept has been pioneered and accepted in the Diawling, Mauritania. However, bigger institutions in Senegal will need to be convinced that the project is feasible, inexpensive and will have mostly beneficiaries. No particular group stands to suffer from a re-inundation of the Ndiaël.

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