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JESS REPORT ON BIOLOGICAL LIMNOLOGY OF THE JUBBA RIVER

JESS Report No. 28

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ABBREVIATIONS AND ACRONYMS

ARD	Associates in Rural Development, Inc.
EC	electrical conductivity
GSDR	Government of the Somali Democratic Republic
JESS	Jubba Environmental and Socioeconomic Studies
JuDAS	Jubba Development Analytical Studies
MJVD	Ministry of Jubba Valley Development (now MNPJVD)
MNPJVD	Ministry of National Plan and Jubba Valley Development
NUS	National University of Somalia
USAID	U.S. Agency for International Development

PREFACE

The Jubba Environmental and Socioeconomic Studies (JESS) are jointly funded by the Government of the Somali Democratic Republic (GSDR) and U.S. Agency for International Development (USAID). The long-range goals of the JESS project are to provide the Ministry of National Plan and Jubba Valley Development (MNPJVD) with the necessary information on soils/land use, natural resources utilization, social and environmental issues, staff training and technical support. JESS is part of a larger project funded by USAID and the GSDR, the Jubba Development Analytical Studies (JuDAS) Project. Technical assistance and JESS management are being provided to MNPJVD by Associates in Rural Development, Inc. (ARD), of Burlington, Vermont.

This report contains the findings of a four-week biological limnology consultancy conducted for ARD from 2 to 31 August 1987, during Phase II of JESS, by Dr. Steven G. Njuguna and Dr. Francis M. Muthuri.

I. EXECUTIVE SUMMARY

During Phase II of the Jubba Environmental and Socioeconomic Studies, a four-week consultancy was conducted in Somalia. The purpose of this consultancy was to carry out a first-time limnological study of the Jubba River.

The physical characteristics of the river water investigated showed that the river is slightly alkaline and well-buffered, with a pH range of 8.0 to 8.5. Electrical conductivity (EC) ranged from 220 to 350 umhos per centimeter and was found to be lower than that of a tributary, Isha Maalim (1,350 umhos per centimeter) and that of a dhesheeg, Harenka Shariffka (700 umhos per centimeter). The Jubba River was found to be remarkably turbid, with Secchi disk readings ranging between 10 and 37 centimeters.

A total of 36 genera of microflora was recorded. The dominant taxa of algae were *Chlorophyta* (green algae) and *Cyanophyta* (blue-green algae). Although the water had high turbidity, its microflora was found to be rich. The microflora will increase prolifically during the first few years of reservoir formation.

Two algal genera are likely to cause problems in the future reservoir. These are the bloom-forming *Anabaena circinalis* and *Mycrocystis aeruginosa*. In the section of the river downstream of the proposed reservoir, the microflora composition and abundance are likely to increase once the dam is completed.

The Jubba River macrophytes are notable in their lack of diversity and abundance, especially in river stretches upstream of the dam site. In downstream areas, *Typha domingensis* and *Phragmites karka* formed the most dominant communities of emergent macrophytes. A floating macrophyte, *Pistia stratiotes*, was recorded and this plant may cause serious problems as an aquatic weed in the proposed reservoir.

Nymphaea lotus, a rooted, floating-leaved macrophyte, was found to be common in canals, ditches and dhesheegs and is expected to colonize the proposed reservoir as a member of the littoral plant community. No submerged macrophytes were found in the Jubba River but the presence of *Chara* sp., a submerged macrophyte, in Isha Maalim stream may provide an inoculum for the proposed reservoir.

Although an inoculum of aquatic weeds is present in the Jubba Valley, their proliferation in the proposed reservoir will depend on the nutrient regime of the water. Downstream of the dam, the macrophyte populations are expected to decrease once the dam is in operation.

The microfauna community in the Jubba River is not rich in species diversity. It was found to be composed of rotifers, cladocerans, pigmented ciliates, a type of copepod, an unidentified nematode and larval forms of other invertebrates and fish.

Rotifers, *Brachionus* sp., dominated the microfauna in most of the areas sampled. The species composition and abundance are expected to increase within the reservoir and in downstream areas. In the first few years after dam completion, an explosive development of microfauna populations is to be expected.

The benthic community of the Jubba River was mainly composed of larval stages of *Ephemeroptera* (mayflies), *Coleoptera* (beetles), *Plecoptera* (stone flies), *Diptera* (flies), *Trichoptera* (caddis flies) and *Odonata* (dragonflies). Other groups of benthic organisms found in the river were *Oligochaeta* (aquatic earthworms) and *Gastropoda* (snails).

The gastropods were found in all sites investigated, but attained highest densities at Faanoole Barrage and Harenka Shariffka dhesheeg where there was slow-moving water. Creation of a reservoir will stimulate greater benthic populations, especially in the initial stages of reservoir formation. Of the benthic organisms, the presence of planorbid snails, vectors of bilharzia, may cause health problems.

It is strongly recommended that another limnological sampling be conducted during low river flow (January to March), when maximum development of microflora, macrophytes, microfauna and benthic organisms is expected. This additional study should include sampling of the irrigation canals, ditches and dhesheegs which were not visited due to floods in addition to the main river channel. It is also recommended that post-impoundment limnological studies be carried out in the reservoir and downstream areas.

II. INTRODUCTION

This report contains the findings of an August 1987 consultancy concerning the limnology of the Jubba River. The scope of work is contained in Appendix A.

The main objective of this consultancy was to conduct limnological studies in the Jubba River with emphasis on the vicinity of the proposed reservoir for the Baardheere Dam. These studies included:

