Water Quality Assessment Report

Mara River Basin, Kenya/Tanzania

Integrated Management of Coastal and Freshwater Systems Program

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Funding for the Water Quality Assessment Report, Mara River Basin, Kenya/Tanzania was provided by the people of the United States of America through the U.S. Agency for International Development (USAID), as a component of the Integrated Management of Coastal and Freshwater Systems Leader with Associates (LWA) Agreement No. EPP-A-00-04-00015-00. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Agency for International Development of the United States Government or Florida International University.

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For bibliographic purposes, this document should be cited as:

GLOWS-FIU. 2007. Water Quality Baseline Assessment Report, Mara River Basin, Kenya/Tanzania. Global Water for Sustainability Program, Florida International University. 61 pp.

ISBN:

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Acknowledgements

We would like to acknowledge all those individuals and institutions that helped to make this assessment a success. A list of individuals and institutions with whom we consulted during the assessment is found on page v of this document. Without the participation, time, ideas and openness of these individuals, this report would not have been possible.

All activities, especially on-the-ground activities, for the water quality baseline assessment were greatly supported by the Global Water for Sustainability (GLOWS) consortium partners WWF – East Africa Regional Program Office (WWF-EARPO) and WWF-Tanzania Program Office (WWF-TPO). We thank Musonda Mumba (WWF-EARPO), Fred Mngube (WWF-TPO) Nina Bhola (WWF-EARPO), Doris Ombara (WWF-Mara), Daniel Koros (WWF-EARPO), Adams Dikirr (WWF-EARPO) and William Kasanga (WWF-TPO) for their time, guidance and assistance.

This assessment was supported by the United States Agency for International Development (USAID). The opinions expressed in this publication are those of the authors and do not necessarily reflect the views of the sponsors and their organizations.

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Acronyms

APHA	American Public Health Association
BMP	Best Management Practices
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DON	Dissolved Organic Nitrogen
FIU	Florida International University
GDP	Gross Domestic Product
GLOWS	Global Water for Sustainability
IWRM	Integrated Water Resources Management
LVEMP	Lake Victoria Environmental Management Program
MCL	Maximum Contaminant Limit
MMNR	Masai-Mara National Reserve
N:P	Nitrogen to Phosphorous Ratio
NGO	Non-Governmental Organization
PCB	Polychlorinated Biphenyl
PPB	Parts per Billion (µg/L)
PPT	Parts per Trillion (ng/L)
SERC	Southeast Environmental Research Centre
SNP	Serengeti National Park
TANAPA	Tanzania National Parks
TDN	Total Dissolved Nitrogen
TDP	Total Dissolved Phosphorous
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TTS	Tanzania Temporary Standards
UDSM	University of Dar es Salaam
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WUA	Water Users' Association
WWF-EARPO	World Wide Fund for Nature East Africa Regional Program Office
WWF-Mara	World Wide Fund for Nature Mara Field Office
WWF-TPO	World Wide Fund for Nature Tanzania Program Office

Preface: About GLOWS

The Global Water for Sustainability (GLOWS) program is a consortium financed by the United States Agency for International Development (USAID) working to increase social, economic, and environmental benefits to people through clean water, healthy aquatic ecosystems and sustainable water resources management. Launched in early 2005, GLOWS works on-the-ground to implement improved practices, build local capacity through multi-level training activities, and share lessons learned and advancements in the practice of Integrated Water Resources Management.

Because water resources touch so many elements of human systems and ecosystems, management must be integrated across water use sectors, across scales of governance, across space in a river basin context, and across time. Many current water problems stem from the fragmented, single-issue and single-sector approaches that have characterized water resources management in the past. GLOWS works to integrate the environmental, technical, governmental, and management elements of IWRM. The basic goal is to manage the human and environmental elements of IWRM to ensure that abundant quantities of sufficiently clean freshwater are available in the correct place at the correct time. This requires a governance and management system that integrates science-based understanding of the natural controls on water abundance and quality with appropriate and effective human technologies and actions.

Working at a basin, watershed or aquifer scale, the GLOWS partner organizations provide expertise across the policy, governance, institutional, educational, and technical dimensions of IWRM. Approaches combine advanced analytical techniques, innovative mechanisms for sustainable resource management and biodiversity conservation, community-based programs in poverty alleviation, improved sanitation and potable water supply, and global networking of local NGOs to achieve IWRM objectives.

Executive Summary

The Global Water for Sustainability (GLOWS) Program is supporting the efforts of the Ministry of Water and Irrigation, Kenya, and the Ministry of Water, Tanzania, to provide credible scientific guidance to water management decisions in the transboundary Mara River Basin. This water quality assessment examined the quality of surface water in the Kenyan and Tanzanian sections of the basin during May-2005, May-2006, and June-2007 with the goal of identifying present water quality issues and informing future monitoring and management actions. This document also summarizes the current policy framework for water quality monitoring and existing programs in the Mara River basin.

The Mara River basin is a transboundary basin shared by Kenya and Tanzania (approximately 65% and 35% of the basin, respectively). The Mara River and its tributaries flow through diverse landscapes. Beginning in the Enupuiyapi Swamp and Mau Forest complex of Kenya, the river flows southwest through regions characterized by small- and large-scale agriculture, two internationally renowned conservation areas, savannah grasslands, and delta wetlands before discharging into Lake Victoria near Musoma Town, Tanzania. The basin supports a wide array of ecosystem and human needs. Stakeholders and sectors of the Mara River Basin include urban settlements and villages, subsistence and large-scale agriculture, livestock, fisheries, tourism, conservation areas and biodiversity, mining and industries. However, stakeholders in the Mara River Basin increasingly face water shortages as well as problems with poor water quality and environmental degradation. Important threats include loss of native forest cover in the upper parts of the catchment and along rivers, agricultural expansion and intensification (including irrigation), human population growth, resource-intensive tourist facilities, and discharge of untreated wastewaters from settlements and tourist hotels.

Currently, there is little systematic monitoring of water quality in the Mara River Basin. On the Kenyan side of the basin, the Ministry of Water and Irrigation has established water quality laboratories in the Narok and Bomet District Offices and a limited number of monitoring campaigns have been conducted. On the Tanzanian side of the basin the Ministry of Water has established a water quality laboratory in Musoma with support from the Lake Victoria Environmental Management Programme, and this office conducts occasional water quality campaigns into the lower Mara Basin.

In order to provide comprehensive baseline information to an assortment of planned and ongoing activities in the Mara Basin, we conducted three surveys of water quality at 21 stations across the river basin from its source on the Mau Escarpment to its outlet at Lake Victoria. The objective of these surveys was to evaluate the condition of the Basin's water quality over

multiple years and identify potential threats. All samples were analysed for physical properties, mineral abundances, and nutrients; a subset of samples was also analysed for mercury and pesticides. Data from prior sampling campaigns were also collected and listed in the appendices. No areas of serious contamination were observed, but a number of results warrant further consideration.

At the time of the surveys, patterns in water quality data varied as a function of position along the river, land use, and rainfall/discharge.

- In general, the mineral content of Mara River water increased downstream, probably due to the combined effects of mineral inputs from agriculture and mining and evaporation from the river surface.
- Nutrient concentrations were highest in the agricultural sectors of the basin, while organic matter was most abundant at the river's source in the Enupuiyapi Swamp and at its mouth in the wetlands bordering Lake Victoria.
- Sediment concentrations were highest in stations sampled after rain events. These stations, in Masai-Mara National Reserve in Kenya and Serengeti National Park in Tanzania, also had the highest concentrations of mercury and aluminium, suggesting that these metals were associated with sediments mobilized following the rains.
- Pesticides (Hexachlorobenzene and 4.4 DDE) were detected at one station on the Amala River near the Mulot trading post in Kenya.
- PCBs (PCB 28/31, PCB 52, PCB 44) were detected in 6 of 8 stations sampled, including those in Masai-Mara National Reserve and Serengeti National Park.

Although concentrations of nutrients, mercury, pesticides, and PCBs were all below existing standards, deleterious effects may still derive from these compounds. Nutrient concentrations are above natural levels and appear to be causing eutrophication in the wetlands at the mouth of the river. Increased nutrient concentrations can lead to increased algal growth or algal blooms which can then sufficate the ecosystem. Mercury and PCBs have a tendency to accumulate in organisms and along food chains, so even low concentrations in water may result in harmful accumulations in wildlife and people.

These findings highlight the need for more systematic monitoring of water quality across the basin, ideally using comparable methodologies and carried out at similar intervals. Furthermore results should be rapidly fed into the management and decision-making process involving both water management agencies in the capital cities as well as local water offices and water user associations. Specific recommendations are offered to begin working toward this goal.

- Water offices on the Kenyan and Tanzanian sides of the basin should harmonize protocols, methodologies and sampling regimes.
- All laboratories should pursue appropriate accreditation for analytical techniques used. In lieu of accreditation, laboratories should develop a program of inter-laboratory comparison and calibration to be repeated annually. This will ensure comparability of results.
- Monitoring programs on each side of the border should develop common quality assurance and quality control (QA/QC) plans detailing protocols of collection, handling, and analysis.
- Kenyan and Tanzanian agencies should conduct joint training sessions for monitors to ensure consistent field techniques and to occasionally introduce new or revised methodologies.
- A joint protocol should be developed to rapidly process data and communicate results to relevant local, national and regional decision makers and stakeholders.

1.0 Introduction

An component to achieving the goals of GLOWS and its partners in the Mara River Basin is to understand the condition of and potential threats to the water quality of the Mara River system. In May-2005, May-2006, and June-2007, GLOWS conducted water quality surveys throughout the entire length of the Mara River Basin. The main purpose of these surveys was to evaluate the condition of the Basin's water quality and to identify potential threats. As up to date analytical procedures, functional laboratory equipment, proper methodologies and a regular sampling program are integral to water quality management, GLOWS also met with water engineers and water laboratories to gather information on the current sampling program within the Basin.

This document describes the results of the water quality surveys and describes the current sampling programs within the basin. In section 2, background information on the Mara River basin is described. The sectors and stakeholders of the basin are also introduced, as are the potential threats to water quality in the basin. Section 3 lists the standards established by the World Health Organization (WHO), Kenya and Tanzania on

Box 1: Vision for the Mara River Basin

The GLOWS consortium is working with local partners toward a future for the Mara River Basin when:

- Water resources in the Mara Basin are managed according to a trans-national agreement that responds to the national water strategies of each country and specifies the transboundary flow prescriptions.
- Decisions about water allocation and management are made by basin-scale Water User Associations (WUAs) composed of members representing all key stakeholders.
- Water management is based on good scientific data collected and maintained by water offices of the national governments on each side of the border. Data are shared freely between the countries.
- Water allocation decisions are based on accurate knowledge of environmental flows, and allocations are guaranteed to support the renowned natural ecosystems of the basin, including the Mau Forest, Mara-Serengeti ecosystem, and Musoma swamps of Lake Victoria.
- Water quantity and quality is maximized through the application of appropriate Best Management Practices by:
    - Large scale industrialized farms and mines
    - Ecotourism companies and hotels
    - Small-scale farmers and Maasai ranchers
- Water is recognized as an economic good with real value. Water users pay a fair price for water and for the environmental services required to maintain water quantity and quality.
- Appropriate technologies are applied by households and communities for water purification and waste disposal. All basin inhabitants enjoy potable water and proper sanitation.
- Fisheries of Musoma Bay and the Mara swamp complex are managed according to legally recognized community-based plans.

water quality. In section 4, we describe the national frameworks for water quality monitoring programs and policies for the management of water in both Kenya and Tanzania. We then describe the water laboratories within the Mara River basin. Information on sampling regimes, analytical procedures, equipment, supplies and needs for the laboratories is also provided. Sections 5 and 6 relate to the baseline water quality surveys. In section 5, sampling sites and the methodologies are described. Section 6 provides the results of the studies in relation to existing and potential pollution. Conclusions and recommendations are presented in sections 7 and 8, respectively.

2.0 Background

The Mara River Basin is a transboundary basin shared by Kenya and Tanzania (approximately 65% and 35% of the basin, respectively)(Fig. 1). It is part of the larger Nile River Basin, which is shared by nine countries. The Mara River begins as the Amala and Nygangores tributaries that flow through the forested Mau Escarpment, tea plantations, settlements and small-scale agriculture in Kenya. The Amala and Nygangores tributaries converge to form the Mara River in a region characterized by large-scale agriculture. The Mara River then meanders through Maasai Group Ranches and two internationally renowned conservation areas, the Masai-Mara National Reserve in Kenya (1718 km^2, all of which is within the Mara River Basin) and the Serengeti National Park in Tanzania (of which 1741 km^2 falls within the Mara River Basin). In these protected areas two other main tributaries, the Talek River and the Sand River, join the Mara River. The mainstem Mara River continues flowing through the savannah grasslands that characterize the Serengeti region in Tanzania before entering the non-protected Mara Swamp (max and discharging into Lake Victoria.

2.1 Stakeholders and Sectors of the Mara River Basin

The Mara River Basin flows though diverse landscapes supporting a wide array of ecosystem and human needs. Stakeholders and sectors of the Mara River include urban settlements and villages, subsistence and large-scale agriculture, forestery, livestock, fisheries, tourism, conservation areas and biodiversity, mining and other industries.

The Mara River Basin is dotted with urban settlements, villages, and missionary communities. On the Kenyan side of the basin, urban settlements include the towns of Bomet and Tenwek Missionary Hospital Community along the Nygangores tributary, and Mulot trading center along the Amala tributary. In Tanzania, urban settlements include Ngoreme and Buhemba and a portion of Mugomo.

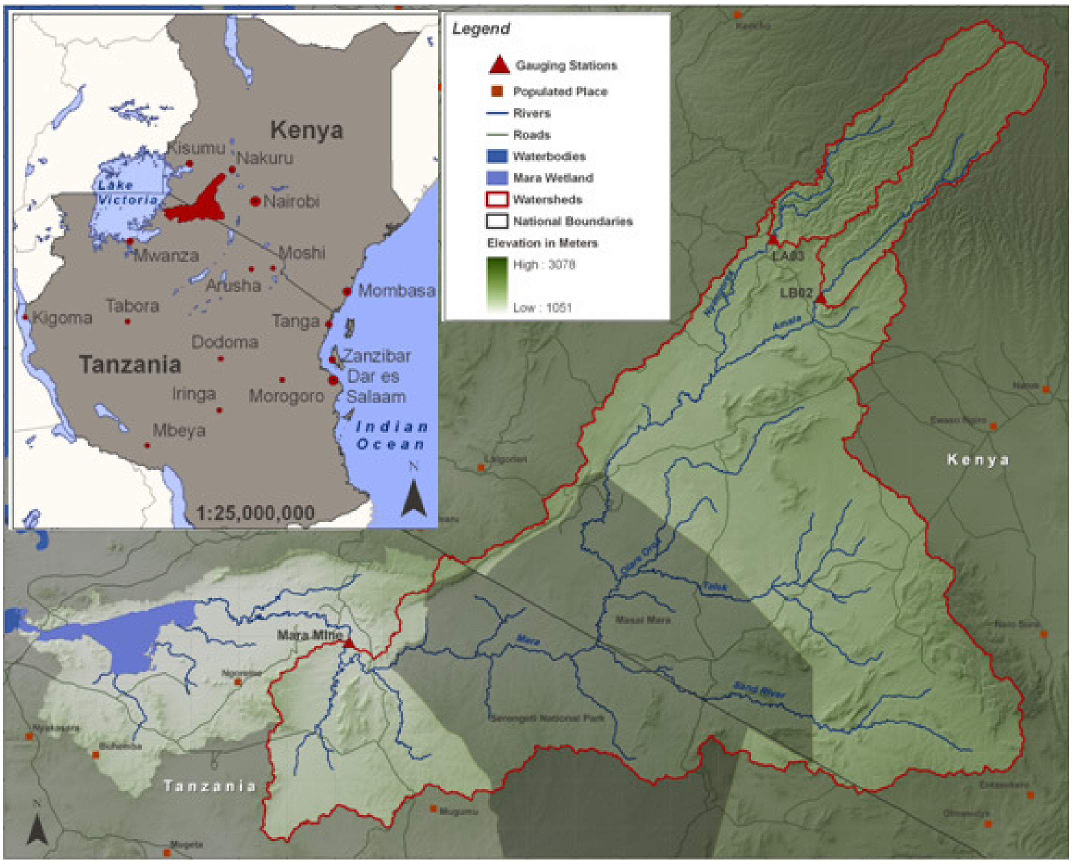

Figure 1. Map of the Mara River Basin. The Masai-Mara National Reserve and Serengeti National Park shaded. Sub-catchments of existing gauging stations are outlined in red. Inset shows position of the Mara Basin in Kenya and Tanzania.

Agriculture accounts for approximately 80% of the employment for both Kenya and Tanzania and contributes an estimated 16 and 43% for the gross domes tic product (GDP), respectively. In Kenya, subsistence farming accounts for the majority of food crops whereas the majority of cash crops are grown on private large-scale plantations. Main agriculture crops for Kenya include maize, sorghum, cassava, sugar and beans, and for Tanzania, include rice, maize, cassava and millet. The main cash crops for both Kenya and Tanzania include tea, coffee and cotton. Livestock accounts for 30% of the agriculture GDP of both Kenya and Tanzania. Fish catch in Kenya was estimated at 162,000 metric tons in 1997 of which, only about 4% was marine (FAO, 2001). The annual fish catch in Tanzania is about 350,000 metric tons (includes both marine and freshwater species). The majority of fish caught is consumed locally (fish contributes to an estimated 30% of the diet of the Tanzanian population) while Nile perch, sardines and prawns are for export (URT, 2001).