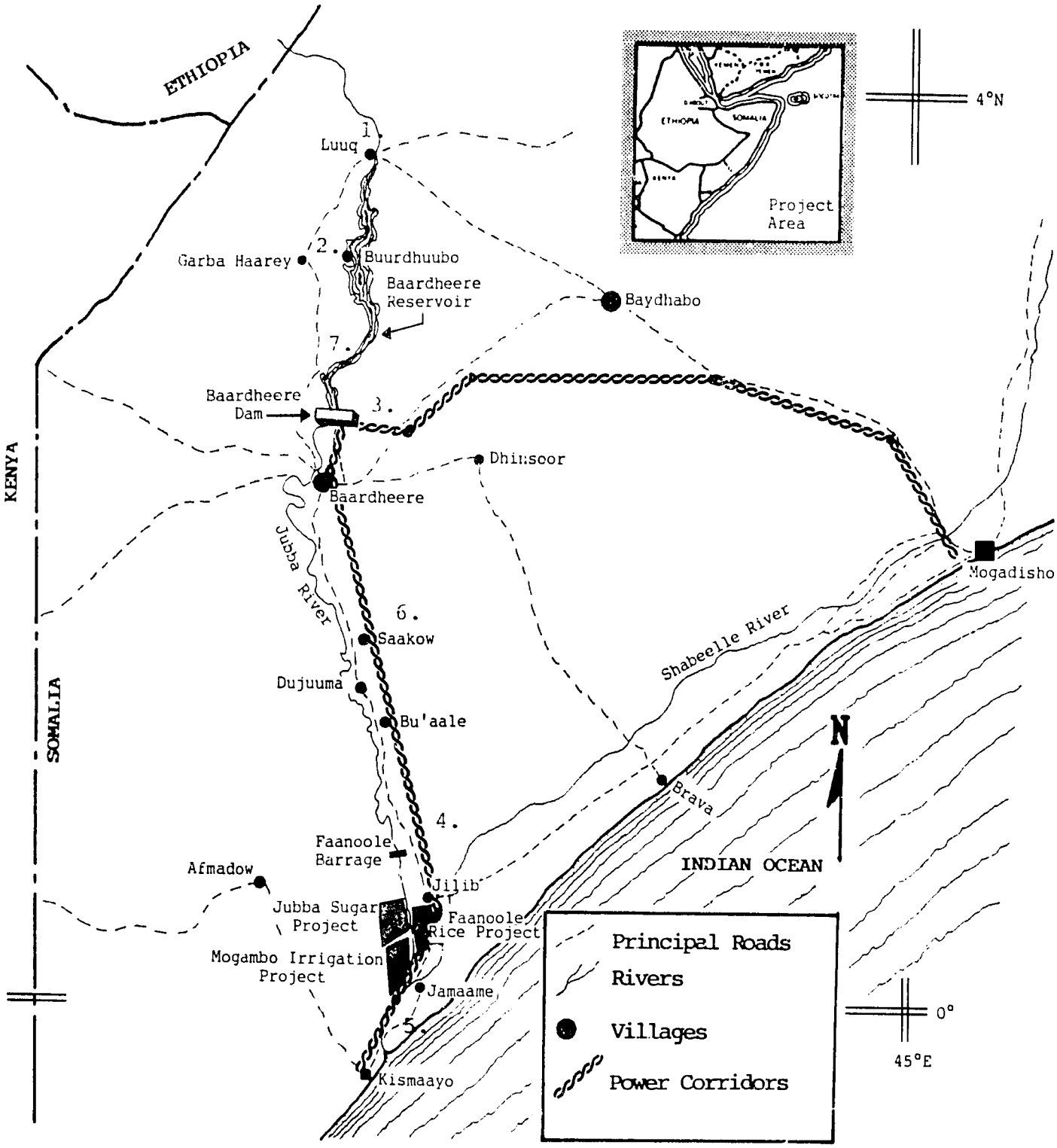
- determining the abundance and diversity of microflora and microfauna in representative habitats of the Jubba River, with special emphasis on the proposed impoundment;
- investigating the potential for phytoplankton proliferation (e.g., algal blooms) in the Baardheere Reservoir and recommending techniques for monitoring algal growth;
- determining the abundance and diversity of emergent, floating and submerged macrophytes and benthic organisms in representative aquatic habitats of the Jubba River, with special emphasis on the proposed impoundment;
- investigating the potential for aquatic weed proliferation in the Baardheere Reservoir and recommending techniques for monitoring the spread of aquatic weeds, with emphasis on exotic species;
- describing the likely changes in aquatic populations which may occur in the proposed impoundment;
- estimating downstream changes in aquatic populations as a result of regulated flow of the Baardheere Dam; and
- commenting, from a limnological perspective, on ramifications of reservoir operations recommended by other consultants.

The Jubba River was sampled from the lower reaches (estuary) to the upper reaches (Luuq) (Figure 1) during a two-week field trip to the Jubba Valley. In addition, a dhesheeg, Harenka Shariffka, near Saakow, and a tributary stream, Isha Maalim Adam, were also investigated.

Analysis of the samples collected was carried out in the Faculty of Chemistry laboratories at the National University of Somalia (NUS).

According to reliable sources, this is the first time a limnological study has been conducted on the Jubba River. This present investigation was a brief study and time was not sufficient to visit all the sites and other areas of limnological interest. Appropriate equipment for intensive limnological investigation was not available. A boat, necessary for a more representative sampling of the river, was not provided. It is anticipated that a more detailed limnological study will be carried out later.

Figure 1. Area of the Baardheere Dam Project and the Jubba Valley Development



III. METHODS

A. Sampling

The locations of sampling stations are shown in Figure 1. Field sampling was carried out 10 to 20 August 1987. Five locations along the Jubba River [Goob Weyn, Faanoole Barrage, Baardheere Dam site, Buurdhuubo (mid-reservoir) and Luuq] were investigated. In addition, sampling was performed at two other locations, a dhesheeg near Saakow and a tributary near Daar Maalim Adam village, 30 kilometers northwest of Baardheere.

B. Field Measurements

At each location, the following physical parameters were measured:

- air and water temperature were measured with a Hach armored thermometer calibrated in tenths of a degree Celsius (Hach Chemical Company, Ames, Iowa, USA);
- Secchi depth was measured with a 20-centimeter black-and-white Secchi disk;
- pH was determined with a Hach Chemical Kit (Hach Company, Ames, Iowa, USA); and
- electrical conductivity (EC) was measured with a YSI model 33 S-C-T meter (Yellow Springs, Ohio, USA).

C. Microflora

Water samples for microflora analysis were collected using an improvised sampler consisting of a calibrated bucket tied to a rope. Surface samples were collected to an approximate depth of 15 centimeters. The samples were collected as far from the riverbank as possible, usually five to 10 meters from water's edge. The middle of the river could not be sampled since a boat was not available and sampling of the river from bridges and ferries was prohibited by the National Security of Somalia. Known volumes of water were passed through a plankton tow net (No. 10W0630, Wards Natural Science Establishment, Rochester, New York, USA) for concentration of the microflora. In a few cases, the plankton net was thrown into the river and towed repeatedly for additional concentration. Epipelic and epiphytic (periphyton) microflora were collected in some littoral areas along the river by scraping mud surfaces and surfaces of partially submerged, dead and living littoral vegetation. All microflora samples were preserved in four percent formalin and

transported to the lab at NUS for microscopic analysis. Identification was based on works available for the eastern Africa region.

D. Macrophytes

The macrophytes were surveyed from the shore. Notes on the dominant species and their approximate spatial extent were made throughout the field study.

At Goob Weyn, a transect line was laid and duplicate quadrats (0.25 square meters) were sampled for macrophyte biomass. Standing crop was estimated for *Typha* and sedge communities.

The collected samples were air dried and later oven dried at 85 degrees centigrade to constant weight at NUS. The data were computed as dry weight per unit area.

Specimens of all aquatic macrophytes found were collected and pressed for subsequent identification. The collected specimens were confirmed against specimens at the University of Nairobi and East African Herbarium, Nairobi.

E. Microfauna

Sampling for microfauna was carried out in the same manner as for microflora. Known volumes of water were passed through a 45 um sieve (Soiltest Inc., Model 365029, Mesh No. 325, Evanston, Illinois, USA) for concentration of microfauna.

Zooplankton samples were preserved in four percent formalin prior to transportation to the lab for analysis. Samples of epipelic and epiphytic microfauna were also collected and preserved in formalin.

Microfauna and microflora samples were examined under a Bausch & Lomb Academic HSM microscope (Model No. 19879) at 100x, 400x and 1000x (oil immersion) at the NUS lab. Identification was based on catalogs and other works available for the eastern Africa region.

F. Benthos

Benthos samples were collected at the stations mentioned in Section A. The sampling sites exhibited a certain degree of variability in their substrates. Luuq and Buurdhuubo had relatively compact substrates. The dam site was slightly disturbed and the substrate was mainly small stones, gravel and

sand. At Faanoole there was soft mud which was heavily colonized by aquatic macrophytes. Goob Weyn had a relatively compact substrate, probably due to human activities (watering point). The dhesheeg was a flooded substrate where sedges and grasses were undergoing decomposition.

Benthic samples were taken with an Ekman Dredge (Bottom Sampling Dredge Code 1061, Chestertown, Maryland, USA). Again, only the edge of the river could be sampled. The area sampled by the Ekman Dredge was 20 centimeters by 11.4 centimeters.

Three replicate samples were collected and pooled into a pail, and all large particles were broken until there was a fine, homogeneous material. The homogenized material was poured through a series of sieves (Hubbard Scientific Co., Northbrook, Illinois, USA). The material remaining on the screens was retrieved into plastic vials and preserved with five percent formalin. In the laboratory, the collected samples (mixtures of mud, rocks, sand, debris and benthic organisms) were emptied into sorting pans and flooded with a sugar concentration (300 grams sugar per liter). The debris was stirred and soft-bodied lifeforms floating on the surface were scooped and preserved in a vial (Lind 1974).

Heavy-bodied organisms, such as snails, were picked from the bottom of the sorting pans with forceps. Organisms separated from the debris were washed free of sugar solution and preserved in five percent formalin. The organisms were identified, counted and reported as numbers of organisms per unit area. Further identification of snails was done at the Malacology Department of the National Museums of Kenya.

III. RESULTS

A. Physical Characteristics

The physical characteristics investigated during the present study of the Jubba River are shown in Table 1.

Air temperature determined during sampling at each site ranged from 28 to 33 degrees centigrade. The water temperature measured at the same time ranged from 26 to 29 degrees centigrade. The river was slightly alkaline with a pH range from 8 to 8.5. It is also well-buffered. Electrical conductivity in the Jubba River ranged from 220 to 350 umhos per centimeter and is lower than that of the Isha Maalim Adam tributary and the dhesheeg. Secchi disk readings varied from 10 to 37 centimeters, showing high turbidity from silt loads.

Table 1. Physical Characteristics

Station	Air (oC)	Water (oC)	pH	EC (umhos/cm)	Secchi (cm)
Goob Weyn	30.5	27.0	8.0	310	10
Faanoole	31.0	27.0	8.3	263	14
Dam site	28.0	26.0	8.5	315	37
Dhesheeg	32.0	29.0	8.5	700	16
Tributary	30.0	28.0	8.5	1350	clear
Buurdhuubo	33.0	27.0	8.5	350	31
Luuq	33.0	27.0	8.0	220	24

B. Microflora

The results of the microflora study are shown in Tables 2, 3 and 4. The Jubba River microflora is rich, including *Bacillariophyta* (diatoms), *Chlorophyta* (green algae), *Cyanophyta* (blue-green algae), *Pyrrophyta* (dinoflagellates) and *Euglenophyta* (flagellated algae). The microflora presented in this report includes planktonic (free-floating), epipelic (on mud), epilithic (on rocks) and epiphytic (on plants).

A total of 36 genera was recorded, the most common being *Chlorophyta* (47 percent). *Cyanophyta* ranked second with 27 percent of the specimens. Only one specimen each for dinoflagellates and euglenophytes was noted.

Faanoole Barrage recorded the highest number of organisms, followed by Goob Weyn in the estuary. In general, the diatoms were more abundant than the other groups of microflora in all stations.

Dominance of microflora varied from Luuq to Goob Weyn. At Luuq, the diatom *Melosira* sp. dominated the planktonic flora. At Buurdhuubo, *Nitzchia* sp., another diatom, was dominant, while *Melosira* sp. and *Stephanodiscus* sp. dominated at the dam site. At Faanoole, *Melosira* sp. and *Cosmarium* sp. (a green alga) were co-dominants. Finally, the estuarine microflora were dominated by a coccoid green alga, *Chlamydomonas* sp., and a blue-green alga, *Amabaena* sp.

It is important to note that although the water of the Jubba River is muddy, it supports a diverse and rich microflora.

Table 2. Number of Species per Sampling Station

Station	Taxon					
	Bac	Chl	Cya	Pry	Eug	Total
Luuq	2	4	4	0	0	10
Buurdhuubo	3	4	4	0	0	11
Dam site	5	5	2	1	0	13
Faanoole	6	8	4	0	0	18
Goob Weyn	5	6	5	0	1	17
Tributary	4	7	4	0	0	15
Dhesheeg	5	3	1	0	0	9

Bac = Bacillariophyta Chl = Chlorophyta Cya = Cyanophyta
Pyr = Pyrrophyta Eug = Euglenophyta

Table 3. Spatial Distribution of Microflora

Taxon	Genus	1	2	3	4	5	6	7
Bacillariophyta	Achananthes				+			+
	Melosira	+	+	+	+	+	+	+
	Navicula	+		+	+	+	+	+
	Nitzchia		+	+	+	+		
	Stephanodiscus			+		+	+	+
	Synedra		+	+	+	+	+	+
Chlorophyta	Ankistrodesmus			+	+		+	
	Chlamydomonas			+	+	+		
	Closterium			+				
	Coelastrum				+	+		
	Cosmarium				+		+	
	Desmidium					+		+
	Gleocystis					+	+	
	Micrasterias	+						
	Oocystis				+	+	+	
	Pediastrum	+	+	+	+			
	Scenedesmus					+		
	Spirogyra						+	+
	Staurastrum						+	
	Tetraedon			+				
Cyanophyta	Anabaena		+		+	+	+	
	Aphanizomenon		+	+				
	Gomphosphaeria	+				+		
	Lyngbya	+	+		+	+	+	
	Merismopedia					+	+	
	Microcystis		+	+	+	+	+	+
	Oscillatoria					+		
	Spirulina	+			+			
Pyrrophyta	Peridinium			+				
Euglenophyta	Unidentified					+		

1 = Luuq
2 = Buurdhuubo
3 = Dam site
4 = Faanoole
5 = Goob Weyn
6 = Tributary
7 = Dhesheeg

Table 4. Microflora Composition and Relative Abundance

Station	Taxon	Genus	Relative Abundance
Luuq	Bacillariophyta	Melosira	D
		Navicula	A
	Chlorophyta	Micrasterias	A
		Pediastrum	P
		Trachelomonas	A
	Cyanophyta	Gomphosphaeria	P
		Lyngbya	C
Buurdhuubo	Bacillariophyta	Melosira	A
		Nitzchia	D
		Synedra	A
	Chlorophyta	Pediastrum	C
		Trachelommonas	P
	Cyanophyta	Anabaena	C
		Aphanizomenon	P
		Lyngbya	P
		Microcystis	C
Dam site	Bacillariophyta	Melosira	D
		Navicula	P
		Nitzchia	C
		Stephanodiscus	D
		Synedra	A
	Chlorophyta	Ankistrodesmus	P
		Chlamydomonas	P
		Closterium	P
		Pediastrum	P
		Tetraedon	A
	Cyanophyta	Aphanizomenon	P
		Microcystis	C
	Pyrrophyta	Peridinium	P
Faanoole	Bacillariophyta	Achnanthes	P
		Melosira	D
		Navicula	D
		Nitzchia	P
		Synedra	A
	Chlorophyta	Ankistrodesmus	P
		Chlamydomonas	A
		Coelastrum	P
		Cosmarium	D
		Oocystis	P
		Pediastrum	P

	Cyanophyta	Anabaena	C
		Lyngbya	P
		Microcystis	C
		Spirulina	P
Goob Weyn	Bacillariophyta	Melosira	P
		Navicula	A
		Nitzchia	P
		Stephanodiscus	A
		Synedra	A
	Chlorophyta	Chlamydomonas	D
		Coelastrum	P
		Desmidium	P
		Gleocystis	C
		Oocystis	C
		Scenedesmus	A
	Cyanophyta	Anabaena	D
		Gomphosphaeria	P
		Lyngbya	P
		Merismopedia	P
		Oscillatoria	A
	Euglenophyta	Unidentified	D
Tributary	Bacillariophyta	Melosira	P
		Navicula	A
		Stephanodiscus	P
		Synedra	P
	Chlorophyta	Ankistrodesmus	P
		Cosmarium	C
		Gleocystis	P
		Oocystis	P
		Spirogyra	D
		Staurastrum	P
		Trachelomonas	P
	Cyanophyta	Anabaena	A
		Lyngbya	C
		Merismopedia	P
		Microcystis	C
Dhesheeg	Bacillariophyta	Achnanthes	P
		Melosira	A
		Navicula	P
		Stephanodiscus	D
		Synedra	P
	Chlorophyta	Desmidium	A
		Spirogyra	D
		Trachelomonas	P
	Cyanophyta	Microcystis	C