The incredible biodiversity, concentrations of wildlife and annual wildlife migrations in the savannah grasslands of Kenya and Tanzania draw tourists from around the world. Protected areas of the Masai-Mara National Reserve and the Serengeti National Park are scattered with more than 60 tourist facilities on the Kenya side of the basin alone. In 2004, approximately

240,000 tourists visited Masai-Mara National Reserve, and in 2002 more than 375,000 visited Serengeti National Park (Kenya CBS 2005, Tanzania NBS 2002). Tourism, which is largely based on wildlife, is a keystone for both Kenya and Tanzania's GDP contributing approximately 12 and 16%, respectively.

The ecosystems of Kenya and Tanzania boast one of the most diverse and populated terrestrial wildlife populations and the largest intact wildlife migration on earth. Serengeti National Park alone covers approximately 14% of Tanzania's land area. Although the first series of laws were in place in the 1920's, Serengeti National Park was not officially created until 1951. In 1959, the neighbouring Ngorongoro Conservation Area was established to support coexistence of both wildlife conservation and Maasai pastoralism (Zeitler, 2000). The open savannah grasslands of the Serengeti continue north across the border into Kenya and are protected within the Masai-Mara National Reserve. The Masai-Mara is a National Reserve managed by local authorities of Narok and Transmara Districts.

Mining in Kenya accounts for less than 1% of the GDP and is dominated by nonmetallic minerals such as fluorspar, salt and soda ash. Gold mining in Kenya is mostly artisanal (Yager, 2003). Mining accounts for 2.3% of Tanzania's GDP with diamonds and gold a mainstay of the country's mineral production (URT, 2001).

2.2 Potential Threats in the Mara River Basin

There are several potential threats to water quality in the Mara Basin, including high human population growth rates, deforestation, potentially unsustainable agricultural expansion and irrigation, untreated wastewater release, and uncontrolled water abstractions. It is estimated that only 58% of the population has access to safe drinking water. Kenya is currently in a 'water stressed' condition (allocation of water is 1000-1700 m^3 per person per year) and is forecasted to become a 'water scarce' nation (allocation of water is less than 1000 m^3 per person per year) in the next 25 years. In Tanzania, it is estimated that 68% of the population has access to safe drinking water. Based on projected population growth, the UN projects that Tanzania will become a 'water stressed' nation by 2025 (UNPFA, 2003 and UNEP, 2002).

The population in the Kenyan portion of the Mara Basin is estimated at 450,000. Nationally the population growth rate is estimated at 2.56%, the unemployment rate is approximately 40% and it is estimated that 50% of the population live below the poverty line, earning less than U$1 per day. The population in the Tanzania portion of the Mara Basin is estimated at 240,000. Nationally the growth rate of 1.83% (2005 est.), and 36% of the population live below the poverty line, earning less than U$ 1 per day.

High population growth rates and agriculture expansion threaten forest ecosystems through increased deforestation. It is estimated that about one-tenth of Kenya's population lives within 5 km of forest, which cover over 30% of Kenya's land (UNEP, 2002). Forest systems are of high commodity value providing timber for fuel, construction material, and the wood carving industry. Impacts of deforestation include increased soil erosion and sediment loads in waterways, decreased soil fertility, loss of biodiversity and possible local climate changes.

Inappropriate agriculture practices contribute to poor water quality by increased pollution from agrochemical run-off. Excess fertilizers, pesticides and herbicides applied to crops eventually enter surface and ground waters. Increased inputs of nitrogen and phosphorous can lead to the eutrophication (see Box 2) of aquatic systems, possibly resulting in blooms of algae (potentially harmful), anoxic (low-oxygen) conditions and fish die-offs. Pesticides and herbicides in waterways can eventually enter the food chain. These chemicals accumulate up the food chain and can become toxic to organisms.

To complicate matters, poorly-managed water abstractions and wastewater releases can decrease much needed flows of clean water downstream. The famous wildebeest migration in the Serengeti/Masai Mara plains is driven by the search for water during the dry season. Hydropower supplies an estimated 78% of Kenya's electricity (UNEP, 2002) and 65% of Tanzania's electricity (Kitova, 2001). Currently, only one hydroelectric dam is operating in the Mara River Basin, at Tenwek on the Nyangores tributary, but more dams or diversions for hydroelectricity may be proposed. In other areas, increased abstractions and drought have led to decreased water supply to hydroelectric dams, with corresponding interruptions to supplies of electricity. Life and livelihoods, agriculture irrigation, biodiversity and wildlife populations, transport, tourism and recreation are all tied to sufficient water supply. Low water supplies can also lead to improper treatment or the non-treatment of wastewater prior to release.

3.0 Water Quality Standards

3.1 National Standards

Countries and organizations ensure 'quality' of freshwater systems through establishment of water quality guidelines. The water quality guidelines most often followed by monitoring programs within Kenya and Tanzania are those established by the World Health Organization (WHO) for drinking water. In Kenya, effluent discharge standards have not been established, but generalized guidelines have been adopted from the British Royal Commission Standards (NTEAP, 2005*a*). In Tanzania, the Tanzania Temporary Standards (TTS) for quality of domestic water have been established under the Water Utilization (Control and Regulation) act No. 42 of 1974, amendment No. 10 of 1981. Also established under this amendment, are standards for effluents and receiving waters (NTEAP, 2005*b*). Guidelines for the variables examined during the May, 2005, baseline water quality campaign from WHO (Drinking Water), Kenya (Effluent Discharge), Tanzania (Receiving, Effluent and Domestic) are presented in Table 1.

4.0 Water Quality Monitoring

4.1 National Frameworks

4.1.1 Kenya

The Ministry of Water and Irrigation (MWI), formerly the Ministry of Water Resources and Development (MWR&D) has a fundamental goal and purpose of conserving, managing and protecting water resources for socio-economic development. The Water Act No. 8 of 2002 provides an enabling institutional and legal framework for the implementation and realization of the objectives stated in the National Policy on Water Resources Management and Development. The Act provides for the Water Resources Management Authority (WRMA), which maintains the responsibility of ensuring the good management of the country's water resources. The WRMA has drafted a Country Strategy Paper on Integrated Water Resources Management.

4.1.2 Tanzania

The Water Utilization (Control and Regulation) Act No. 42 of 1974 with its amendment in 1981 declares that all of the country's water is vested to the state, sets conditions on the use of water and authorizes the Principal Water Officer with authority to be responsible for setting policy and allocation of water rights at the national level. For designated water drainage basins with established Basin Water Offices, the responsibilities are under the Basin Water Officer.

4.2 Current Status of Monitoring

There are currently four water laboratories with responsibility for the Mara River Basin, three of which are operated by government agencies and one private laboratory at Mara Mines. Equipment, methodologies, and parameters analysed are not consistent between laboratories. Information about the Kenyan and Tanzanian laboratories is presented in Tables 2 and 3, respectively.

4.2.1 Kenya

Two water quality laboratories are operated by the Ministry of Water and Irrigation in Kenya, one in the Bomet District near the Nygangores River and one in the Narok District just south of the confluence of the Nygangores and Amalo Rivers. The water laboratory of the Bomet District is a well-stocked

Table 1: Guidelines and standards for maximum allowable levels of the different variables as set by the World Health Organization (WHO) and the government of Kenya

		WHO[1]	Kenya[2]				
		Drinking Water	Domestic Water	Effluent Discharge into the Environment[3]	Effluent Discharge into Public Sewers	Irrigation Water	Recreational Waters
Variable	**Units**						
Temperature	°C			Discharge of effluents shall not raise the temperature of the receiving water by more than 3˚ C	20-35		30
Total Dissolved Solids	mg/L	1000	1200	1200	2000	1200	
Total Sus-pended Solids	mg/L		30		250		
Turbidity	NTU	5					50
PH		<8.0	6.5-8.5	6.5-8.5	6.0-9.0	6.5-8.5	6-9
Chlorine	mg/L	5		0.10 free residue	5 (as Free)		
Ammoniacal nitrogen	mg/L		0.5	100[4]	20		
Nitrate	mg/L	50	10	100[4]	20		
Phosphorous	mg/L				30		
Aluminium	mg/L	0.2				5	
Mercury	mg/L	0.001		0.005	0.05		0.001

[1] Column modified from Chapman (1996).
[2] Column modified from WRMA (2006)
[3] Values are daily/monthly average discharge values, however, the documents does not specify what each parameter falls under.
[4] Parameter is defined as ammonia, ammonium compoundes, nitrate compounds and nitrite compounds (sum total of ammonia-N times 4 plus nitrate-N and nitrite-N)

Table 2: Guidelines and standards for maximum allowable levels of the different variables as set by the World Health Organization (WHO) and the government of Tanzania

		WHO[1]	**Tanzania[2]**					
		Drinking Water	**Receiving Water Standards**			**Effluent Standards**		**Domestic Water**
Variable	**Units**		**Cat. 1[3]**	**Cat. 2[4]**	**Cat. 3[5]**	**Cat. 4[6]**	**Cat. 5[7]**	
Temperature	°C		Discharge of effluents shall not raise the temperature of the receiving water by more than 5°C			Discharge of effluents shall not raise the temperature of the receiving water by more than 5°C	35°C or not more than 5°C above ambient temperature of the supplied water whichever is greater	
Total Dissolved Solids	mg/L	1000	2000	2000	No limit	3000	7500	
Total Suspended Solids	mg/L		Discharge of effluents shall not cause formation of sludge or scum in the receiving water.			Discharge of effluents shall not cause formation of sludge or scum in the receiving water.	No Limit	
Turbidity	NTU	5	Discharge of effluents shall not cause formation of sludge or scum in the receiving water.					30

[1] Column modified from Chapman (1996).
[2] Column modified from NTEAP (2005b).
[3] Category 1 is defined by NTEAP (2005*b*) as water that is suitable for drinking, water supplies, swimming pools, food and beverage manufacturing industries, pharmaceuticals manufacturing industries or industries requiring a water source of similar quality.
[4] Category 2 is defined by NTEAP (2005*b*) as water suitable for use in feeding domestic animals; in fisheries, shell cultures, recreation and water contact sports.
[5] Category 3 is defined by NTEAP (2005*b*) as water suitable for irrigation and other industrial activities requiring water of standards lower than those of water in category 1 and 2.
[6] Category 4 is defined by NTEAP (2005*b*) as effluents meant for direct discharge into receiving waters.
[7] Category 5 is defined by NTEAP (2005*b*) as effluents meant for indirect discharge into receiving waters (e.g. via a sewage treatment plant).

Table 2: *Continued*

		WHO[1]	**Tanzania[2]**					
		Drinking Water	**Receiving Water Standards**			**Effluent Standards**		**Domestic Water**
Variable	**Units**		**Cat. 1[3]**	**Cat. 2[4]**	**Cat. 3[5]**	**Cat. 4[6]**	**Cat. 5[7]**	
pH		<8.0	6.5-8.5	6.5-8.5	6.5-9.0	6.5-8.5		6.5-9.2
Dissolved Oxygen[8]	mg/L		6	5	3			
Dissolved Oxygen [9]	%		80	60	40			
Chlorine	mg/L	5				1.0 (as Free)	5 (as Free)	
Total Hardness	mg/L							600
Calcium Hardness	mg/L							----
Magnesium Hardness	mg/L							300
Ammoniacal nitrogen	mg/L					10	No Limit	----
Nitrate	mg/L	50	50	50	100	50	80	31/100

[1] Column modified from Chapman (1996).
[2] Column modified from NTEAP (2005*b*).
[3] Category 1 is defined by NTEAP (2005*b*) as water that is suitable for drinking, water supplies, swimming pools, food and beverage manufacturing industries, pharmaceuticals manufacturing industries or industries requiring a water source of similar quality.
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[6] Category 4 is defined by NTEAP (2005*b*) as effluents meant for direct discharge into receiving waters.
[7] Category 5 is defined by NTEAP (2005*b*) as effluents meant for indirect discharge into receiving waters (e.g. via a sewage treatment plant).
[8] Values listed are minimum allowable levels.

Organic phosphorous	mg/L							

Table 2: ***Continued***

		WHO[1]	**Tanzania[2]**					
		Drinking Water	**Receiving Water Standards**			**Effluent Standards**		**Domestic Water**
Variable	**Units**		**Cat. 1[3]**	**Cat. 2[4]**	**Cat. 3[5]**	**Cat. 4[6]**	**Cat. 5[7]**	
Phosphorous	mg/L		Variable[9]			6	45	
Aluminium	mg/L	0.2	0.3	0.3	0.3	2	5	
Mercury	mg/L	0.001	0.001	0.001	0.005	0.005	0.005	----
Total pesticides	µg/L							
Organochlorine Pesticides	mg/L		0.0005	0.0005	0.001	0.005	0.005	
Aldrin and Dieldrin	µg/L	0.03						
Chlordane	µg/L	0.2						
Chlorphyrifos	mg/L	0.03						
DDT and metabolites	µg/L	1						
Methoxychlor	µg/L	20						

[1] Column modified from Chapman (1996).
[2] Column modified from NTEAP (2005*b*).
[3] Category 1 is defined by NTEAP (2005*b*) as water that is suitable for drinking, water supplies, swimming pools, food and beverage manufacturing industries, pharmaceuticals manufacturing industries or industries requiring a water source of similar quality.
[4] Category 2 is defined by NTEAP (2005*b*) as water suitable for use in feeding domestic animals; in fisheries, shell cultures, recreation and water contact sports.
[5] Category 3 is defined by NTEAP (2005*b*) as water suitable for irrigation and other industrial activities requiring water of standards lower than those of water in category 1 and 2.
[6] Category 4 is defined by NTEAP (2005*b*) as effluents meant for direct discharge into receiving waters.
[7] Category 5 is defined by NTEAP (2005*b*) as effluents meant for indirect discharge into receiving waters (e.g. via a sewage treatment plant).
[9] Defined by NTEAP (2005*b*) as the lowest possible concentration that should be aimed for in waters that are susceptible to eutrophication or excessive weed growth, or in rivers and streams draining into such waters.

laboratory but was without a water engineer in 2005. The Mara Field Office of WWF-EARPO has been working closely with the Narok district water engineers and had accomplished two monitoring surveys of the Kenyan Mara as of May 2005.

4.2.2 Tanzania

In Tanzania, the Ministry of Water operates a water quality laboratory in Musoma District, and Barrick Gold Mines has a laboratory on-site at their Tarime District location. The Musoma water laboratory is well-equipped and receives much of its funding from the Lake Victoria Environmental Management Programme. Focus is on the water quality of Lake Victoria and there are limited sampling sites in the Mara River. The WWF Mara Program has worked with the Musoma laboratory and provided funding for an initial water quality study in the Tanzanian Mara.

We are unsure of the water quality program Barrick Gold Corporation has underway presently. In 2005, Placer Dome operated the Mara Mine. Placer Dome did many of their physical and chemical parameters on-site; however, many samples (i.e.: trace metals, etc.) were sent off-site to accredited labs. Monitoring of surface water was done on a quarterly basis. Six sites were monitored along the Mara River and six sites were monitored along the Tigite River (a tributary to the Mara). Placer Dome had also initiated studies of sediment cores and fish tissue in the Mara Swamp. We do not have results from any of these studies.

5.0 Water Quality Monitoring Assessment

5.1 Sampling Sites

Samples were collected and readings taken from 21 sites along the mainstem Mara River and its tributaries during May-2005, June-2006, and June-2007 (Fig. 2). Locations of sampling sites were replicated from initial water quality studies previously performed by WWF (2004) and Kenya Ministry of Water and Irrigation Narok District (2004). A summary of site descriptions for each station is listed in Table 4.

Table 3: Summary of Mara river basin water laboratory analyses and methodologies in Kenya.