D = Dominant A = Abundant C = Common P = Present

C. Macrophytes

Perhaps the most notable characteristics of the Jubba River are the low diversity and the limited abundance of aquatic macrophytes. Only 24 species of aquatic macrophytes have been encountered. Some of them are not strictly aquatic but are hygrophilous ephemerals. Rooted macrophytes are the most prevalent vegetation of the Jubba River. Among the rooted emergent macrophytes, *Phragmites karka* and *Typha domingensis* dominate greater sections of the river. Development of aquatic macrophytes was more pronounced in the lower reaches (Faanoole and downstream) than the upper reaches (Faanoole to Luuq). For example, dense stands of emergent macrophytes were well developed at Goob Weyn and Faanoole. In these sites, the littoral vegetation was relatively more heterogenous and some general zonation could be distinguished.

Two broad zones of vegetation were recognized at Goob Weyn, the *Typha* and sedge zones. The *Typha* zone was a monoculture of *Typha domingensis* which extended to the water's edge. These plants reached a height of four meters. The aboveground standing crop of this community was estimated to be 1710 g m^{-2}. This included live plant material of 1350 g m^{-2} and dead plant material of 360 g m^{-2}. Behind the *Typha* zone was the sedge zone, dominated by *Fimbristylis dichotoma*. This zone was poorly interspersed with *Phragmites karka*, *Panicum maximum*, and *Ipomoea pes-caprae*. The aboveground standing crop of this zone was 1950 g m^{-2}, which included live plant material of 690 g m^{-2} and dead plant material of 1260 g m^{-2}.

Table 5. Standing Crop of Emergent Vegetation at Goob Weyn

Plant Community	Aboveground Standing Crop (g m^{-2}) Living	Dead	Total
Typha zone	1,350	360	1,710
Sedge zone	690	1,260	1,950

At Faanoole Barrage, there was even greater aquatic macrophyte development than at Goob Weyn. *Typha domingensis* formed the dominant zone, stretching for more than 10 meters into the barrage water. *Ipomoea cairica*, a creeper, occasionally grew and twined around *Typha domingensis* plants. Free-floating macrophytes, *Pistia stratiotes* and *Lemna* spp., were found on the surface of the calm, sheltered backwaters and grew as the understory of *Typha domingensis*. *Polygonum senegalense* was also found in the sheltered backwater. Behind the *Typha domingensis* zone on the landward side was a zone of *Phragmites*

karka, Panicum maximum and *Echinochloa haploclada*, which blended with the terrestrial vegetation.

In other sites along the main river, emergent macrophytes were very poorly developed and did not form a distinct community. Scattered species of *Sphaeranthus polycephalus, Vahlia somalensis, Polygonum senegalense, Cyperus michelianus, Fimbristylis bisumbellata, Sporobolus helvolus* and *Echinochloa colona* were found growing on the exposed mud at the riverbank. At Buurdhuubo, *Sphaeranthus polycephalus* and *Phragmites karka* were recorded. At Luuq, *Phragmites karka* was spotted growing on an island between the town and the World Concern camp.

No submerged macrophytes were encountered in the Jubba River. However, a submerged macrophyte was recorded at a tributary stream, Isha Maalim Adam, about 30 kilometers northeast of Baardheere. In this stream, which was transparent to the bottom, large clumps of *Chara* grew from the stream bottom to the surface. There was also a thick growth of filamentous green algae *(Spirogyra)* that was heavily trapped in *Chara* growth.

Apart from Faanoole, no floating macrophytes were encountered in any other section of the river. However, *Pistia stratiotes* and *Lemna* were common plants in ditches and pools in the Jamaame area. Floating-leaved macrophytes were not recorded at the sites investigated along the Jubba River. Nevertheless, *Nymphaea lotus*, a floating-leaved macrophyte, had infested ditches, canals and pools of water in the Jamaame area. *Nymphaea lotus* was also recorded in the dhesheeg near Saakow.

Table 6. Aquatic Macrophytes of the Jubba Valley

Site	Species	Family
Goob Weyn	Typha domingensis	Typhaeceae
	Phragmites karka	Gramineae
	Ipomoea pes-caprae	Convolvulaceae
	Fimbristylis dichotoma	Cyperaceae
	Panicum maximum	Gramineae
Faanoole	Typha domingensis	Typhaceae
	Phragmites karka	Gramineae
	Panicum maximum	Gramineae
	Polygonum senegalense	Polygonaceae
	Cyperus immensus	Cyperaceae
	Cyperus exaltatus	Cyperaceae
	Echinochloa haploclada	Gramineae
	Ipomoea cairica	Convolvulaceae
	Pistia stratiotes	Araceae
	Lemna sp.	Lemnaceae
Dam site	Sporobolus helvolus	Gramineae
	Echinochloa colona	Gramineae
	Frimbristylis bisumbellata	Cyperaceae
	Cyperus michelianus	Cyperaceae
	Polygonum senegalense	Polygonaceae
	Sphaeranthus polycephalus	Compositae
	Vahlia somalensis	Vahliaceae
Buurdhuubo	Sphaeranthus polycephalus	Composite
	Phragmites karka	Gramineae
Luuq	Phragmites karka	Gramineae
Dhesheeg	Nymphaea lotus	Nymphaeaceae
	Cyperus longus	Cyperaceae
	Cyperus rotundus	Cyperaceae
Tributary	Chara sp.	Characeae
	Cyperus sp.	Cyperaceae
	Eleocharis geniculata	Cyperaceae

Table 7. Composition and Relative Abundance of Microfauna

Station	Organism	Relative Abundance
Luuq	Brachionus calicifloris	D
	Mesocyclops	C
	mayfly larvae	P
	chironomid larvae	P
Buurdhuubo	B. calicifloris	D
	B. falcatus	A
	mayfly larvae	P
	chironomid larvae	P
Dam site	B. calicifloris	D
	B. plicatilis	C
Faanoole	B. plicatilis	D
	Brachionus sp.	C
	Philodina sp.	P
	Daphnia sp.	P
	Paramecium sp.	P
	Colpoda sp.	P
Goob Weyn	Colpoda sp.	D
	unidentified ciliate	A
	unidentified nematode	P
	fish larvae	P
Tributary	B. plicatilis	D
	Mesocyclops sp.	P
Dhesheeg	B. falcatus	A
	Philodina sp.	P
	Moina micrura	C
	Mesocyclops sp.	A

D = Dominant A = Abundant C = Common P = Present

D. Microfauna

The results of microfaunal analysis are shown in Table 7. The microfauna of the Jubba River consisted of 15 different organisms. These included five rotifers, two cladocerans, one copepod, three ciliated protozoans, three larval forms (mayfly, chironomid, and fish) and one nematode.

A rotifer, *Brachionus calicifloris*, was the most abundant zooplankter at the Luuq, Buurdhuubo and dam site stations. At Faanoole Barrage, another rotifer, *Brachionus plicatilis*, predominated. *B. plicatilis* was also the dominant species at the tributary station.

The estuarine community was dominated by pigmented ciliates. Three larval forms of mayfly, chironomids and fish were found to form an important component of the microfauna at Luuq, Buurdhuubo and Goob Weyn. Planktonic microfauna contributes significantly to the diet of fish and forms an essential link between heterotrophic fish and autotrophic microflora.

E. Benthos

The groups of benthic organisms found along the Jubba River are shown in Table 8. They include mainly the larval forms of flies, beetles, mayflies, stone flies, caddis flies and dragonflies. Other groups of benthic organisms recorded in the river were oligochaetes and snails.

Of the benthic organisms, only the flies and snails were represented in all the sites investigated. The benthic larval form of flies recorded in the sites were chironomids. Six species of snails were recorded along the river (Table 9). While living snails were encountered in all the sites except at Goob Weyn and Luuq, their highest density was recorded at Faanoole and the dhesheeg, both of which represent areas of slow-moving or stagnant water.

Table 8. Composition of Macrobenthos

Organisms	Density (organisms m^{-2})					
	Luuq	Buurdhuubo	Dam	Faanoole	Goob Weyn	Dhesheeg
Mayflies	146 20%	0	205 23%	29 3%	15 14%	0
Beetles	88 12%	73 16%	175 20%	29 3%	29 29%	0
Stone flies	0	29 6%	44 5%	29 3%	0	44 12%
Dipterans	292 41%	88 19%	102 11%	351 39%	44 43%	29 8%
Caddis flies	0	88 19%	336 38%	0	0	0
Dragonflies	0	0	0	0	0	29 8%
Oligochaetes	161 22%	161 34%	0	0	0	0
Snails	29 4%	29 6%	29 3%	453 51%	15 14%	263 72%
Totals	716 100%	468 100%	891 100%	891 100%	103 100%	365 100%

Table 9. Snail Distribution

Site	Snail Species
Goob Weyn	snail shells
Faanoole	Bulinus forskali Cleopatra africana snail shells
Dam site	Cleopatra africana
Buurdhuubo	Melanoides sp.
Luuq	snail shells
Dhesheeg	Cleopatra africana Gabbiella parvipilla Bulinus nasutus

V. DISCUSSION AND CONCLUSIONS

In new reservoirs, biological development passes through three major stages during the initial years. First, there is deoxygenation in the hypolimnion due to the decay of drowned vegetation. Second, the organic matter is mineralized and nutrients are released into the water. Finally, the increased nutrient content results in the explosive growth of microflora, microfauna, benthos, macrophytes and fish (Balon and Coche 1974; Moss 1980; Petr 1978; Symoens et al. 1988; Visser 1970). The initial high productivity of the tropical impoundments is followed by a decline in productivity corresponding to a change in nutrient status (Balon and Coche 1974; Petr 1978).

The microflora of the Jubba River is rich in terms of species diversity. The total number of microflora reported (36 genera) is high considering the river had been mightily flushed during floods in May and June 1987. An increase in the number of microflora taxa is expected during low-flow conditions, when the river will have characteristics more similar to those of the proposed reservoir. The recorded high diversity of microflora indicates that the reservoir will maintain a viable algal population since the genera of microflora identified can all proliferate in the lentic conditions created by the newly formed reservoir. In 1967, in Lake Kariba, 31 species of phytoplankters were present. This number increased to 39 species in 1970 (Begg 1973, cited in Balon and Coche 1974). As has been found in the Jubba River, where 16 species of chlorophytes were recorded in the present study, chlorophytes were dominant in Lake Kariba, with 15 species in this algal division.

It is important to note the presence of cyanophytes (blue-green algae) at all the stations sampled. It is anticipated that when the Baardheere Reservoir is formed, blooms of blue-green algae will form during the initial stages. The three algal species that are likely to form blooms are *Anabaena circinalis*, *Microcystis aeruginosa* and *Aphanizomenon* spp. The diatoms have also been known to form blooms as a result of eutrophication. Blooms of *Microcystis aeruginosa* have been reported to produce sufficient toxins to cause human health problems and cattle deaths (Noble and Hemens 1978). *Aphanizomenon* and *Anabaena* blooms are also reported to have caused fish kills, cattle deaths and human health problems (Barica 1975). In addition, the blue-green algae impart noxious taste and odors to water.

Conditions that favor the growth of blue-green algae, such as high pH, high alkalinity and an abundance of nutrients (Fogg et al. 1973), are found in the Jubba River (Jobin 1986). The blue-green algae are also capable of growing under the low-light conditions found in the turbid waters of the Jubba River.

With ample micronutrients, suggested by the high electrical conductivity of the river water (Payne 1986), and sufficient soluble silica available, indicated by high pH and high temperatures, the nutrients that are likely to limit phytoplankton growth are nitrogen and/or phosphorus, the principal growth-limiting nutrients for phytoplankton in aquatic ecosystems. According to Jobin (1986), the Jubba River has high concentrations of nitrogen and phosphorus, with nitrate-nitrogen values ranging from one to 20 milligrams per liter and phosphate-phosphorus values of 0.001 to five milligrams per liter. These high concentrations do not suggest phosphorus or nitrogen limitation. These concentrations are indicative of eutrophic conditions and are highly suspect. At Baardheere, for example, the NO_3-N values reported range from 3.4 to four milligrams per liter. These levels are extremely high for a river system that apparently is not grossly polluted. NO_3-N concentrations reported for Lake Kariba ranged from 0.003 to 0.097 milligrams per liter (Balon and Coche 1974). As pointed out by Mitchell (1970) it is seldom that NO_3-N concentration in Lake Kariba reaches 0.020 milligrams per liter. Such low concentrations are in line with observations made in most East African lakes where NO_3-N remains below 0.030 milligrams per liter. The world average NO_3-N value is 0.3 milligrams per liter and this corresponds to Visser's average for East and West Africa lakes and rivers (Balon and Coche 1974). The mean NO_3-N concentration for African rivers is 0.8 milligrams per liter, according to Livingstone (1963). The limiting concentration of PO_4-P for phytoplankton development is 0.010 milligrams per liter (Talling and Talling 1965). This limiting value is far below the maximum value of five milligrams phosphorus per liter reported for the Jubba River by Jobin (1986). On page B-11 of Jobin's report, it is stated that the water chemistry values are very unreliable for the Jubba River due to high turbidity and color of the river water when obtained with the colorimetric Hach kit. The methods used by Jobin in nutrient analysis are unknown to the authors since only tables of data extracted from the report were made available to them.

The increased algal growth due to the initial nutrient flux into the water will result in larger populations of zooplankton. The 15 species of microfauna recorded in this present study represent a viable zooplankton population. Begg (1973, cited in Balon and Coche 1974) found only 20 species of zooplankton in Lake Kariba in 1967, with rotifers and cladocerans co-dominants. The dominant zooplankters found in the Jubba River during the study period were rotifers. As in Lake Kariba, the microfauna community in the Jubba River lacks diversity. It is worth noting that the Jubba River was sampled after a major flood. In addition, ditches, canals and dhesheegs which were not visited due to the flooding contained considerable unsampled species of microfauna representative of a lentic environment. These

habitats would serve as sources of inoculum for the proposed reservoir.

In the newly formed reservoir, the zooplankton population explosion will be followed by an increase in both the populations and diversity of fish species. Thus, during the initial years of the creation of the dam, exceptional fish harvests can be expected. This peak in fish production is expected to decline after three to four years unless the eutrophic conditions are sustained by inputs from agricultural activity around the reservoir or from the upper catchment.