Kenya					
Bomet District[1]			**Narok District**		
Analyses	**Instrument**	**Methodology**	**Analyses**	**Instrument**	**Methodology**
Acidity		Titration	Temperature	Hanna HI9810	Meter
Color		Meter	Conductivity	Hanna HI9810	Meter
Hardness		Titration	TDS	Hanna HI9810	Meter
Alkalinity		Titration	pH	Hanna HI9810/Lovibond PC MultiDirect	Meter/Phenol Red
pH		Phenol Red	Turbidity	Secchi Disk	Secchi Disk
Suspended Solids		Volumetric	Alkalinity	Lovibond PC MultiDirect	Acid/Indicator
Calcium		EDTA Titration	Chlorine	Lovibond PC MultiDirect	DPD
Chloride		Titration	Total Hardness	Lovibond PC MultiDirect	Metallphthalein
Fluoride		SPADNS	Calcium Hard-ness	Lovibond PC MultiDirect	Murexide
Ammonium		Colorimetric/ Titra-tion	Magnesium Hardness	Lovibond PC MultiDirect	Calculated from Total and Calcium Hardness
Total Nitro-gen		Titration/Colorimetric	Chloride (Cl^-)	Lovibond PC MultiDirect	Silver Nitrate/Turbidity
Nitrate		Colour Brucine	Fluoride (Fl^-)	Lovibond PC MultiDirect	SPADNS
Nitrite		Spectrophotometer	Nitrate (NO_3^-)	Lovibond PC MultiDirect	Chromotropic Acid
Dissolved Oxygen		Modified Winkler Method	Nitrite (NO_2^-)	Lovibond PC MultiDirect	N(1-Naphthyl)ethylenediamine
Phosphate		Ascorbic Acid	Orthophosphate (PO_4^-)	Lovibond PC MultiDirect	Ascorbic Acid
Silica		Colour	Sulphate (SO_4^{2-})	Lovibond PC MultiDirect	Bariumsulphate-Turbidity
Sulphate		Turbid/ Gravitational	Aluminium (Al)	Lovibond PC MultiDirect	Eriochrome Cyanine
Sulfite		Titration	Bromine (Br)	Lovibond PC MultiDirect	DPD
COD		Titration	Iron (Fe)	Lovibond PC MultiDirect	PPST
Oil and Grease		Funnel Extraction	Manganese (Mn)	Lovibond PC MultiDirect	Formaldoxim
BOD	Respirometric Oxitop Box				

[1]At time of visit (May 2005) there is no water engineer on-site. List of methods found at the laboratory included EPA 1979 Methodologies and other sheets with procedures. Methodologies listed on these sheets are included above.

Table 4: Summary of Mara river basin water laboratory analyses and methodologies in Tanzania.

Tanzania					
Placer Dome Gold Mines[1]			**Musoma District[2]**		
Analyses	**Instrument**	**Methodology**	**Analyses**	**Instrument**	**Methodology**
Temperature			Total Phosphorus		APHA
Conductivity			Orthophosphate		APHA
TDS			Silicate		APHA
pH			Biogenic Silicate		APHA
Alkalinity			Nitrite		APHA
Free Chlorine			Nitrate		APHA
Total Chlorine			Ammonium		APHA
Chloride			Total Nitrogen		APHA
Nitrate and Nitrite (N+N)			BOD		APHA
Sulphate (SO_4^{2-})			PH		APHA
Total Mercury (THg)			Dissolved Oxygen		APHA
Total Cyanide	PharmSpec UV-1700				
Free Cyanide	PharmSpec UV-1700				
Weak Acid Dissociable Cyanide	PharmSpec UV-1700				

[1]Placer Dome Gold Mines no longer operates Mara Mine. We have no information about the laboratory in the mine today under the new operator, Barrick Gold Corporation.
[2]Musoma Water Laboratories fall under the LVEMP program and have a well-stocked laboratory. Their methodologies follow the APHA as listed in Table 3.

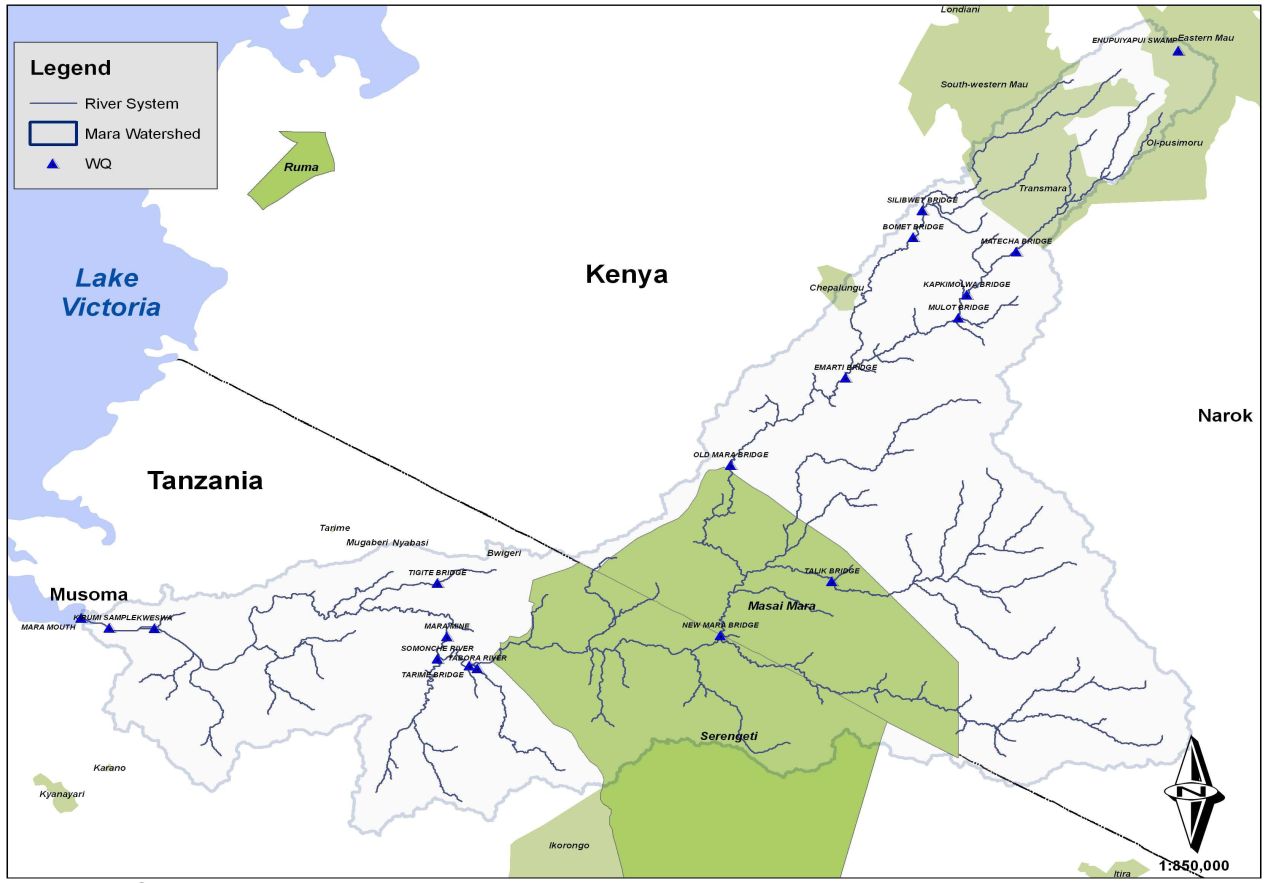


Figure 2: Sampling site locations along the Mara River and its tributaries. The Mara river watershed is outlined in grey and national parks/forest complexes are shaded green. Sampling sites are indicated by a blue triangle.

Table 5. Summary of site names and descriptions sampled during the May, 2005, water quality sampling campaign.

Station Number	Station Name	Tributary/ River	Land-Use Type/Major Issue	Station Description
1	Enupuiyapi Swamp	Amala	Plantations	Headwaters for the Mara River. Surrounding area is used for Cypress and Eucalyptus plantations.
2	Matecha Bridge	Amala	Waste Management, Agriculture	Settlements, agriculture (tea).
3	Kapkimolwa	Amala	Waste Management, Agriculture	Settlements, agriculture (tea).
4	Mulot Bridge	Amala	Waste Management, Agriculture	Located downstream of the convergence of the Ngasiat River with the Amala River. Trading center, small-scale agriculture.
5	Silibwet Bridge	Nyangores	Waste Management, Agriculture	The surrounding community is largely involved in tea farming.
6	Tenwek Dam	Nyangores	Hospital, Dam, Waste Management	This is the location of the sole dam in the Mara River system. The dam was developed to provide electrical power to the surrounding hospital and community. Recent years have found increased silting of the reservoir enough to significantly reduce (to 30% of full) capacity of dam.
7	Tenwek Treated Wastewater		Hospital, Dam, Waste Management	Sample was taken from pipe which feeds treated wastewater into the hillside.
8	Tenwek Downstream	Nyangores	Hospital, Dam, Waste Management	The surrounding community was developed around the missionary hospital.
9	Bomet Bridge	Nyangores	Waste Management, Agriculture	Located in the Bomet district downstream of Tanwek community hospital. Bomet is in the process of securing funding for the construction of a wastewater treatment plant.
10	Emarti Bridge	Mara	Large-scale Agriculture	Located downstream of the convergence of the Amala and Nyangores Rivers. Acts as a division between the Transmara and Narok Districts. Flows through Group ranches of both urban and traditional settlements
11	Old Mara Bridge	Mara	Tourism	Located within the Masai-Mara National Reserve.
12	Talek Bridge	Talek	Tourism	Located within the Masai-Mara National Reserve.

Table 5. Summary of site names and descriptions sampled during the May, 2005, water quality sampling campaign.

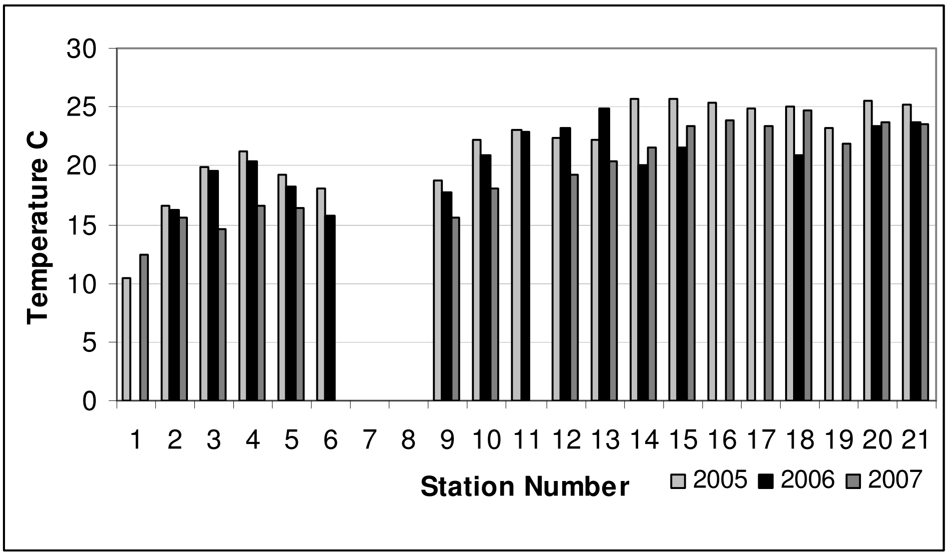
Station Number	Station Name	Tributary/ River	Land-Use Type/Major Issue	Station Description
13	New Mara Bridge	Mara	Tourism	Located in the Masai-Mara National Reserve just above the Kenyan-Tanzanian border.
14	Tabora	Tabora	Waste Management, Agriculture	Tabora stream originates from Mugomo, which is the main town in Serengeti District. This stream feeds into the Mara upstream of the Tarime/Serengeti bridge. Farming and domestic activities are common.
15	Tarime	Mara	Mining, Waste Management	Settlements, agriculture and other human activities.
16	Somonche	Somonche	Mining, Waste Management	Settlements, agriculture, human activities and mining.
17	Mara Mines	Mara	Mining, Waste Management	Settlements, agriculture and human activity.
18	Tigite	Tigite	Mining, Waste Management	Tigite stream feeds into the Mara upstream of Bisarwi. Common activities along this stream include gold mining (Placer Dome), small-scale-gold mining, farming and domestic uses. There are a number of settlements within this region.
19	Kwesawa	Mara	Waste Management, Agriculture	Small-scale farming and fishing are main activities within this area. This station is sampled quarterly by the Musoma Lab for the LVEMP program concerning water hyacinths. Anoxia is commonly noted in this area.
20	Kirumui Bridge	Mara	Waste Management, Agriculture	Small-scale farming, domestic activities and fishing.
21	Lake Victoria at Mara River Mouth	Lake Victoria/ Mara	Waste Management, Agriculture	Activities in this area include fishing and farming. There are noted problems with eutrophication and weed (papyrus and hyacinth) overgrowth.

6.0 Findings of Water Quality Assessment

6.1 Temperature

Temperature for all three surveys ranged from 10.4˚C to 25.7˚C along the Mara River and its tributaries (Fig. 3). Temperature is affected by many factors including but not limited to season, time of day, altitude and cloud cover. Temperature tended to increase along the Mara River as altitude decreased. The lowest temperature was recorded at the Enupuiyapi Swamp (sta. 1), the source of the Mara River. The highest temperature was recorded at the Tarime (sta. 15) station on the Mara main stem located in the open savannah grasslands of Tanzania. Variations in temperature among stations also may be attributed to differences in time of sampling and/or the presence of rains.

Figure 3: Temperature (°C) along the Mara River and its tributaries during the three sampling campaigns.



6.2 Alkalinity and pH

Alkalinity is one of a number of measures of the mineral content of natural waters. During the three surveys alkalinity ranged from 12 ppm at the Enupuiyapi Swamp (sta. 1 - 2005) to 215 ppm at Tabora (sta. 14 - 2007) (Fig. 4). Higher alkalinity was detected in the treated wastewater from Tenwek (sta. 7) in 2005 and in Talek Bridge (sta. 12) and Tigite (sta. 18) in 2006. Tabora Stream (sta 14) had the highest levels of alkalinity in both years. Elevated alkalinity values alone are not a cause for concern. pH is a measure of the acidity of water. pH of Mara waters during the three campaigns ranged from 4.8 at the Enupuiyapi Swamp (sta. 1) to 7.6 at Somonche (sta. 16) and Mara Mines (sta. 17), with an average of 7.1 ± 0.7 (Fig. 5). All values, except the 4.8 level at Enupuiyapi, fall within acceptable pH values from WHO, Kenya and Tanzania (Table 1). There was not a significant difference in pH between the years sampled. Most natural waters fall within a pH range of 6.0 to 8.5. The low value measured at the Enupuiyapi swamp station is likely caused by an abundance of natural organic acids in the swamp waters (Chapman, 1996).

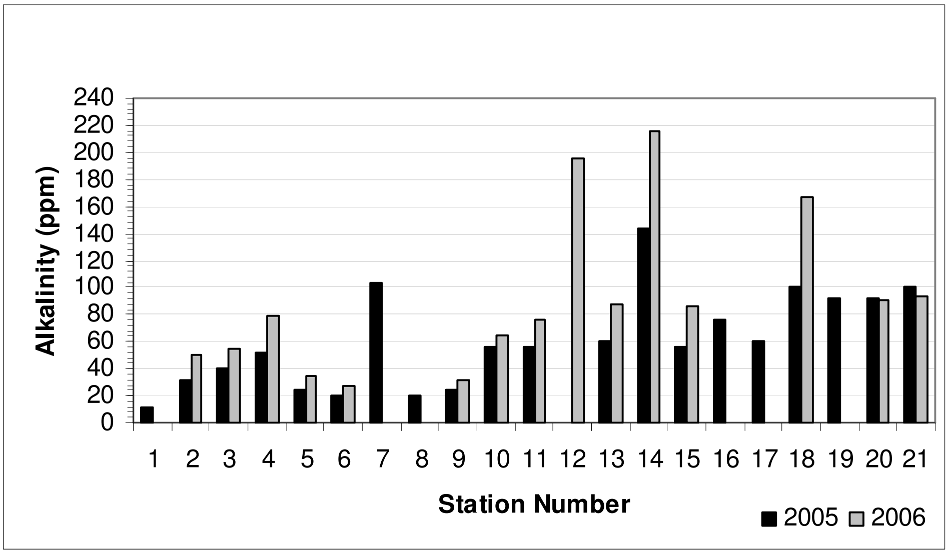


Figure 4. Alkalinity (ppm) along the Mara River and its tributaries during the 2005 and 2006 sampling campaigns.

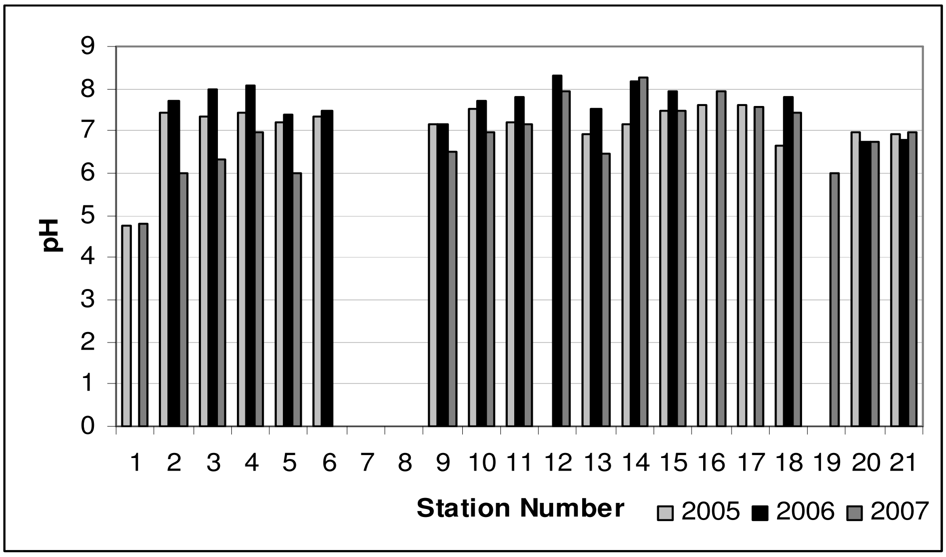


Figure 5. pH along the Mara River and its tributaries during the three sampling campaigns.

6.3 Electrical Conductivity, Total Dissolved Solids and Salinity

Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Salinity are all measures of the mineral content of natural waters, and results for these parameters followed similar patterns across the Mara Basin. Lowest values were detected in the Enupuiyapi Swamp (sta. 1) and highest values were detected in Talek Bridage (sta. 18) and the stream at Tabora (sta. 14) (Figs. 6-8). In general, values increased downstream. Increases may be related to mineral inputs as well as evaporation from the river channel. TDS levels are well under the maximum acceptable levels as defined by the WHO, Kenya and Tanzania guidelines (Table 1). Conductivity, TDS and salinity levels along the Amala River increased from the headwaters in the Enupuiyapi Swamp (sta. 1) to the point of convergence with the Nyangores River to form the Mara River. However, the Nygangores River maintained consistent levels of conductivity (~50 μS/cm^2), TDS (~0.04 g/L) and salinity (~0.02 ppt) at all three sampling sites (Silibwet (sta. 5), Tenwek (sta. 6) and Bomet (sta. 9)). Low conductivity and TDS are often characteristics of forested rivers (Chapman and Chapman, 2003; Ngoye and Machiwa, 2004); however, from this study alone it is difficult to ascertain whether differences between the two tributaries are a natural occurrence or are the result of anthropogenic impacts.

Figure 6. Conductivity (EC; μS/cm^2) along the Mara River and its tributaries during the three sampling campaigns.

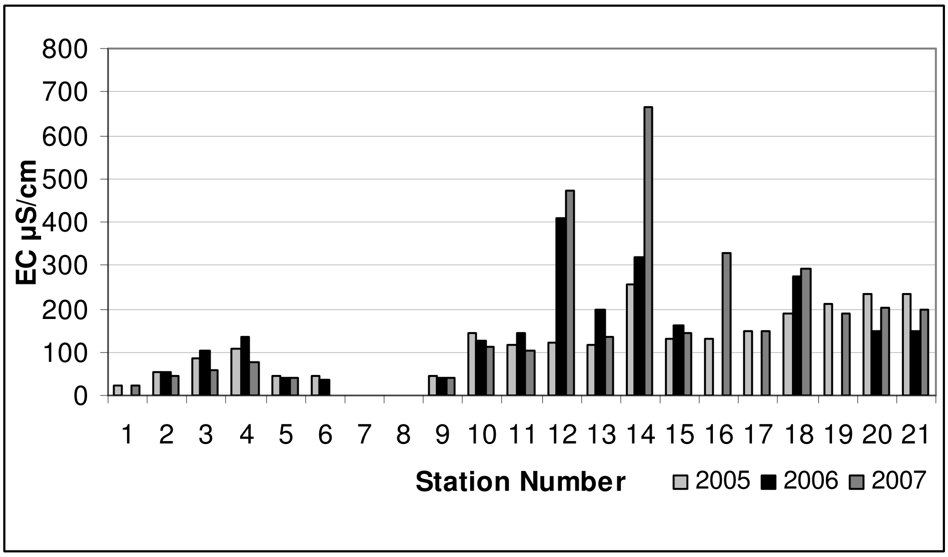


Figure 7. Total dissolved solids (TDS; g/L) along the Mara River and its tributaries during the May 2005 sampling campaign. Station number identifications are located in Table 4.

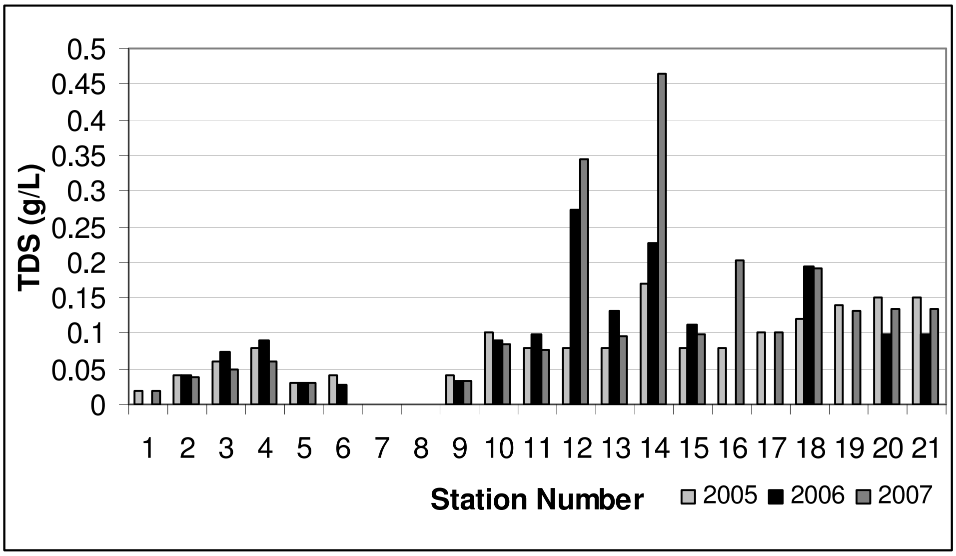
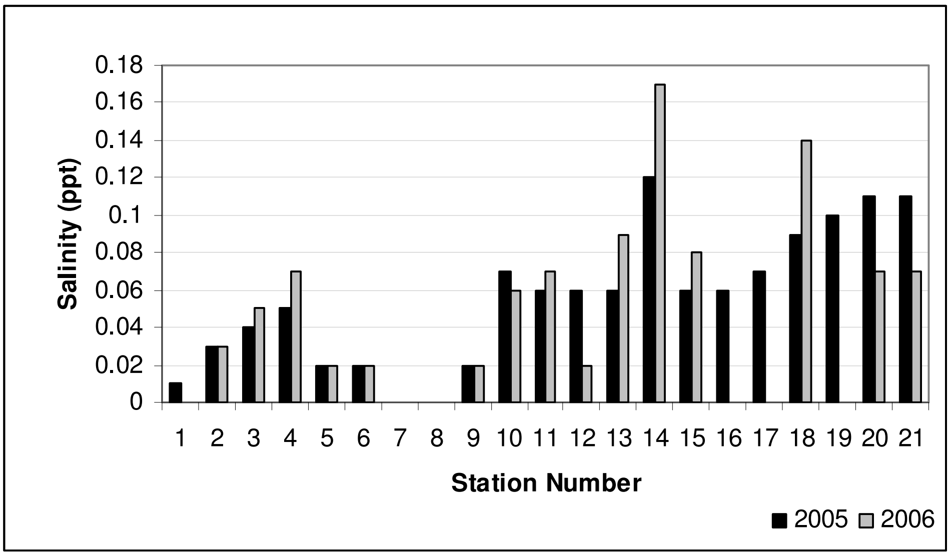


Figure 8. Salinity (ppt) along the Mara River and its tributaries during the 2005 and 2006 sampling campaigns.



Box 2: Sediments, Ecosystems and Health

The story of sediments in water goes beyond the muck. Sediment loads may increase in aquatic systems through erosion from poor agriculture practices, grazing and deforestation, mining activities, construction and dredging. Increased sediments load may negatively impact aquatic biota by reducing light penetration, reducing suitable habitat, smothering fish fry, clogging gills and ultimately altering the biodiversity of the system.

Beyond the physical effects, increased sediment loads may also alter the chemistries of aquatic systems. Sediment plays a major role in the transport of pollutants attached to sediments. Contaminated sediments can have lethal effects on benthic (bottom-dwelling) organisms or can be ingested and accumulated through the food chain affecting higher trophic levels. Disturbances (i.e., dredging) can re-suspended contaminated sediments, exposing organisms in the water to potentially toxic contaminants.

6.4 Turbidity and Total Suspended Sediments

Turbidity and Total Suspended Sediments (TSS) are measures of the level of suspended solids in water, which may be mineral or organic material. High levels of turbidity and TSS reduce light penetration in the water column, which may then reduce photosynthesis by submerged aquatic plants (See Box 1). During May, 2005, turbidity ranged from 7.1 NTU at the river mouth (sta. 21) to 1999 NTU at the New Mara site (sta.13) located within the Masai-Mara National Reserve (Fig. 9). Total suspended sediments (TSS) ranged from 0.02 g/L at the river mouth to 2.79 g/L at New Mara. The WHO and Tanzania set maximum turbidity levels for drinking water at 5 and 30 NTU, respectively (Table 1). Higher levels of turbidity and TSS experienced at the Old Mara, Talek, and New Mara stations in 2005 occurred after rainstorms (Fig. 10). These rainstorms were most likely the cause of increased turbidity and TSS levels at these locations. Deforestation (Chapman and Chapman, 2003) and insufficient soil conservation practices in agricultural regions (Bugenyi and Balirwa, 2003) may also be attributed to increased turbidity and TSS values. Both turbidity and TSS were low on dates sampled in 2006 and 2007.

Figure 9: Turbidity (NTU) along the Mara River and its tributaries during the three sampling campaigns.

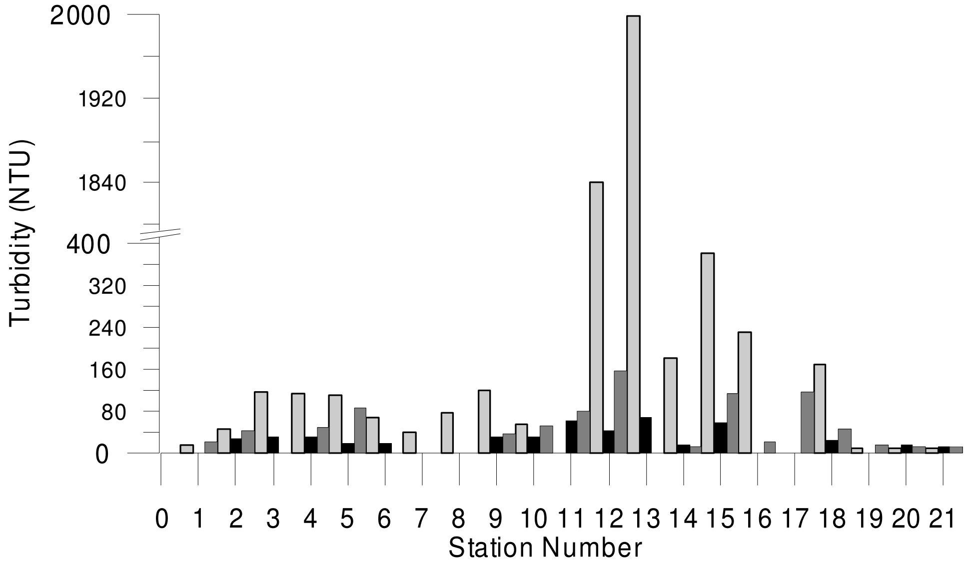
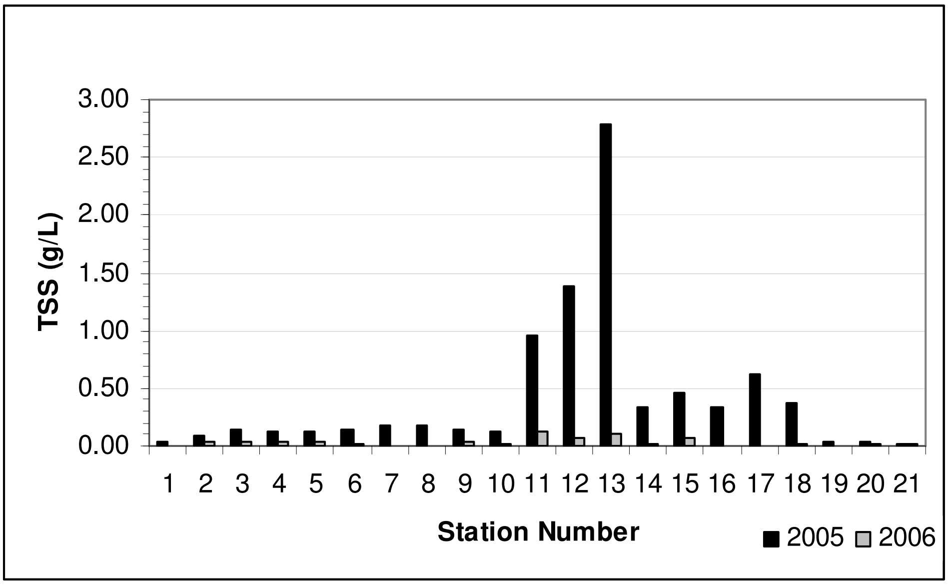


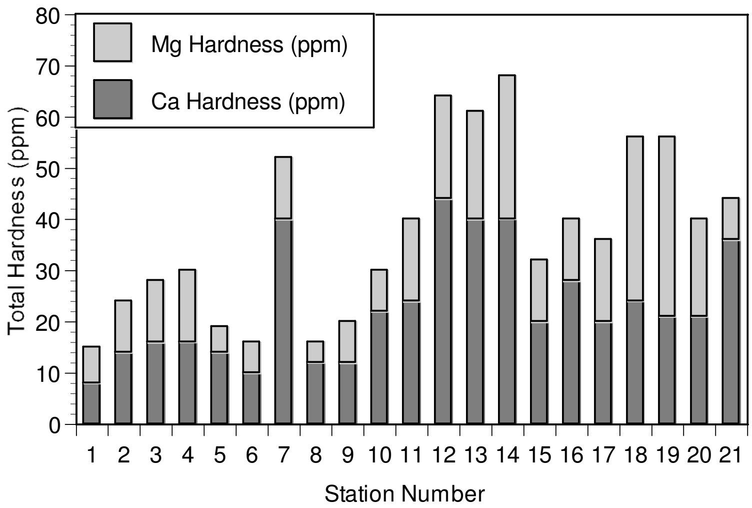
Figure 10: Total suspended solids (TSS; g/L) along the Mara River and its tributaries during the 2005 and 2006 sampling campaigns.



6.5 Hardness

Hardness is another parameter reflecting the mineral content of natural waters and was only measured during the 2005 sampling campaign. Total hardness ranged from 15 ppm at Enupuiyapi swamp to 68 ppm at Tabora (sta. 14) (Fig. 11). Total hardness levels fell well below the maximum allowable level as set for Tanzania domestic waters (600 mg/L; Table 1). Calcium hardness ranged from 8 ppm at Enupuiyapi swamp (sta. 1) to 44 ppm at Talek Bridge (sta. 12). Magnesium hardness ranged from 7 ppm at Enupuiyapi swamp (sta. 1) to 35 at Kwesawa (sta. 19) station. Calcium salts were most prevalent, ranging from 53% to 82% of total hardness, excluding Tigite (sta. 18) and Kwesawa (sta. 19) stations (43 and 38%, respectively), which is typical of surface waters (Chapman, 1996). Hardness can vary with river flow, where low flow typically has increased hardness values relative to high flow/flood values.

Figure 11: Total hardness (ppm) along the Mara River and its tributaries during the May 2005 sampling campaign. Magnesium hardness is indicated by light grey shading and calcium hardness by dark grey shading.



6.6 Dissolved Oxygen

Dissolved oxygen (DO) is among the most important water quality parameters for its strong influences on aquatic organisms. DO levels below 50% saturation are generally an indication of high levels of dissolved organic matter, which may derive from natural or anthropogenic sources. Anthropogenic sources of organic material include domestic sewage and agricultural wastes. Patterns in DO concentrations were similar during the three surveys, ranging from a low of 5.7% at Kwesawa (sta. 19) in 2005, near the river mouth, to 95% at Tigite (sta. 18) in 2007 (Fig. 12). The lowest levels were measured in the Mara swamp near the mouth of the river. Relatively low DO was also measured at Station 1 in the Enupuiyapi swamp. With the exception of these swamp locations, DO levels are above the guideline criteria as set by Tanzania for receiving waters suitable for fisheries and domestic livestock (Table 1) in all other stations. Low DO levels found at the Enupuiyapi swamp are likely attributed to high organic matter (Chapman, 1996) as previously noted under the pH section.

***Box 3:* Eutrophication**

Eutrophication is the result of excess inputs of nitrogen and phosphorous (nutrients) into aquatic systems. Increased nutrient availability stimulates algae growth and leads to large concentrations. Oxygen, which is produced during algal growth, off-gases to the atmosphere and is consumed during the decomposition algal detritus. Consequently, oxygen levels in eutrophic waters drop and hypoxic (low-oxygen) conditions develop. Under such low-oxygen conditions, fish and other aquatic organisms may suffocate, causing potentially massive die-offs. The prevention of eutrophication requires minimizing excessive nutrient inputs. Sources of these inputs include generally agricultural run-off, development and wastewater effluent. It is important for the prevention of eutrophication to properly manage effluents.

Increased fertilizer use and runoff has contributed to a widespread occurrence of eutrophication within Lake Victorian waters and, subsequently, anoxic conditions as indicated by low DO levels (Bugenyi and Balirwa, 2003) as found within the river mouth sites (Kwesawa, Kirumui Bridge and River Mouth).