When a river valley is dammed, the river changes from a lotic to a lentic system. This reduces the rate of water flow. Coupled with an increase in nutrients, a characteristic of the initial stages of man-made lakes, it is expected there will be development of aquatic macrophytes in the proposed reservoir. Gaudet (1979) described the following pattern of succession of aquatic macrophytes in man-made lakes: the floating macrophytes develop first, followed by the sudd; there is a later decrease in floating macrophytes, an increase in submerged macrophytes and finally a development of drawdown flora. Such a sequence has been very pronounced in Lake Kariba.

Two of the floating macrophytes likely to cause great problems in the proposed reservoir are *Pistia stratiotes* and *Eichhornia crassipes*. In this survey, *Pistia stratiotes* was recorded in Faanoole Barrage and pools in the Jamaame area. Although there was no observation of *Eichhornia crassipes*, it has been reported that this weed infests irrigation canals (Tillman, personal communication).

As in other man-made lakes, one would expect *Pistia stratiotes* and *Eichhornia crassipes* to be pioneers in the proposed reservoir since they are independent of depth and substream requirements and are not affected by changes in water level. During the initial stages (the first three years of existence) of Lake Brokopondo (Surinam, South America) only floating macrophytes such as *Eichhornia crassipes*, *Ceratopteris pteridoides*, *Lemna valdiviana* and *Spirodela biperforata* colonized the lake (Van Donselaar 1968). Results of this study show that *Pistia stratiotes* and *Eichhornia crassipes* were not found in the upper reaches of the river (above dam site). As a result, it is rather difficult to predict whether and when they might become a problem in the proposed reservoir. *Pistia stratiotes* and *Eichhornia crassipes* are most likely to become obnoxious pests if introduced during the initial stage of reservoir formation, since the lake will have high nutrient content at this time. The infestation of these weeds will depend mainly on their introduction to the reservoir by birds and other agents of dispersion.

Floating weeds have been known to cause major problems in African man-made lakes. Some of the problems that have been noted in these lakes are summarized in Table 10.

Table 10. Problems Caused by Aquatic Weeds (Symoens et al.)

Location	Species Concerned	Type of Problem
Lake Kariba	*Salvinia molesta*	interferes with navigation and fishing reduces recreation health hazard
Volta Lake	*Pistia stratiotes* *Ceratophyllum demersum*	health hazards
Lake McLlwaine	*Eichhornia crassipes*	health hazard reduces recreation
Haartebeesport Dam	*Eichhornia crassipes*	interferes with navigation interferes with production of potable water
Cabora Bassa	*Eichhornia crassipes* *Salvinia molesta* *Pistia stratiotes*	interfere with navigation

In addition to the above problems, the presence of aquatic weeds in the proposed reservoir may pose a problem of water loss. There are a number of measurements to indicate that aquatic weeds lose considerable quantities of water by evapotranspiration. For example, evapotranspiration losses from *Eichhornia crassipes* communities have been reported to be 3.7 times higher (Timmer and Weldon 1967), four to five times higher (Little 1967) and 6.6 times higher (Penfound and Earle 1948) than evaporation losses from open water. However, this does not hold true for all aquatic weeds. Work on *Salvinia molesta* showed that evapotranspiration losses from weed mats were the same as evaporation losses from open water (Little 1969). Brezny et al. (1973) reported lower evapotranspiration loss from *Pistia stratiotes* than evaporation loss from open water.

The absence of submerged macrophytes in the Jubba River is mainly due to its high turbidity. *Chara* was the only submerged macrophyte found in this survey, although *Ceratophyllum demersum* was recorded previously in a dhesheeg north of Jilib (Jobin 1986). In the proposed reservoir the water will be much more

transparent and this will allow greater light penetration, favoring the establishment of a submerged macrophyte community. These macrophytes will be established in the reservoir where the water depth does not exceed 10 meters and where the plants will not be adversely affected by large lake fluctuations.

The proposed reservoir will also be colonized by the rooted, floating-leaved macrophytes. Where the reservoir is shallow, there will be development of water lily zones, as *Nymphaea lotus* is a common feature of the ditches, canals and dhesheegs of the Jubba Valley.

Although this survey has revealed poor development of emergent macrophytes in the upper reaches of the river, including the dam site, the inoculum is present in appreciable amounts. Hence, it is expected that the reservoir will be fringed by emergent macrophyte communities dominated by *Typha domingensis* and *Phragmites karka*. *Polygonum senegalense* will also be an important species in this community, especially where water does not exceed a depth of three meters.

Following the river impoundment, a large amount of terrestrial vegetation will be submerged. This flooded vegetation will play an important role in the development of the reservoir ecosystem, providing food as well as habitat in the form of drowned trees for the benthic organisms. Therefore, an increase in benthic population in the proposed reservoir can be expected. Especially important will be an increase in chironomid and ephemeropteran larvae, which have been reported to be an important source of food for the insectivorous fish in Lake Volta (Petr 1970).

The benthic organisms in the proposed reservoir most likely to cause health problems are the snails. Certain members of the genus *Bulinus* are the vectors of *Schistosoma haematobium*, which causes schistosomiasis (bilharzia). *Bulinus nasutus* has been reported to be the main intermediate host of *Schistosoma haematobium* in northwest and northeast Tanzania, coastal and western Kenya and some parts of Uganda, while *Bulinus abyssinicus* has been found to be the intermediate host of *Schistosoma haematobium* in Somalia (Brown 1980).

The above species of snails have been reported to occur in the waters of the Jubba Valley. *Bulinus nasutus* was found in Harenka Shariffka dhesheeg, while *Bulinus abyssinicus* was reported in the Faanoole Canal (Jobin 1986). The results of this study have shown that slow-moving and stagnant waters harbor the greatest snail population. Hence, the creation of the reservoir will provide conditions that favor an increase in snail population. Since some of the snails are vectors of bilharzia, the incidence of this disease can be expected to rise around the proposed reservoir. The situation will be made even worse by the

presence of aquatic weeds such as *Ceratophyllum demersum*. The presence of this submerged weed in the proposed reservoir will provide ideal habitat for the *Bulinus* snail. In the dense *Ceratophyllum* beds, the snails feed, deposit eggs and find protection from predators.

The sedimentation rate of silt contained in the Jubba River was found to be fast. Water trapped behind emergent macrophytes at Faanoole Barrage is clear. Silt in the water samples collected at various points along the river settled quickly once the samples were placed on the laboratory bench. An experiment on the clarification rate carried out with water drawn from the river at Baardheere, where the Secchi depth measured 37 centimeters, showed that the Secchi depth increased to 75 centimeters in 13 days (Jobin 1986). It is expected that the proposed dam will have water of increased transparency and clarity. This in turn will extend the zone of effective light penetration into the water, resulting in increased algal production and stimulating development of submerged aquatic macrophytes such as *Ceratophyllum demersum*.

Initial flooding of the dam is expected to increase the surface area for periphyton, or attached algae, which will develop on the bottom of the newly formed shallows, submerged vegetation and newly developed macrophytes. These shallow inshore areas favor a higher primary production compared with the open water due to frequent stirring to the bottom, increased nutrient release from the sediments and the proximity to inflows of nutrient-rich water and nutrient-rich effluents, as from agricultural sources.

In the section of the river downstream of the proposed dam, the composition and abundance of phytoplankton species will be increased. The reservoir will serve as a source of inoculum, since the discharge will contain abundant and diverse phytoplankton. The water will be of higher clarity, enhancing further development of the phytoplankton if the volume of outflow is maintained at average levels.