Figure 12: Dissolved oxygen (DO; %) along the Mara River and its tributaries during the three sampling campaigns.
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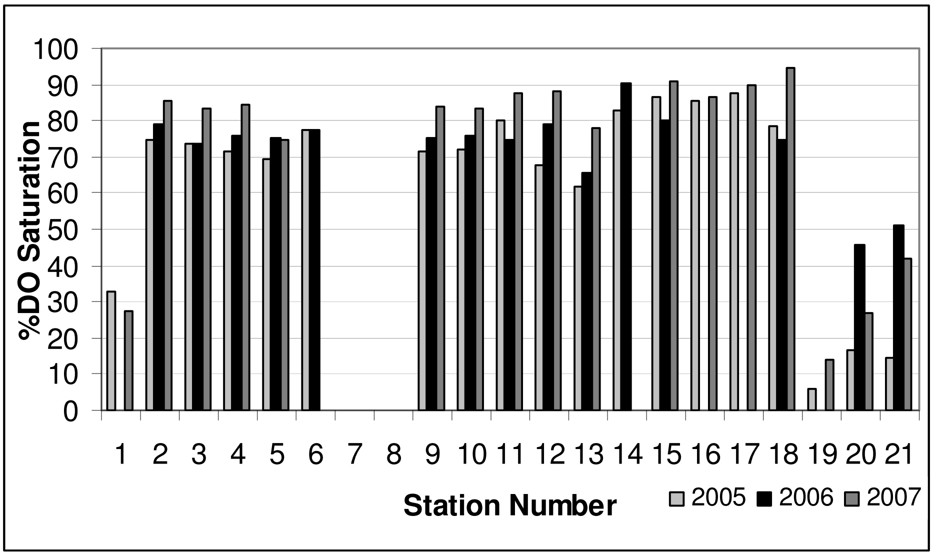


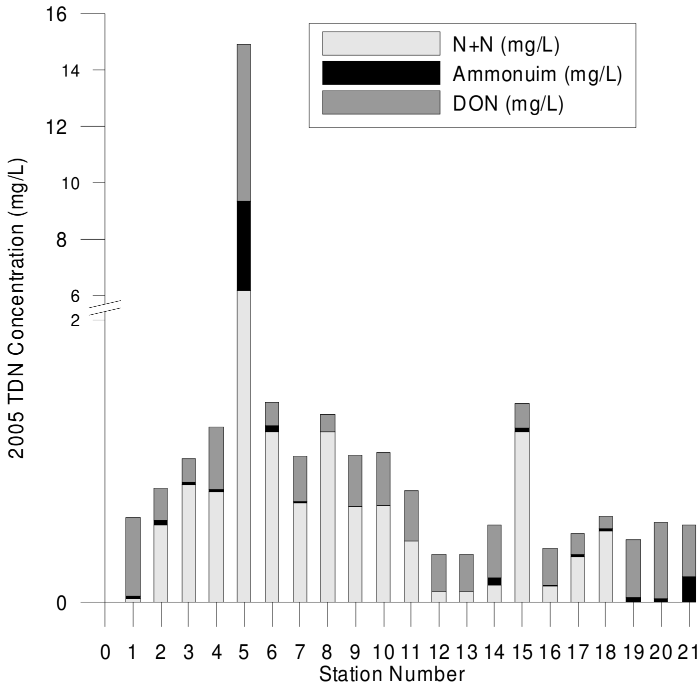
It is unclear whether the low DO measured near the mouth of the Mara River are related to nutrient inputs from the Mara Basin or from Lake Victoria itself. Whatever the source, the low DO levels at these stations are known to be harmful to many fish species (Chapman, 1996).

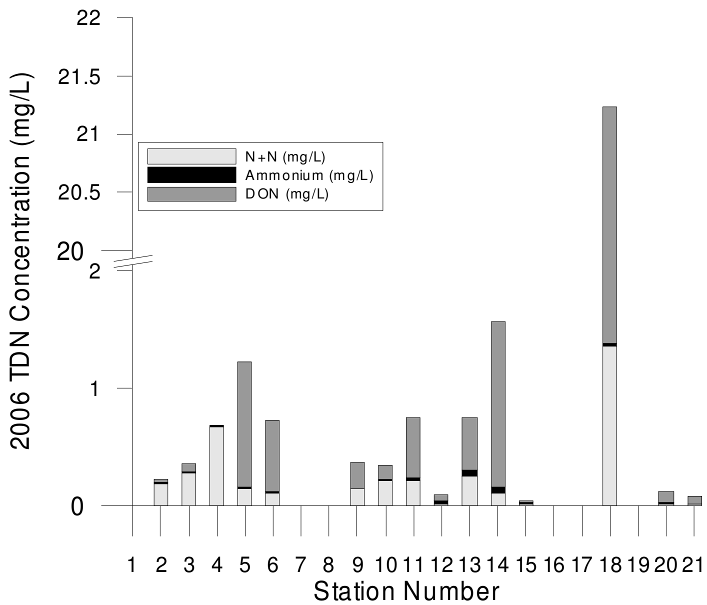
6.7 Nutrients and Dissolved Organic Carbon

Nutrients and Dissolved Organic Carbon (DOC) are integral to the functioning of healthy aquatic ecosystems. Problems arise, however, when concentrations of these parameters greatly exceed natural abundances. Waters containing an excess of nutrients are said to be eutrophic (See Box 3). The dominant nutrients in aquatic systems are nitrogen (N) and phosphorus (P), and both occur in organic and inorganic forms. We analysed total dissolved N and P, which include the sum of organic and inorganic forms. We also analysed inorganic forms, which for N include nitrate/nitrite (N+N) and ammonium (NH_4^+) and for P includes phosphate (PO_4^{3-}). Algal blooms are fuelled by inorganic forms of these nutrients, but total dissolved values (from which organic nutrient levels can be calculated) also provide useful information to assess the condition of freshwaters.

During the 2005 campaign, total dissolved nitrogen (TDN) ranged from a low of 0.3. mg/L at Talek Bridge (sta. 12) to 15.0 mg/L at Silibwet Bridge (sta. 5). Dissolved organic nitrogen (DON) (calculated as the difference between TDN and the sum of inorganic values) ranged from 0.9 mg/L in the Tigite River (sta. 18, a tributary to the Mara) to 5.58 mg/L at Silibwet Bridge (sta. 5) (Fig. 13). The concentrations of N at Silibwet are nearly seven times those detected at other sites. Silibwet is a station on the Nyangores River in an area dominated by tea plantations. At the next downstream station (Tenwek Dam), concentrations were again below 2 mg/L and similar to other stations in the middle portion of the basin. Concentrations of TDN in 2006 were also generally below 2.0 mg/l, with the exception of the stream at Tigite, which recorded a concentration of 21.2 mg/l, the majority of which is organic N.

Figure 13: Total dissolved nitrogen (TDN; mg/L) along the Mara River and its tributaries during the a) May 2005 and b) June 2006 sampling campaigns.





Nitrate is present in both ground- and surface waters as the end product of the aerobic decomposition of organic nitrogenous matter. Nitrate is taken up by plants as a nutrient and assimilated into proteins. Anthropogenic inputs of nitrate include fertilizers, domestic and industrial wastewaters. Extremely high nitrate concentrations in drinking waters have been associated with 'blue baby' syndrome; in which, nitrate is reduced to nitrite and reacts with haemoglobin to form methohaemoglobin, which is not an effective carrier of oxygen in the blood. Nitrite is another, more toxic, form of inorganic N that is rarely present in significant concentrations because it is rapidly oxidised to nitrate. In our analyses we analysed for the sum of nitrate/nitrite (N+N), assuming that nitrate was by far the dominant form. N+N levels detected in Mara River waters were all below the WHO maximum contaminant level (MCL) for drinking water of 45 mg/L (Fig. 13). N+N levels ranged from 0 mg/L at Kwesawa (sta. 19), Kirumui Bridge (sta. 20) and the River Mouth (sta. 21) to 6.19 mg/L at Silibwet. N+N concentrations were generally below 2 mg/L in the basin, which precludes the possibility of direct toxicity to humans but may still contribute to eutrophication of waters in the Mara Swamp at the mouth of the river.

Ammonia is a common form of inorganic N present in both ground- and surface waters and is the dominant form of inorganic N under low-oxygen conditions. Plants and microbes take up ammonia as a nutrient source. As expected, ammonium is the dominant form of inorganic N in Enupuiyapi Swamp and in the three stations (19-21) at the mouth of the basin. Ammonium concentrations were below the WHO standard of 0.5 mg/L at all stations except Silibwet (sta. 5)(3.17 mg/L)(Fig. 13).

Phosphorous (P) is often the limiting nutrient in freshwater systems, which means that aquatic primary production changes in direct proportion to concentrations of P until another factor becomes the limiting factor. Natural inputs of phosphorous include decay of organic matter, excretion by organisms and weathering of P-containing rocks and sediments. Excessive inputs of phosphorous (as found in fertilizers, detergents and mining processes) lead to eutrophication. As with N, the highest concentrations of total dissolved phosphorous (TDP) and PO_4^{3-} in the Mara Basin were found in the tea-producing area of Silibwet Bridge (sta. 5) (1.21 and 1.15 mg/L, respectively, Fig. 14-15) in 2005. Concertrations in 2006 were generally lower.

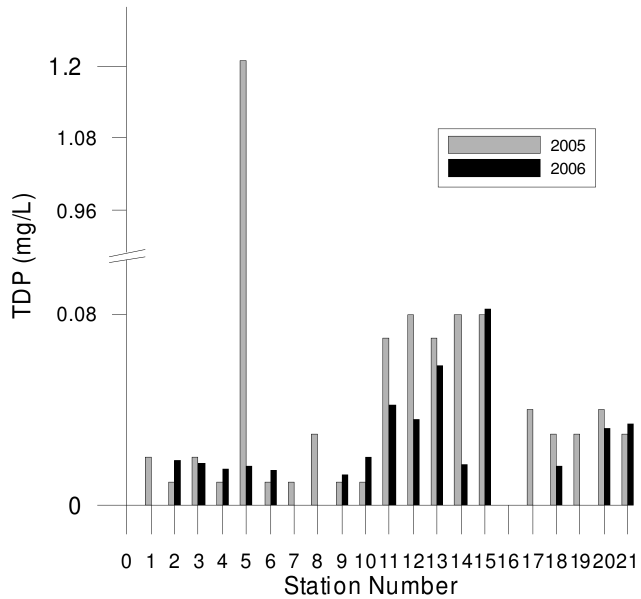


Figure 14: Total dissolved phosphorous (TDP; mg/L) along the Mara River and its tributaries in 2005 and 2006.

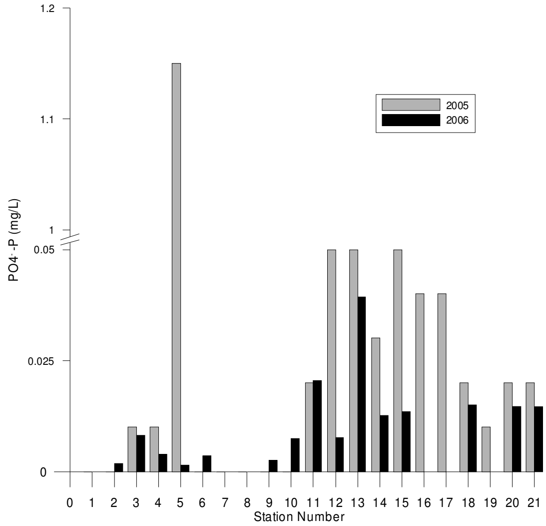


Figure 15: Phosphate (PO_4^{-3}, mg/L) along the Mara River and its tributaries during the 2005 and 2006 sampling campaigns.

The Redfield ratio is a useful indicator of limiting nutrients in aquatic ecosystems. This ratio is an approximation of the average value of the chemical composition of aquatic algae (N:P=16) (Redfield, 1934). Freshwater systems are often characterized by phosphate limitation with nitrogen in excess of the 16 N:P Redfield ratio (Valiela, 1995). Ratios below this value indicate nitrogen limitation. The N:P ratios of the Mara River during 2005 ranged from 6.7 N:P (molar) at Somonche (sta. 16) to 200 at Silibwet Bridge (sta. 5) (Fig. 16), but most stations recorded N:P ratios in excess of 16, suggesting that P-limitation dominates in the Mara system.

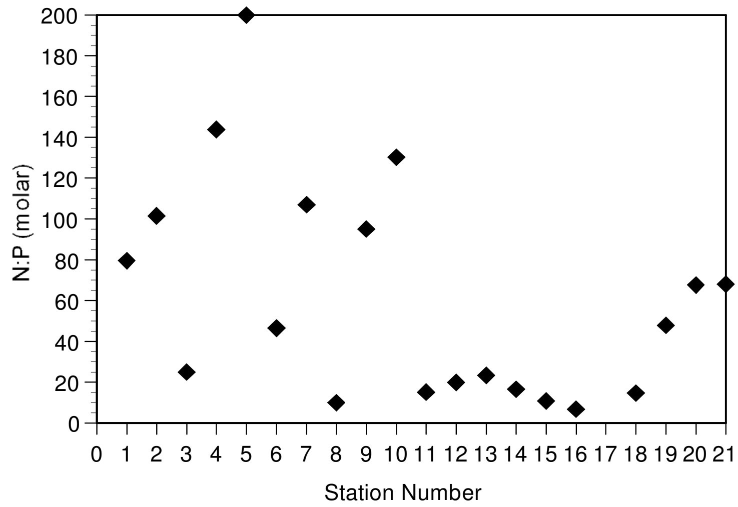
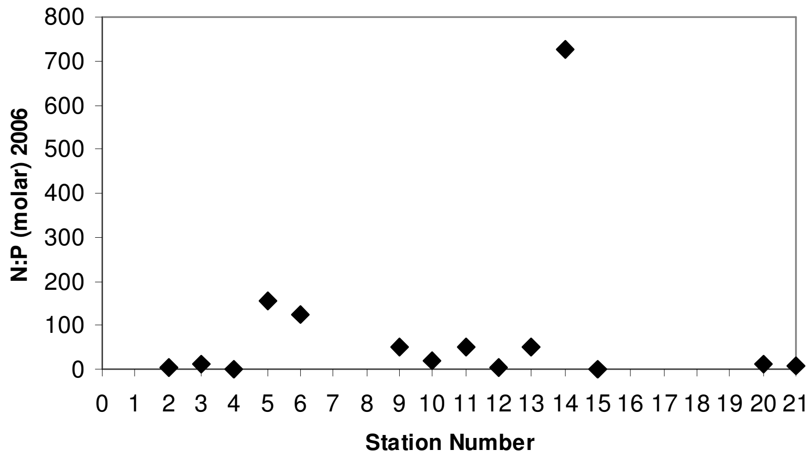


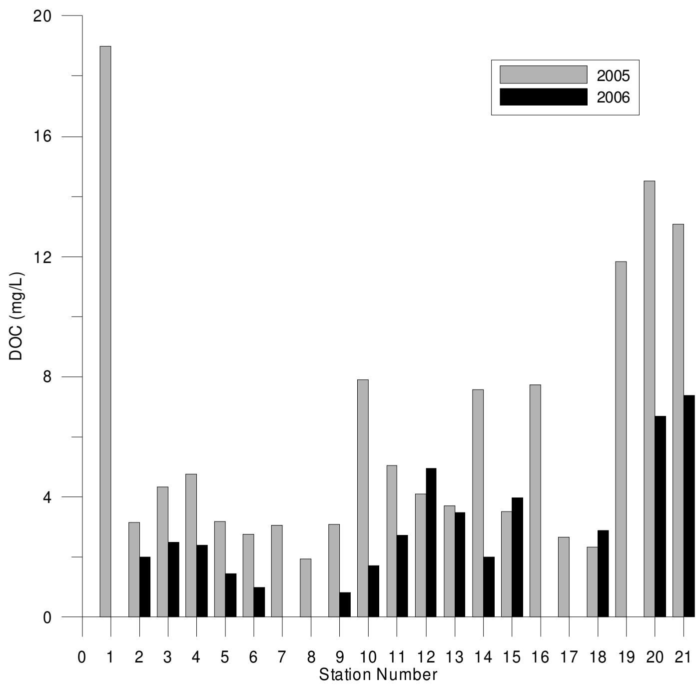
Figure 16: The nitrogen to phosphorous (N:P) ratios (molar) along the Mara River and its tributaries during a) 2005 and b) 2006 sampling campaigns.



Dissolved organic carbon (DOC) levels ranged from 19.0 mg/L in Enupuiyapi Swamp (St. 1) to 1.92 mg/L downstream of Tenwek Dam (sta. 6) in 2005 (Fig. 17). The influence of tidal waters from

Lake Victoria is suggested by the increased DOC levels at the river mouth stations (Kwesawa, Kirumui Bridge and River Mouth) (Allan, 1995). Increased DOC levels at the Enupuiyapi swamp further indicate the presence of high organic matter as was noted in the sections on pH and dissolved oxygen.

Figure 17: Dissolved organic carbon (DOC; mg/L) along the Mara River and its tributaries during the 2005 and 2006 sampling campaigns.

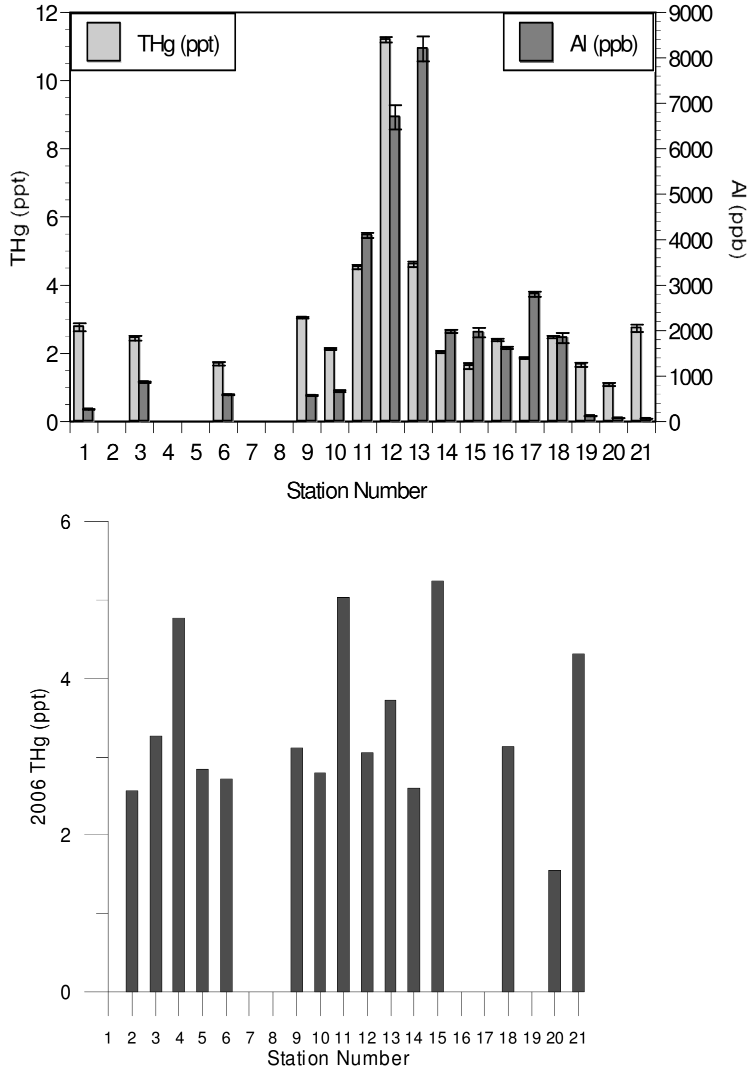


Neither the WHO, Kenya nor Tanzania have established standards for DOC, but the South African Water Quality Guidelines (Department of Water Affairs and Forestry, 1996) have defined an ideal DOC range of 0-5 mg/L for domestic waters. Though quantitative links between DOC and potential human health effects have not been established, it is important to note for drinking waters that DOC may react with chlorine during the chlorination process to form potentially toxic and carcinogenic compounds called trihalomethanes (THMs) (Clesceri, 1998; Department of Water Affairs and Forestry, 1996).

6.8 Mercury and Aluminium

Total Mercury (THg) levels at all stations in the Mara Basin in were below WHO drinking water, Kenyan effluent, and Tanzanian receiving and effluent water standards (Table 1), ranging from 1.09 ppt (parts per trillion) at Kirumi Bridge (sta. 20) to 11.20 ppt at Talek Bridge (sta. 12) in 2005 (Fig. 18). Considering the tendency of Hg to bioaccumulate in tissues and to biomagnify along food chains (See Box 4), even low levels of Hg could be deleterious to Mara aquatic ecosystems. Aluminium levels ranged from 60.5 ppb (parts per billion) at the river mouth (sta. 21) to 8194 ppb at the New Mara bridge (sta. 13) site. Aluminium levels as found in this study fall well below the guidelines for WHO drinking waters and Tanzanian receiving waters (Table 1). It is of interest to note that both THg and Al levels are higher within the Masai-Mara National Reserve and the Serengeti National Park relative to sites upstream and downstream of the conservation areas (Fig. 18). It would be expected to find increased THg levels near and/or downstream of gold mining operations. However, given the nature of THg to bind to sediments, the increased levels of THg within the national parks are well correlated to the increased levels of TSS within these sites.

Figure 18: Total mercury (THg, ppt) and aluminium (Al, ppb) along the Mara River and its tributaries during the 2005 and 2006 sampling campaigns. THg is indicated by light grey shading and Al by dark grey shading in the 2005.



***Box 4:* Bioacculumation and Biomagnification**

Bioaccumulation and biomagnification are important processes in how substances move through the food chain. Bioaccumulation is the increase of a substance within an organism over a period of chronic exposure. Bioaccumulation occurs when the ingestion rate of a substance is greater than its excretion rate resulting in a higher concentration within the organism compared to the substance's concentration in the environment. Biomagnification is the increase of a substance from one trophic level to the next (as it moves up the food chain).

Compounds such at DDT and its daughter DDE, PCBs and mercury have all been found to bioaccumulate and biomagnify. In the case of mercury, it becomes methylated to a bioavailable (usable by organisms) form called methylmercury. Methylmercury is taken up by bacteria and plants, which are then eaten by fish that are then consumed by humans. The consumption of methylmercury-contaminated fish exposes humans to high levels of mercury, which can bioaccumulate resulting in adverse health affects to humans.

6.9 Pesticides

As an initial survey, water samples were collected in 2005 at a subset of eight stations and analysed for 26 pesticide compounds and 18 PCBs (Appendix A). Table 5 lists all compounds analyzed and their corresponding concentrations at sampling sites. The majority of samples had undetectable levels of pesticides. At the Mulot site (sta. 4), trace levels of DDE were detected. All sampled stations, with the exception to Mulot and Bomet (sta. 9), had detectable levels of PCB 44 (polychlorinated biphenyl 44). Neither WHO, Kenya, nor Tanzania have set guidelines for PCBs, however, the US Environmental Protection Agency (US EPA) has set a standard for PCBs at 0.5 ppb (EPA, 2002). All PCB levels detected in this study fall below the guideline, but again due to the bioaccumulative behaviour of PCBs additional study is required to determine whether PCBs are accumulating in Mara food chains. The US EPA has also set a maximum contaminant limit (MCL) for Hexachlorobenzene at 1 ppb (EPA, 2002), below which the level at Mulot Bridge (sta. 4) falls.

6.10 Comparisons with Other Water Quality Data

This current baseline assessment reports the results of three sampling campaigns (one per year) in the Mara River Basin. Sound management of water quality requires routine monitoring of water quality data upon which trends or anomalies can be detected. Section 4.2 of this report describes some of the other water quality monitoring efforts in the basin. Where possible, results from those efforts were obtained and compared to the results of this study. Appendix C presents Kenyan Mara water quality data as reported by Nile Basin Initiative Transboundary Environmental Action Project (NTEAP 2005a) and from the Bomet and Narok District Water

Offices. Appendix D lists the water quality data reported by WWF-TPO (2004). In both Appendices, results of this study from 2005 are reported for comparison.

The data presented in this report are generally comparable to previous data reported from the same sites. However, inconsistencies are present and are most likely a function of methodological sensitivity or potential contamination within the analysis process. The most obvious of these inconsistencies are the results presented for Ammonium. In all instances, Ammonium data presented in this report are lower than those presented in the other reports, suggesting that the methods used in other studies were not as sensitive.

Effective monitoring programs set protocols for sampling, site selection, analytical methodologies, quality assurance and control, and data management. Adherence to established protocols makes it possible to compare data from different sampling campaigns. The overall consistency between the findings of this study and those of previous campaigns suggest that proper protocols were followed in each study. Thus, the combined data sets can be confidently used to assess longer term water quality conditions in the Mara River Basin.

7.0 Summary and Conclusions

The Mara River supports a wide array of human and ecosystem water needs. However, population growth, agricultural expansion, headwater deforestation, water abstractions, and untreated wastewater releases threaten the supply of sufficient and clean water to all stakeholders and sectors within the basin, particularly in the dry season. Increasing water demands in the upper basin in combination with contamination sources also seriously threaten the environmental flows needed to sustain wildlife in Masai-Mara National Reserve, Serengeti National Park, and Mara Wetlands. Systematic monitoring and reporting of water quality across the basin by local water offices and major water users is essential to achieving an integrated program of water management that meets the needs of the various water use sectors while simultaneously supporting ecosystem needs.

The results of water quality monitoring programs are generally compared against established standards to assess the condition of water bodies and their level of impairment for prescribed uses. Both Kenya and Tanzania recognize guidelines established for drinking water by the WHO. Kenya also recognizes British Royal Commission Standards for effluent discharges. Only Tanzania, however, has established national standards for effluents, receiving waters, and domestic waters. Although provisional, these Tanzania Temporary Standards are an important step towards fully enforceable standards. Where applicable, the results of this study were compared to WHO drinking water standards, given that many inhabitants of the Mara Basin take their drinking water directly from rivers.

Currently, there is little systematic monitoring of water quality in Mara River Basin. On the Kenyan side of the basin, the Ministry of Water and Irrigation has established water quality laboratories in the Narok and Bomet District Offices and a limited number of monitoring campaigns have been conducted. On the Tanzanian side of the basin the Ministry of Water has established a water quality laboratory in Musoma with support from the Lake Victoria Environmental Management Programme, and this office conducts occasional water quality campaigns into the lower Mara Basin. TANAPA conducts occasional water quality monitoring in Serengeti National Park (including at a UNESCO Ecohydrology study site), and Barrick Gold Mines has conducted regular monitoring of rivers in the area of its activities. Barrick's monitoring, however, is for the company's own compliance purposes and results are not routinely distributed to local authorities.

In order to provide comprehensive baseline information to an assortment of planned and ongoing activities in the Mara Basin, we conducted annual surveys of water quality at 21 stations across the river basin from its source on the Mau Escarpment in Kenya to its outlet at Lake Victoria at Musoma Town in Tanzania. All samples were analysed for physical properties, mineral abundances, and nutrients; a subset of samples was also analysed for mercury and pesticides. No areas of serious contamination were observed, but a number of results warrant further consideration and follow-up actions.

At the times of the surveys in May-2005, June-2006, and June-2007 patterns in water quality data varied as a function of position along the river, land use, and rainfall/discharge.

- In general, the mineral content of Mara River water increased downstream, probably due to the combined effects of run-off and mineral inputs from agriculture and mining and evaporation from the river surface.
- Nutrient concentrations were highest in the agricultural sections of the basin, while organic matter was most abundant at the river's source in the Enupuiyapi Swamp and at its mouth in the wetlands bordering Lake Victoria.
- Sediment concentrations were highest in stations sampled following rain events. These stations in and around Masai-Mara National Reserve and Serengeti National Park also had the highest concentrations of mercury and aluminium, suggesting that these metals were associated with sediments mobilized following the rains.

- Pesticides (Hexachlorobenzene and 4,4' DDE) were detected at only one station on the Amala River near the Mulot trading post.
- PCBs (PCB 28/31, PCB 52, PCB 44) were detected in 6 of 8 stations sampled, including those in Masai-Mara National Reserve and Serengeti National Park.

Although concentrations of nutrients, mercury, pesticides, and PCBs were all below existing standards, deleterious effects may still derive from these compounds. Nutrient concentrations are above natural levels and appear to be causing eutrophication in the wetlands at the mouth of the river. Mercury and PCBs have a tendency to accumulate in organisms and along food chains, so even low concentrations in water may result in harmful accumulations in wildlife and people.

Table 6: Summary of pesticide data in the Mara river basin during the May 2005 baseline water quality campaign. **Bold** text indicates detectable levels of measured compounds and highlighted text indicates pesticides that were detectable. All data are reported in units of ppb (µg/L).

Station Number	**4**	**9**	**10**	**11**	**13**	**15**	**16**	**17**
Chlrorinated Benzenes								
Tetrachlorobenzene 1,2,4,5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tetrachlorobenzene 1,2,3,4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pentachlorobenzene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hexachlorobenzene	**0.02**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hexachlorocyclohexanes								
Alpha HCH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beta HCH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gamma HCH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delta HCH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chlorodane-related Compounds								
Heptachlor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptachlor Epoxide/OCS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alpha Chlordane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gamma Chlordane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Methoxychlor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Cyclodiene Pesti-cides								
Aldrin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dieldrin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Endrin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Chlorinated Pesti-cides								
Chlorpyrifos	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mirex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Endosulfan sulfate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Endosulfan II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DDTs and Related Com-pounds								
2,4' DDE/ENDOSULFAN I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4,4' DDE	**0.19**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2,4' DDD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4,4' DDD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2,4' DDT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Station Number	**4**	**9**	**10**	**11**	**13**	**15**	**16**	**17**
4,4' DDT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Individual PCBs								
PCB8/5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB18/17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB28/31	0.00	**0.14**	0.00	0.00	0.00	0.00	0.00	0.00
PCB52	0.00	0.00	0.00	0.00	**0.22**	0.00	0.00	0.00
PCB44	0.00	**0.06**	0.00	**0.09**	**0.08**	**0.10**	**0.09**	**0.10**
PCB66/95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB101/90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB87/115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB153/132	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB138 /160	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB187	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB180	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB170/190	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB195/208	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB206	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PCB209	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

8.0 Recommendations

The results presented in this report represent 'snapshots' of the water quality throughout the Mara Basin during May-2005, June-2006, and June-2007. Nevertheless, the results suggest that, although no parameters were detected in excess of recognized standards, high nutrient loads and detectable amounts of mercury, pesticides, and PCBs may be impairing water quality. These findings highlight the need for more systematic monitoring of water quality across the basin, ideally using comparable methodologies and carried out at similar intervals. Furthermore results should be rapidly fed into the management and decision-making processes in the basin that affect water resources quality and quantity. That requires reporting results both to water management agencies in the capital cities as well as to local water offices and water user associations. Given these observations, we offer the following specific recommendations.

- Water offices on the Kenyan and Tanzanian sides of the basin should harmonize protocols, methodologies and sampling regimes.
- All laboratories should pursue appropriate accreditation for analytical techniques used. In lieu of accreditation, laboratories should develop a program of inter-laboratory comparison and calibration to be repeated annually. This will ensure comparability of results.
- Monitoring programs on each side of the border should develop common quality assurance and quality control (QA/QC) plans detailing protocols of collection, handling, and analysis.
- Kenyan and Tanzanian agencies should conduct joint training sessions for monitors to ensure consistent field techniques and to occasionally introduce new or revised methodologies.
- A joint protocol should be developed to rapidly process data and communicate results to relevant local, national and regional decision makers and stakeholders.

The GLOWS program is committed to supporting the efforts of water management agencies to continue developing their water quality monitoring programs over the coming years. As a direct follow-up to our 2005 activities, we propose the following activities for 2006, in collaboration with local partners.

- Conduct additional analyses of water quality as a function of flows levels. There is potential for increased levels of contamination during low water periods.
- Test for biological contamination in river samples.
- Assist local water offices to implement the recommendations made above.

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Appendix A

Methodologies Employed in this Baseline Assessment

In situ physical and chemical parameters (temperature [˚C], electrical conductivity [EC], total dissolved solids [TDS], salinity, dissolved oxygen [DO] and pH) were measured on-site with an YSI 556 handheld multimeter probe. Samples for turbidity, alkalinity, hardness (total, calcium and magnesium) and total and free chlorine were analyzed at the end of the sampling day's activities. Samples for analysis at Florida International University's (FIU) watershed laboratory were collected in 60 ml HDPE bottles. All bottles were acid-cleaned, rinsed twice with distilled water and rinsed twice with sample water prior to collection. Samples for total dissolved nitrogen (TDN), total dissolved phosphorus (TDP), dissolved organic carbon (DOC), dissolved organic nitrogen (DON), nitrate + nitrite (N+N), ammonium (NH_4^+) and orthophosphates (PO_4^-) were filtered through a 0.45 µm Millipore Nylon 47mm membrane. Samples were preserved with H_2SO_4 to a pH<2, with exception for PO_4^- and total suspended solids (TSS). All were maintained on ice or in a freezer until transported to FIU, where they were kept frozen until analysis. Samples for total mercury (THg) and aluminum (Al) were collected in nitric acid-cleaned 125 ml HDPE bottles. Pesticide samples were collected in I-Chem certified 500 ml wide-mouth glass jars.

Alkalinity and hardness (total, calcium and magnesium) were sampled using LaMotte environmental test kits. TDN and TDP were digested following the persulfate oxidation method for the simultaneous digestion of total nitrogen and phosphorous (Valderamma, 1981; Bronk, *et al*., 2000). DOC was analyzed on a Shimadzu TOC-V_{CSH} employing the high oxidation method. TDN, TDP, N+N, NH_4^+, and PO_4^- were analyzed on a Technicon RFA. N+N was analyzed by the automated cadmium reduction method; NH_4^+ by the automated phenolate methodology; and PO_4^- by the automated ascorbic acid method (Clesceri, *et al.,* 1998). THg and Al^- were analyzed at FIU's Southeast Environmental Research Center (SERC) tracemetal laboratory using an HP-4500 ICP-MS. Pesticides were analyzed at SERC's pesticide laboratory using HP-6890/HP-5973 GC-MS. A summary table of methodologies employed in this baseline study is listed in Appendix A.

Table A1: Methodologies and instrumentation used for water sample analysis as part of the May 2005 sampling of the Mara River in Kenya and Tanzania. Italized parameters indicated those that were analyzed in the field, normal text was analzyed back at FIU.