Experience with the construction and operation of existing reservoirs has shown that in most systems there is an initial deoxygenation of water in the hypolimnion due to the incorporation of organic matter from the flooded riverbed and floodplains. This deoxygenated condition may last from a few months to several years. In some cases, such as Lakes Nasser-Nubia and Kainji, the hypolimnial deoxygenated condition during thermal stratification seems to be a yearly occurrence (Symoens et al. 1981). Deoxygenation of the water below the thermocline reduces effective volume for primary production and for fish production. If the discharge from the reservoir is withdrawn from the hypolimnion through subsurface spillways rather than surface spillways, the aquatic flora and fauna are adversely

affected. This hypolimnial water is devoid of oxygen and high in hydrogen sulfide, causing a reduction in aquatic populations downstream. The adverse effects of hydrogen sulfide from spillage water on the biota below the dam wall in Lake Kariba have been documented by Begg (1973, cited in Balon and Coche 1974).

Once a new reservoir has filled, the average river flow below the dam may be a little less than it was before. The seasonal pattern of flow is considerably changed, resulting in great changes in the lower river systems. The Jubba River floodplain will be reduced, with resultant reduction in diversity and abundance of macrophytes, especially on the lower reaches of the river. With the reduction of the floodplain, it is expected that there will not be enough water to feed the dhesheegs. This will result in a further reduction of diversity and abundance of aquatic populations downstream.

The silt load in a newly created dam is deposited in the reservoir itself. The silt deposit on the floodplains, which provides nutrient replenishment of the floodplains and serves as a detrital food source for inshore fishery, is greatly reduced. The fishery in the Mediterranean Sea off the River Nile delta is known to have declined since the closure of the Aswan High Dam, which impounds Lake Nasser-Nubia (Rzoka 1976). Further, without the silt loads to replenish the estuaries, coastal erosion may exceed the replenishment rate. This would lead to loss of the brackish water habitat and an increase in salt intrusion into the river and groundwater. During the filling of Lake Volta, the river flow was reduced and the one percent salinity level moved upriver to about 50 kilometers from the sea (Moss 1980).

Finally, the dam will be a barrier to migrant fish, the most important being the eels, of which *Anguilla bengalensis* has been reported in the Jubba River by Meredith (1986).

This investigation required more time than was available. The actual time spent at each sampling site, an average of about two hours, was insufficient. A full day at each site would have allowed for more detailed work and replication of samples. Therefore, the absence of a species in the lists given does not necessarily mean it did not occur in the river.

Due to the shortage of the time available and extensive flooding in the lower reaches, making some sites inaccessible, it was not possible to investigate permanent dhesheegs, irrigation canals and ditches. These are very important sources of inoculum of flora and fauna for the proposed reservoir. The determination of primary production and measurement of chlorophyll a were also not carried out due to lack of appropriate equipment and chemicals. Macrophyte cover, primary production and biomass

studies were not conducted, again due to the shortage of time allocated to the whole survey.

Because of the above restrictions, the results presented in this final report are only preliminary. It is recommended that a follow-up study be carried out during a low-water season such as between January and March.

VI. RECOMMENDATIONS

Once the reservoir is formed, it is recommended that seasonal monitoring of phytoplankton growth be carried out. This monitoring should include measurements of primary production, phytoplankton biomass and species composition. It is also recommended that zooplankton and benthic community production, biomass and species composition be determined regularly, as well as measurements of primary production, standing crop cover and species composition of aquatic macrophytes. Especially important in this respect will be the monitoring of aquatic weeds, which can cause tremendous problems in the management of the proposed reservoir.

Post-impoundment surveys should be conducted regularly to locate new growths of aquatic weeds, particularly the exotic species, which could pose problems in the future. Monitoring for water weeds can be carried out by aerial surveys. Such surveys have been done in Lake Kariba (Mitchell 1974; Mitchell and Rose 1979) and Cabora Bassa (Bond and Roberts 1978). The surveys were done from a four- or six-seater aircraft flying about 300 meters above the lake surface at an air speed of 200 to 250 kilometers per hour. Three or four observers independently map areas of weed coverage to a scale map of the reservoir. The maps of several observers are compared after each flight and a composite map is compiled. The areas are subsequently measured with a planimeter.

In addition to the above method, a large number of aerial photographs can be taken and used as a basis for the estimation of extent of aquatic macrophytes. This procedure will provide a more accurate record of the area covered by water weeds and a useful check on the mapping estimate of aquatic weeds coverage. As a further check, the areas occupied by water weeds can be estimated from extensive boat surveys.

It is strongly recommended that another sampling be carried out during the low-flow months of January through March, when maximum development of microflora, macrophytes, microfauna and benthic organisms can be expected to occur in the Jubba River. The present study was carried out after a major flood and during high water flow.

Finally, the GSDR should establish a fully equipped laboratory for limnological and water quality studies. The training of local limnologists is absolutely essential for successful management of the reservoir.

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APPENDIX A

Scope of Work--Phase II--Limnology

Consultants: Dr. F. M. Muthuri
Dr. S. C. Njuguna

1. The contractors will conduct a four-week consultancy in Somalia beginning on or about June 1987 for Associates in Rural Development, Inc. (ARD), as part of the Jubba Environmental and Socioeconomic Studies (JESS).

2. The main focus of this consultancy will be to conduct limnological studies in the vicinity of the proposed reservoir for the Baardheere Dam.

3. Prior to departure for Somalia, the consultants will receive written or telephone briefings from the ARD project manager or the JESS team leader.

4. Upon arrival in Somalia, the consultants will hold briefing meetings with the USAID project manager, or designate, and the JESS team leader, or designate, to discuss the consultants' scope of work. At these meetings, a means for progress reporting during this consultancy will be defined.

5. Dr. Njuguna will determine the abundance and diversity of microflora and microfauna in representative aquatic habitats of the Jubba River, with special emphasis on the estuary and proposed impoundment. In addition, primary production measurement will also be done in the above habitats.

6. Dr. Njuguna will address the potential for phytoplankton proliferation (e.g., algal blooms) in the proposed Baardheere Reservoir and recommend techniques for monitoring algal growth.

7. Dr. Muthuri will determine abundance and diversity of emergent, floating and submerged macrophytes and benthic organisms in representative aquatic habitats of the Jubba River, with special emphasis on the estuary and proposed impoundment.

8. Dr. Muthuri will address the potential for aquatic weed proliferation in the proposed Baardheere Reservoir and recommend techniques for monitoring aquatic weed spread, with emphasis on exotic species.

9. Based upon survey data and physicochemical water parameters, the consultants will describe likely changes in aquatic populations in the proposed impoundment.

10. To the extent possible, the consultants will estimate downstream changes in aquatic populations as a result of regulated flow of the Baardheere Dam.

11. From a limnological perspective, the consultants should comment on ramifications of reservoir operations recommended by other consultants, such as power engineers and health experts.

12. A word-processed draft report for this consultancy will be delivered to the JESS team leader at least one full day prior to departure from Somalia. This report will be written in a format which meets guidelines the consultants will receive from the JESS team leader. This report will constitute a basis for final briefing with the USAID project manager, the JESS team leader and project personnel from the Ministry of Jubba Valley Development (MJVD). Revisions for a final report should be completed within two weeks after receiving comments from JESS and ARD and be submitted to the ARD project manager.