Analysis	Units	Instrument	Specification/Type	APHA Methodology #	APHA Methodology Title
Temperature	^{o}C	YSI 556 Multiprobe System	YSI Precision ™ thermistor	2550	Laboratory and Field Method
Specific Conductivity	(mS/cm)	YSI 556 Multiprobe System	4-electrode cell with autorang-ing	2510	Laboratory Method
Conductivity	(mS/cm)	YSI 556 Multiprobe System	4-electrode cell with autorang-ing	2510	Laboratory Method
TDS	(g/L)	YSI 556 Multiprobe System	4-electrode cell with autorang-ing	*Particular method not listed in 20th edition	*Particular method not listed in 20th edition
Salinity	(ppt)	YSI 556 Multiprobe System	Calculated from conductivity and temperature	2520 B.	Electrical Conductivity Method
Dissolved Oxygen [DO] Saturation	(%)	YSI 556 Multiprobe System	Steady state polarographic	4500-O G.	Membrane Electric Method
Dissolved Oxygen [DO] Concentration	(mg/L)	YSI 556 Multiprobe System	Steady state polarographic	4500-O G.	Membrane Electric Method
PH	pH scale	YSI 556 Multiprobe System	Glass combination electrode	4500-H^{+}	Electrometric Method
Turbidity	(NTU)	LaMotte Portable Turbidity Meter Model 2020	Nephelometric turbidity	2130 B.	Nephelometric Method
Total Hardness	(ppm)	LaMotte Individual Test Kit, Hardness	Direct Read Titrator	2340 C.	EDTA Titrimetric Method
Calcium Hardness	(ppm)	LaMotte Individual Test Kit, Hardness (PHT-CM)	Direct Read Titrator	2341 C.	EDTA Titrimetric Method
Magnesium Hardness	(ppm)	LaMotte Individual Test Kit, Hardness (PHT-CM)	Calculated from Total and Calcium Hardness	2342 C.	EDTA Titrimetric Method

Analysis	Units	Instrument	Specification/Type	APHA Methodology #	APHA Methodology Title
Alkalinity	(ppm)	LaMotte Individual Test Kit, Alkalinity	Direct Read Titrator	2320 B.	Titration Method
Total Suspended Solids (TSS)	(g/L)	Microscale		2540 D.	TSS Dried at 103-105C
Dissolved Organic Carbon (DOC)	(mg/L)	Shimadzu TOC-V_{CSH}		5310 B.	High Temperature Combustion Method
Total Dissolved Nitrogen (TDN)	(mg/L)	Technicon RFA		4500-N C.	Persulfate Method
Total Dissolved Phosphorus (TDP)	(mg/L)	Technicon RFA		4500-P H.	Manual Digestion and Flow Injection Analysis for Total Phosphorus
Nitrate and Nitrite (N+N)	(mg/L)	Technicon RFA		4500-NO3 F.	Automated Cadmium Reduction Method
Ammonium (NH_4^+)	(mg/L)	Technicon RFA		4500-NH4 G.	Automated Phenate Method
Orthophosphate (PO_4)	(mg/L)	Technicon RFA		4500-P F.	Automated Ascorbic Acid Method
Dissolved Organic Nitrogen (DON)	(mg/L)	Technicon RFA	Calculated from TDN, N+N, and NH_4^+		
Dissolved Organic Phosphorus (DOP)	(mg/L)	Technicon RFA	Calculated from TDP and PO_4		
Carbon:Nitrogen Ratio (C:N)	(molar)	Technicon RFA	Calculated from DOC and DON		
Analysis	**Units**	**Instrument**	**Specification/Type**	**APHA Methodology #**	**APHA Methodology Title**
Carbon:Phosphorus Ratio (C:P)	(molar)	Technicon RFA	Calculated from DOC and DOP		

Nitrogen:Phosporus (N:P)	(molar)	Technicon RFA	Calculated from DON and DOP		
Total Mercury (THg)	(ppt) (ng/L)	HP-4500 Plus: Inductively Coupled Plasma Mass Spectrometry (ICP-MS)		3500-Hg/3125 B.	Mercury/Inductively Coupled Plasma/Mass Spectrometry (ICP/MS) Method
Aluminum (Al)	(ppm) (mg/L)	HP-4500 Plus: Inductively Coupled Plasma Mass Spectrometry (ICP-MS)		3500-Al/3125 B.	Mercury/Inductively Coupled Plasma/Mass Spectrometry (ICP/MS) Method
Chlorinated Benzenes	(ppb) (µg/L)	HP-6890/HP-5973 GC-MS	Tetrachlorobenzene 1,2,4,5 Tetrachlorobenzene 1,2,3,4 Pentachlorobenzene Hexachlorobenzene		
Hexachlorocyclohexanes (HCH)	(ppb) (µg/L)	HP-6890/HP-5973 GC-MS	Alpha HCH Beta HCH Gamma HCH Delta HCH		
Chlorodane-related Compounds	(ppb) (µg/L)	HP-6890/HP-5973 GC-MS	Heptachlor Heptachlor Epoxide/OCS Alpha Chlordane Gamma Chlordane Methoxychlor		
Other Cyclodiend Pesticides	(ppb) (µg/L)	HP-6890/HP-5973 GC-MS	Aldrin Dieldrin Endrin		
Analysis	**Units**	**Instrument**	**Specification/Type**	**APHA Methodology #**	**APHA Methodology Title**
Other Chlorinated Pesticides	(ppb) (µg/L)	HP-6890/HP-5973 GC-MS	Chlorpyrifos Mirex Endosulfan sulfate Endosulfan II		

DDTs and Related Compounds	(ppb) (µg/L)	HP-6890/HP-5973 GC-MS	2,4' DDE/ENDOSULFAN I 4,4' DDE 2,4' DDD 4,4' DDD 2,4' DDT 4,4' DDT		
Individual PCBs	(ppb) (µg/L)	HP-6890/HP-5973 GC-MS	PCB8/5 PCB18/17 PCB29 PCB28/31 PCB52 PCB44 PCB66/95 PCB101/90 PCB87/115 PCB153/132 PCB105 PCB138 /160 PCB187 PCB180 PCB170/190 PCB195/208 PCB206 PCB209		

Appendix B

Table B1: Complete dataset for GLOWS May 2005 water quality baseline assessment.

	Country	Kenya													Tanzania							
	Station Name	Enupuiyapui Bridge	Matecha Bridge	Kapkimolwa Bridge	Mulot Bridge	Silibwet Bridge	Tanwek Dam	Tanwek Wastewater	Tanwek Downstream	Bomet Bridge	Emarti Bridge	Old Mara Bridge	Talek Bridge	New Mara Bridge	Tabora	Tarime	Somonche	Mara Mines	Tigite	Kwesawa	Kirumui Bridge	River Mouth
	Station Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Variable	**Unit**																					
Temperature	C	10.42	16.58	19.89	21.16	19.19	18.01			18.65	22.13	23.07	22.44	22.18	25.67	25.72	25.32	24.93	25.03	23.19	25.54	25.19
pH		4.75	7.45	7.34	7.42	7.18	7.35			7.14	7.53	7.19		6.90	7.16	7.46	7.62	7.62	6.65		6.96	6.93
Alkalinity	ppm	12	31	40	52	24	20	104	20	24	56	56		60	144	56	76	60	100	92	92	100
Conductivity	µS/cm^2	24	55	85	107	45	46			46	146	119	121	117	258	130	129	148	189	209	235	232
TDS	g/L	0.02	0.04	0.06	0.08	0.03	0.04			0.04	0.10	0.08	0.08	0.08	0.17	0.08	0.08	0.10	0.12	0.14	0.15	0.15
Salinity	ppt	0.01	0.03	0.04	0.05	0.02	0.02			0.02	0.07	0.06	0.06	0.06	0.12	0.06	0.06	0.07	0.09	0.10	0.11	0.11
Turbidity	NTU	14.1	44.5	115	112	110.5	67.5	39.5	77.5	120	55.4	900	1840	1999	180	380	230	550	170	9.9	8	7.1
Total Suspended Solids	g/L	0.03	0.09	0.14	0.13	0.13	0.14	0.17	0.17	0.15	0.13	0.96	1.38	2.79	0.34	0.47	0.34	0.63	0.38	0.04	0.04	0.02
Total Hardness	ppm	15	24	28	30	19	16	52	16	20	30	40	64	61	68	32	40	36	56	56	40	44
Calcium Hard-ness	ppm	8	14	16	16	14	10	40	12	12	22	24	44	40	40	20	28	20	24	21	21	36
Magnesium Hardness	ppm	7	10	12	14	5	6	12	4	8	8	16	20	21	28	12	12	16	32	35	19	8

	Station Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Dissolved Oxygen	%	32.6	75	73.9	71.7	69.5	77.6			71.3	72.3	80	67.8	61.6	82.8	86.4	85.5	87.7	78.5	5.7	16.4	14.6
Total Dissolved Nitrogen	mg/L	0.60	0.81	1.02	1.24	14.94	1.43	1.02	1.34	1.04	1.06	0.79	0.34	0.35	0.54	1.42	0.37	0.48	0.62	0.44	0.57	0.55
Dissolved Organic Nitrogen	mg/L	0.56	0.23	0.17	0.44	5.58	0.17	0.32	0.12	0.36	0.37	0.36	0.26	0.26	0.38	0.18	0.26	0.15	0.09	0.41	0.54	0.37
Nitrate	mg/L	0.02	0.55	0.83	0.78	6.19	1.21	0.70	1.21	0.68	0.69	0.43	0.08	0.08	0.12	1.21	0.11	0.32	0.50	0.00	0.00	0.00
Ammonium	mg/L	0.02	0.03	0.02	0.02	3.17	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.01	0.02	0.02	0.03	0.02	0.18
Total Dissolved Phosphorous	mg/L	0.02	0.01	0.02	0.01	1.21	0.01	0.01	0.03	0.01	0.01	0.07	0.08	0.07	0.08	0.08	0.12	0.04	0.03	0.03	0.04	0.03
Phosphate	mg/L	0.00	0.00	0.01	0.01	1.15	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.05	0.03	0.05	0.04	0.04	0.02	0.01	0.02	0.02
Nitrogen: Phosphorous Ratios	molar	79.4	101.5	24.9	143.7	199.8	46.4	106.8	9.9	95.0	130.2	15.1	19.8	23.3	16.5	10.8	6.7	0.0	14.5	47.7	67.6	68.0
Dissolved Organic Carbon	mg/L	18.99	3.13	4.33	4.75	3.17	2.74	3.04	1.92	3.07	7.88	5.04	4.10	3.71	7.55	3.49	7.74	2.64	2.33	11.81	14.52	13.06
Carbon: Nitrogen Ratios	molar	39.3	15.8	29.4	12.5	0.7	18.4	11.1	19.1	10.1	25.0	16.2	18.7	16.4	23.5	22.3	35.3	20.9	29.8	33.5	31.3	41.5
Carbon: Phosphorous Ratios	molar	3119.5	1606.6	733.1	1796.5	132.4	851.6	1188.6	189.5	957.0	3251.1	245.1	369.7	381.9	386.2	239.4	238.1	0.0	433.6	1601.5	2113.1	2819.8
Total Mercury	ppt	2.76		2.44			1.69			3.04	2.13	4.53	11.20	4.61	2.04	1.63	2.39	1.86	2.48	1.67	1.09	2.73
Aluminium	ppb	267		866			586			571	667	4094	6691	8194	1981	1955	1618	2799	1836	118	72	60
Pesticides	See Table 5																					

Appendix C

Table C1: Water quality dataset for Kenya modified from NTEAP (2005a) with comparisons to data collected for the GLOWS March 2006 water quality baseline assessment. Grey shading indicates GLOWS sampling sites similar to those presented by NTEAP.

	Station Name	Mulot Bridge	ILB2 Amala at Mulot	ILB2 Amala at Mulot	ILB2 Amala at Mulot	ILB2 Amala at Mulot	ILB2 Amala at Mulot	ILB2 Amala at Mulot	Bomet Bridge	ILA3-Nyangores at Bomet	ILA3-Nyangores at Bomet	ILA3-Nyangores at Bomet	ILA3-Nyangores at Bomet	Mara-Transmara/ Narok Border	Mara	ILA3 Mara
Variable	**Unit**															
Date	dd/mm/yy	2/5/05	31/8/01	23/3/02	22/7/03	28/11/03	5/6/04	7/9/04	3/5/05	30/9/02	11/4/01	31/8/01	23/3/02	14/4/01	30/8/01	22/7/03
pH		7.42		6.58					7.14							
Total Nitrogen	(mg/L)		0.70					0.58				0.81			1.12	
Total Dissolved Nitrogen	(mg/L)	1.24	0.67				0.66	0.88	1.04			0.67			0.82	
Nitrate	(mg/L)	0.78	0.44			0.46	1.24		0.68		2.13	0.67		1.86	0.57	
Ammonium	(mg/L)	0.02	0.50	0.60					0.00			0.14	0.92		0.12	
Nitrite	(mg/L)		0.02	0.11		0.05	0.00				0.01	0.01	0.01	0.04	0.02	
Total Phosphorous	(mg/L)		0.08	0.10	0.21	0.04	0.20			0.04	0.38	0.06	0.11	0.89	0.06	0.29
Total Particulate Phosphorous	(mg/L)		0.06												0.03	
Total Dissolved Phosphorous	(mg/L)	0.01	0.02	0.07	0.05		0.41		0.01			0.01	0.08		0.03	0.03
Phosphate	(mg/L)	0.01		0.09	0.04	0.04	0.00		0.00				0.06			0.03

Table C2: Water quality dataset from the Kenyan Mara with comparisons to data collected for the GLOWS March 2006 water quality baseline assessment. Grey shading indicates GLOWS sampling sites, italized data are from the Narok District Water Office (2004) and **bold** data are modified from the Narok and Bomet District Water Offices (2004) and from the Bomet District Water Office (2004).

	Station Name	Matecha Bridge	*Matecha Bridge*	*Matecha Bridge*	*Matecha Bridge*	**Matecha Bridge**	Kapkimolwa Bridge	*Kapkimolwo Bridge*	*Kapkimolwo Bridge*	*Kapkimolwo Bridge*	**Kapkimolwo Bridge**
Variable	**Unit**										
Date	dd/mm/yy	2/5/05	*21/7/04*	*29/7/04*	*5/8/04*	**16/12/04**	2/5/05	*21/7/04*	*29/7/04*	*5/8/04*	**16/12/04**
Temperature	C	16.58	*16.9*	*14.2*	*15.1*	**19.6**	19.89	*17.7*	*15.1*	*15.2*	**19.2**
pH		7.45	*7.4*	*7.3*	*7.4*	**7.1**	7.34	*7.5*	*7.3*	*7.4*	**6.9**
Colour	(Pt/Co)					**12**					**13**
Alkalinity	ppm	31	*21*	*13*	*18*	**40**	40	*43*	*16*	*20*	**40**
Conductivity	μS/cm^2	55	*310)*	*40*	*50*	**110**	85	*160*	*50*	*110*	**110**
TDS	g/L	0.04	*0.15*	*0.02*	*0.04*	**61**	0.06	*0.07*	*0.02*	*0.05*	**60**
Turbidity	NTU	44.5				**180**	115				**180**
Total Hardness	ppm	24	*9*	*7*	*7*	**20**	28	*23*	*10*	*12*	**22**
Calcium Hardness	ppm	14	*<50*	*<50*	*<50*	**<50**	16	*<50*	*<50*	*<50*	**<50**
Chloride	(mg/L)					**<0.5**					**<0.5**
Bromine	(mg/L)		*0.31*	*0.1*	*0.2*	**0.2**		*0.29*	*0.28*	*0.13*	**0.27**
Fluoride	(mg/L)		*1.49*	*0.32*	*0.29*	**0.75**		*0.61*	*0.38*	*0.36*	**0.81**
Nitrate	(mg/L)	0.03	*<1*	*<1*	*<1*	**1.1**	0.02	*<1*	*<1*	*<1*	**1.1**
Nitrite	(mg/L)		*<0.01*	*<0.01*	*<0.01*	**0.01**		*<0.01*	*<0.01*	*<0.01*	**0.01**
Sulphate	(mg/L)		*5.4*	*6.4*	*5.6*	**11**		*16.2*	*8.8*	*7.5*	**12**
Iron	(mg/L)		*0.07*	*0.07*	*0.09*	**0.1**		*0.07*	*0.1*	*0.07*	**0.1**
Copper	(mg/L)					**<0.05**					**<0.05**

Table C2: Continued.