13. The report will discuss the limitations inherent in the field sampling conducted at one time in a very temporally variable riverine system. The possible errors in overall conclusions resulting from this limitation will be emphasized.

14. At the discretion of the JESS team leader, the consultants may be required to present a one-hour training session at the MJVD on a topic related to this consultancy.

APPENDIX B

Field Notes: Jubba River Limnological Study
2 to 31 August 1987

Sunday 2 August to Sunday 9 August 1987

- held briefing meetings with JESS team leader--discussed scope of work
- assembled field equipment
- introduced to the National University of Somalia Chemistry Department
- obtained permits for field visits
- obtained USAID contractor identification cards
- obtained documents to permit us to take photographs of features of limnological interest

Monday 10 August 1987

- left Mogadisho for Jilib at 0830 hours
- crossed the Shabeelle River at Awdegle at 1000 hours; a brownish, chocolate-colored river, terrestrial vegetation merged with river, no aquatic macrophytes observed
- the lower Shabeelle area appeared to be very productive--bananas, mangoes and grapefruits grown on the farms
- arrived at Jilib at 1630 hours; the vehicle got stuck near the entrance to the JESS guest house compound for two-and-a-half hours

Tuesday 11 August 1987

- early in the morning, at 0600 hours, we started to fill a channel dug across the driveway to enable driving out from the JESS compound
- at 0800 hours we left Jilib on our way to Kismaayo
- at 0900 hours we crossed the Jubba River at Kamsuuma
- at Kamsuuma we observed *Phragmites karka*, thick growths of *Nymphaea lotus* and *Pistia stratiotes*

- arrived at Kismaayo at 1030 hours, where we presented our papers to government authorities
- from Kismaayo, we started looking for a suitable sampling site near the estuary
- located sampling site at Goob Weyn at 1230 hours, where we worked for three-and-one-half hours
- left for Jilib at 1600 hours
- in Jamaame we collected specimens of *Pistia stratiotes* and took photographs of *Nymphaea lotus* community
- there were extensive banana plantations in this region

Wednesday 12 August 1987

- presented papers to the government authorities
- left Jilib for Faanoole Barrage, arrived at 1325 hours
- on our way to Faanoole we observed some growth of *Typha domingensis* in the ditches and ponds along the road
- began sampling at Faanoole at 1300 hours; the barrage seemed very rich in fish and the Chinese personnel spent hours catching fish
- we were especially excited to find *Pistia stratiotes* at this site

Thursday 13 August 1987

- woke up at 0500 hours, broke camp and after breakfast, at 0800 hours, we set off for Bu'aale and Saakow
- the drive was OK as far as the Faanoole turnoff
- thereafter the road to Bu'aale became bad and five kilometers after the Faanoole turnoff we started using the winch
- at one spot we spent at least three hours trying to get the Blazer out of the mud

- real trouble started when one of the belts of the power steering mechanism broke, fluid started to pour from the engine and one of the indicators started showing "water in fuel"

- after getting out of this spot, we realized that the brakes were no longer working satisfactorily

- with power-steering gone, the steering wheel became very rigid

- after several attempts to forge ahead, we realized the vehicle was beginning to lose power and decided to turn back to Jilib and proceed to Mogadishu to have the vehicle repaired

- driving back to Jilib was a nightmare; we worked nonstop--using the winch, digging up the soaked soil, paving the road, pushing the truck, etc.; the winch got cut

- we made it to a small village near Faanoole and the truck stopped and all attempts to start it going failed

- we decided to call it a day, it was 2200 hours, and Abdi Kadir (Golden Boy) made us spaghetti with onion sauce and after taking a few canned beers we slept

Friday 14 August 1987

- in the morning we woke up, took orange squash for breakfast, cleaned the oil filter and changed a flat tire

- at 1000 hours Hassan and Kenyan went to Faanoole for help to get the Blazer started

- a mechanic from Faanoole Barrage helped repair the vehicle and we left Fanoole for Mogadisho at 1200 hours

- we arrived in Mogadisho at 2200 hours and reported to Gus Tillman about the problems of the Safari

Saturday 15 August 1987

- on Saturday morning, we took a rest while the vehicle was being repaired

- in the afternoon we started preparations for the second trip, scheduled for Sunday 16 August 1987

Sunday 16 August 1987

- woke up at 0600 hours all set for the trip
- Gus Tillman met us for a briefing on the trip and finances
- we waited for a whole day, the vehicle was not ready and the trip was postponed to the next day

Monday 17 August 1987

- left FSU for Baardheere at 0730 hours
- we passed through semi-arid stretches where camel, cow, goat and sheep rearing and sorghum cultivation were the major human activities
- in addition, we noticed that there was a remarkable extent of overgrazing and environmental degradation
- we arrived in Baardheere at 1430 hours and presented our papers to the government authorities

Tuesday 18 August 1987

- we left for the dam site at 0715 hours, arriving at 0830 hours
- work at the dam site was finished at 1000 hours
- we went back to Baardheere Guest House and had an early lunch at 1100 hours, thereafter we left for Harinka Shariffka dhesheeg, five kilometers upstream of Saakow
- we arrived at the dhesheeg at 1530 hours and began our investigation immediately
- this was a temporary dhesheeg and was very much influenced by human activities
- around the dhesheeg was a crop of sesame and it was evident the farmers plant their crops as the water in the dhesheeg recedes

Wedensday 19 August 1987

- woke up at 0545 hours and started preparing for the trip
- at 0930 hours we left for Buurdhuubo

- we reached Isha Maalim Adam stream at 1030 hours
- this was a clear water stream which had good growth of *Chara* and filamentous green algae (*Spirogyra*)
- after taking some measurements we proceeded on our way to Buurdhuubo
- we arrived in Buurdhuubo at 1430 hours and began sampling immediately
- most of the surrounding area was littered with many small houses for refugees

Thursday 20 August 1987

- left camp site at Buurdhuubo at 0800 hours
- passed through scrubland and arrived in Garba Haarey at 0915 hours
- we arrived in Luuq at 1230 hours
- we camped in World Concern compound
- after finishing our sampling we crossed the Jubba River in a motorboat
- like Buurdhuubo, the area had many refugees

Friday 21 August 1987

- left Luuq for Mogadisho at 0840 hours
- on the way we encountered large herds of camels
- on arrival in Mogadisho at 2000 hours we reported to Gus Tillman and briefed him on our trip

Saturday 22 to Sunday 31 August 1987

- analysis of the collected samples at the National University of Somalia
- met the director of USAID mission in Somalia and discussed our limnological study of the Jubba River
- wrote our draft report on our limnological findings
- submitted our report to Gus Tillman
- left Somalia for Kenya on 31 August 1987

APPENDIX C

Comments

1. In preparation of the final report, we have taken into account comments from James H. Morgan and Gus Tillman. Some of the comments from these two reviewers are contradictory.

2. This final report does not describe or quantify physical and chemical characteristics of the Jubba River in detail since these were addressed by other consultants (e.g., Water Quality and Public Health Engineering, W. Jobin; Hydrology, another consultant).

3. The Jubba River was studied soon after a mighty flood. Some areas were still flooded during the study and therefore were inaccessible. A second study during low-flow conditions is necessary.

4. The time allocated for the biological limnology study was too short. A two-month period would have been sufficient.

5. A boat, which was essential for sampling, was not provided. Hence, sampling had to be done from the shores, introducing bias into the results.

6. Lack of appropriate equipment and chemicals meant that some important measurements could not be made (e.g., primary production and chlorophyll a).

7. Communication and guidance while in Somalia and thereafter were not explicit.