	Station Name	Mulot Bridge	*Mulot Bridge*	*Mulot Bridge*	*Mulot Bridge*	**Mulot Bridge**	Emarti Bridge	*Emarti Bridge*	*Emarti Bridge*	**Emarti Bridge**
Variable	**Unit**									
Date	dd/mm/yy	2/5/05	*21/7/04*	*29/7/04*	*5/8/04*	**16/12/04**	2/5/05	*21/7/04*	*29/7/04*	**16/12/04**
Temperature	C	21.16	*18.1*			**19.5**	22.13	*17.6*	*15.3*	**19.5**
pH		7.42	*7.6*	*7.4*	*7.7*	**6.9**	7.53	*7.3*	*7.4*	**6.8**
Colour	(Pt/Co)					**15**				**15**
Alkalinity	ppm	52	*36*	*19*	*29*	**42**	56	*39*	*22*	**46**
Conductivity	$\mu S/cm^2$	107	*160*	*70*	*130*	**120**	146	*330*	*280*	**120**
TDS	g/L	0.08	*0.08*	*0.03*	*0.06*	**0.08**	0.10	*0.16*	*0.13*	**0.08**
Turbidity	NTU	112				**200**	55.4			**300**
Total Hardness	ppm	30	*19*	*14*	*14*	**21**	30	*21*	*15*	**22**
Calcium Hardness	ppm	16	*<50*	*<50*	*<50*	**<50**	22	*<50*	*<50*	**<50**
Chloride	(mg/L)					**<0.5**				**<0.5**
Bromine	(mg/L)		*0.09*	*0.43*	*0.18*	**0.28**		*0.2*	*0.15*	**0.3**
Fluoride	(mg/L)		*0.7*	*0.4*	*0.43*	**0.8**		*0.96*	*0.49*	**0.98**
Nitrate	mg/L	0.02	*<1*	*<1*	*<1*	**1.3**	0.00	*<1*	*<1*	**1.5**
Nitrite	(mg/L)		*<0.01*	*<0.01*	*<0.01*	**0.02**		*<0.01*	*<0.01*	**0.02**
Sulphate	(mg/L)		*38.2*	*7.3*	*8*	**12.3**		*19.8*	*21.8*	**12.3**
Iron	(mg/L)		*0.07*	*0.06*	*0.08*	**0.11**		*0.05*	*0.09*	
Copper	(mg/L)					**C0.05**				

Table C2: Continued.

	Station Name	Old Mara Bridge	Old Mara Bridge	Old Mara Bridge	New Mara Bridge	New Mara Bridge	New Mara Bridge	Mara Serena	Mara Serena	ILB2 Nyan-gores River (Opposite In-take)	ILB2 Nyan-gores River (In-take Screen)	ILB2 Nyango-res River (T.M.Const.Dis charge En-trance)	ILB2 Nyango-res River (T.M.Const.SW Discharge Pt.)
Variable	**Unit**												
Date	dd/mm/yy	6/5/04	**15/12/04**	**16/11/04**	6/5/04	**15/12/04**	**16/11/04**	**15/12/04**	**16/11/04**	5/2/04	5/2/04	5/2/04	5/2/04
Temperature	C	23.07	**20**	**18.3**	22.18	**20.1**	**19.2**	**20.6**	**19**	23	23	23	24
pH		7.19	**6.5**	**7.2**	6.90	**6.3**	**6.4**	**6.5**	**6.5**	8	8	7.9	7.6
Colour	(Pt/Co)		**18**	**10**		**20**	**10**	**20**	**13**	58	58	60	64
Alkalinity	ppm	56	**48**	**46**	60	**50**	**42**	**48**	**39**	20	20.1	20	19.8
Conductivity	mS/cm^2	119	**130**	**110**	117	**130**	**130**	**130**	**120**	71.4	70.9	76	117.3
TDS	g/L	0.08	**0.08**	**0.05**	0.08	**0.1**	**0.06**	**0.1**	**0.05**				
Turbidity	NTU	900	**340**	**50**	1999	**350**	**120**	**350**	**100**	22.8	22.6	23	26.4
Dissolved Oxygen	mg/L									8.8	8.9	6.8	6.7
Total Hardness	ppm	40	**23**	**20**	61	**25**	**21**	**25**	**21**	13	12.9	13	13.1
Calcium Hardness	ppm	24	**<50**	**<50**	40	**<50**	**<50**	**<50**	**<50**	1.4	1.4	1.6	1.5
Magnesium Hardness	ppm	16			21					2	2.1	2.2	2.1
Chloride	(mg/L)		**<0.5**	**<0.5**		**<0.5**	**<0.5**	**<0.5**	**<0.5**	3.8	3.7	4.2	4
Bromine	(mg/L)		**0.32**	**0.32**		**0.2**	**0.2**	**0.32**	**0.32**				
Fluoride	(mg/L)		**0.97**	**0.5**		**0.98**	**0.98**	**0.98**	**0.94**				
Nitrate	mg/L	0.00	**1.3**	**1**	0.00	**1.5**	**1.3**	**1.5**	**1.1**				
Nitrite	(mg/L)		**0.02**	**0.01**		**0.04**	**0.02**	**0.04**	**0.01**				
Sulphate	(mg/L)		**11**	**12.9**		**14**	**12.3**	**13.9**	**11**				
Iron	(mg/L)			**0.12**		**0.15**		**0.16**	**0.13**				
Copper	(mg/L)			**<0.05**		**<0.05**		**<0.05**	**<0.05**				
Mangenese	(mg/L)									<0.01	<0.01	<0.01	<0.01
Free CO_2	(mg/L)									2.4	2	2.4	2.3
Oil & Grease	(mg/L)									Nil	Nil	Nil	0.1

Appendix D

Table D1a: Water quality dataset for the Tanzanian Mara River from the Tanzanian/Kenyan border site to the Mara Mine Gauging Station. Italized data is from WWF-TPO (2004) and is compared to data collected for the GLOWS March 2006 water quality baseline assessment as indicated by grey shading.

	Station Name	New Mara Bridge	*TZ/KNY-Border (Mara River)*	*Confluence of Borogonja Stream and Mara River*	*Borogonja Stream*	*Kogatende Bridge*	Tabora	*Tabora Stream*	Tarime	*Tarime/Serengeti Bridge*	Mara Mines	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*
Variable	**Unit**																	
Date	dd/mm/yy		*23/11/04*	*23/11/04*	*23/11/04*	*23/11/04*		*24/11/03*		*01/03/04*		*21/05/04*	*14/02/04*	*17/01/04*	*17/01/04*	*21/01/04*	*22/01/04*	*27/01/04*
Temperature	C	22.18	*23.4*	*24.1*	*27*	*24.4*	25.67	*20.6*	25.72	*25.4*	24.93	*24.2*	*32.8*	*23.8*	*24.3*	*25.1*	*24.4*	*28.3*
pH		6.90	*7.23*	*7.34*	*8*	*7.5*	7.16	*7.9*	7.46	*8.18*	7.62	*9.13*	*8.15*	*7.63*	*7.98*	*7.51*	*7.43*	*8.52*
Colour	(Pt/Co)									*425*								
Alkalinity	ppm	60	*54*	*76*	*50*	*64*	144	*82*	56	*60*	60	*102*	*116*	*42*	*42*	*84*	*110*	*64*
Conductivity	*m*S/cm^2	117	*170*	*186*	*180*	*170*	258	*200*	130	*377*	148	*334*	*504*	*127.5*	*131.8*	*494*	*427*	*222*
TDS	g/L	0.08	*0.08*	*0.09*	*0.09*	*0.08*	0.17	*0.10*	0.08	*0.19*	0.10	*0.17*	*0.25*	*0.06*	*0.07*	*0.25*	*213*	*111*
Salinity	ppt	0.06					0.12		0.06		0.07							
Turbidity	NTU	1999					180		380	*90*	550							
Total Suspended Solids	g/L	2.79					0.34		0.47		0.63	*0.18*	*0.05*	*0.14*	*0.34*	*0.11*	*0.09*	*0.01*
PV	(mg/L)		*84*	*112*	*104*	*152*		*124*		*6*								
Total Hardness	ppm	61	*26*	*35*	*24*	*39*	68	*32*	32		36	*36*	*74*	*26*	*25*	*56*	*30*	*31*
Calcium Hardness	ppm	40	*8*	*10.8*	*6.4*	*12.4*	40	*7.6*	20		20	*10*	*22*	*6.4*	*8.8*	*2.4*	*3.2*	*10.8*
Magnesium Hardness	ppm	21	*0.15*	*0.2*	*0.2*	*0.2*	28	*0.32*	12		16	*0.27*	*0.46*	*0.24*	*0.07*	*0.63*	*0.54*	*0.58*
Chloride	(mg/L)		*17.02*	*25.52*	*19.14*	*12.9*		*58.23*		*24.09*		*19.85*	*35.45*	*98.55*	*39.00*	*24.79*	*28.34*	*17.75*

Table D1a: Continued

	Station Name	New Mara Bridge	*TZ/KNY-Border (Mara River)*	*Confluence of Borogonja Stream and Mara River*	*Borogonja Stream*	*Kogatende Bridge*	Tabora	*Tabora Stream*	Tarime	*Tarime/Serengeti Bridge*	Mara Mines	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*	*Mara Mine Gauging Station*
Variable	**Unit**																	
Dissolved Oxygen	%	61.6	*5.83*	*7.08*	*6.74*	*6.81*	82.8	*6.81*	86.4		87.7							
Total Dissolved Nitrogen	mg/L	0.35	*3*	*2.9*	*0.8*	*2*	0.54	*1.1*	1.42		0.48							
Ammonium	mg/L	0.00	*0.99*	*0.29*	*0.19*	*0.2*	0.05	*0.31*	0.02		0.02							
Nitrite	(mg/L)		*0.6*	*0.4*	*0.55*	*0.7*		*0.9*				*0.25*	*0.27*	*0.95*	*0.46*	*0.44*	*0.48*	*0.57*
Total Phosphorous	(mg/L)		*0.4*	*0.25*	*0.44*	*0.25*		*0.2*				*0.08*						
Total Particulate Phosphorous	(mg/L)		*0.28*	*0.27*	*0.26*	*0.27*		*1.41*				*1.37*	*0.34*	*1.07*	*1.05*	*0.95*	*4.47*	*3.03*
Silica	(mg/L)		*0.08*	*0.1*	*0.09*	*0.1*		*0.4*				*0.45*	*0.32*	*0.44*	*0.32*	*0.29*	*0.47*	*0.47*
Dissolved Reactive Silica	(mg/L)											*12.60*	*4.44*	*5.27*	*6.04*	*11.54*	*11.59*	*5.87*

Table D1b: Water quality dataset for the Tanzanian Mara River from the Tigite Bridge and Kirumi Bridge stations. Italized data is from WWF-TPO (2004) and is compared to data collected for the GLOWS March 2006 water quality baseline assessment as indicated by grey shading.

	Station Name	Tigite	*Tigite Stream*	Kirumi Bridge	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*
Variable	**Unit**																
Date	dd/mm/yy		*1/3/02*		*21/7/99*	*21/7/99*	*21/7/99*	*6/8/99*	*2/9/99*	*2/9/99*	*24/11/99*	*7/12/99*	*8/11/99*	*8/12/99*	*10/9/03*	*6/10/03*	*10/12/03*
Temperature	C	25.03	*25.4*	25.54					*28*	*24.1*	*25.9*	*28.7*	*24.4*	*23.1*	*24.1*	*25.1*	
pH		6.65	*7.67*	6.96											*7.91*	*7.66*	*7.22*
Colour	(Pt/Co)		*617*		*1000*	*100*	*NIL*	*128*	*200*	*145*	*40*	*45*	*120*	*130*			
Alkalinity	ppm	100	*50*	92	*130*	*104*	*134*	*120*	*110*	*102*	*120*		*118*		*80*	*74*	*80*
Conductivity	*m*S/cm^2	189	*258*	235	*575*	*233*	*255*	*262.4*	*285*	*240*	*242.8*	*145*	*290*	*156*	*182.6*	*189*	*506*
TDS	g/L	0.12	*0.13*	0.15	*0.29*	*0.12*	*0.13*	*0.13*	*0.14*	*0.12*	*0.12*	*0.07*	*0.15*	*0.08*	*0.09*	*0.10*	*0.25*
Salinity	ppt	0.09		0.11													
Turbidity	NTU	170	*140*	8	*500*	*20*	*NIL*	*80*	*40*	*30*	*15*	*15*	*NIL*	*65*			
Sed/Load	(T/d)																*0.00*
T. Coliform	(per 100 mL)															*840*	
F. Coliform	(per 100 mL)															*110*	
PV	(mg/L)		*9.6*		*4.8*	*5*	*3.8*	*2.8*	*24*	*35*		*4.03*		*5.1*		*54*	
Total Hard-ness	ppm	56		40											*80*	*43*	
Calcium Hardness	ppm	24		21											*9.2*	*10*	
Magnesium Hardness	ppm	32.00		19.00											*0.39*	*0.04*	
Chloride	(mg/L)		*12.05*			*19.14*	*39.70*	*14.18*	*22.60*	*20.56*	*24.20*	*20.07*	*22.60*	*19.00*	*17.02*	*16.00*	*14.18*
Dissolved Oxygen	%	78.50		16.40								7.08		9.17			4.70
Ammonium	mg/L	0.02		0.02												52.76	234.68
Nitrite	(mg/L)																108.71

Table D1b: Continued

	Station Name	Tigite	*Tigite Stream*	Kirumi Bridge	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*	*Kirumi Bridge*
Variable	**Unit**																
Total Phosphorous	(mg/L)															15.07	54.46
Total Particulate Phosphorous	(mg/L)														35.00	96.92	92.79
Silica	(mg/L)														24.00	17.48	41.79
Dissolved Reactive Silica	(mg/L)															12.32	5.21
Sulphate	(mg/L)															5.76	2.44

Table D1c: Water quality dataset for the Tanzanian Mara River from the Mara River Mouth site from June 1999 to December 2000. Italized data is from WWF-TPO (2004) and is compared to data collected for the GLOWS March 2006 water quality baseline assessment as indicated by grey shading.

	Station Name	River Mouth	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*
Variable	**Unit**																
Date	dd/mm/yy		*6/8/99*	*6/8/99*	*6/8/99*	*7/8/99*	*28/7/00*	*3/8/00*	*21/8/00*	*21/8/00*	*13/9/00*	*20/9/00*	*25/9/00*	*9/10/00*	*16/10/00*	*23/10/00*	*16/12/00*
Temperature	C	25.19			*24.2*	*23.5*	*23*	*23.6*	*24.2*	*26*	*25.1*	*24.9*	*24.8*	*25.5*	*26.7*	*24.8*	*26.3*
pH		6.93			*7.1*	*7.3*	*7.55*	*6.27*	*7.6*	*8.9*	*7.34*	*7.16*	*7.12*	*7.02*	*7.1*	*6.75*	*6.84*
Colour	(Pt/Co)		*120*	*100*		*105*	*120*	*75*		*500*	*300*	*100*	*200*	*140*	*150*	*NIL*	*750*
Alkalinity	ppm	100	*120*	*115*	*78*	*74*	*78*	*58*		*66*	*58*	*62*	*64*	*72*	*68*	*70*	*120*
Conductivity	*m*S/cm^2	232	*180.8*	*168.2*	*222*	*207*	*176*	*119.9*	*213*	*139.5*	*163.1*	*139.9*	*178.5*	*185.5*	*168.2*	*161.9*	*337*
TDS	g/L	0.15	*90.4*	*84.1*	*111*	*103.5*	*80*	*85*	*106*	*69.8*	*81.7*	*70.1*	*89.4*	*93*	*84.1*	*81*	*168.7*
Turbidity	NTU	7.1	*40*	*30*		*20*	*20*	*15*		*250*	*120*	*60*	*80*	*30*	*30*	*NIL*	*80*
Total Suspended Solids	g/L	0.02			*0.012*												
T. Coliform	(per 100 mL)				*280*	*2000*		*8000*	*<1*	*<1*	*T. N. T. C*	*1600*	*20*	*40*	*<1*	*20*	*980*
F. Coliform	(per 100 mL)				*90*	*100*		*<1*	*<1*	*<1*	*200*	*800*	*<1*	*<1*	*<1*	*<1*	*200*
PV	(mg/L)		*3.4*	*2.8*	*25.16*	*24*	*9.8*	*62*			*4.2*	*7.4*	*10.4*	*6*	*7.2*	*7*	
Total Hardness	ppm	44			*44*	*36*	*48*	*49*	*39*	*30*	*33*	*30*	*29*	*32*	*28*	*36*	*82*
Calcium Hardness	ppm	36			*7.6*	*9.2*		*11.2*	*8.4*	*9.6*	*10*	*10*	*9.6*	*11.6*	*10*	*9.2*	*17.2*
Magnesium Hardness	ppm	8			*0.54*	*0.32*		*0.51*	*0.44*	*0.15*	*0.20*	*0.12*	*0.12*	*0.07*	*0.07*	*0.32*	*0.95*
Chloride	(mg/L)		*12.05*	*9.98*	*41.83*	*31.20*	*45.47*	*33.32*			*25.52*	*19.14*	*24.82*	*21.27*	*19.14*	*33.32*	*33.32*

Table D1c: Continued

Dissolved Oxygen	%	14.6							*3.2*			*4.3*	*2.5*	*2.1*	*3.7*	*2.5*	
Nitrite	(mg/L)				*0.00*												
Total Phosphorous	(mg/L)				*0.11*												
Phosphate	mg/L	0.02			*0.08*												
Silica	(mg/L)				*0.36*												

Table D1d: Water quality dataset for the Tanzanian Mara River from the Mara River Mouth site from January 2001 to June 2004. Italized data is modified from WWF-TPO (2004) and is compared to data collected for the GLOWS March 2006 water quality baseline assessment as indicated by grey shading.

	Station Name	River Mouth	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*	*Mara River Mouth*
Variable	**Unit**																					
Date	dd/mm/yy		*25/1/01*	*26/1/01*	*20/4/01*	*22/5/01*	*22/5/01*	*23/5/01*	*30/6/01*	*2/7/01*	*27/7/01*	*20/8/01*	*27/11/02*	*8/1/03*	*13/01/03*	*4/3/03*	*8/7/03*	*10/9/03*	*10/12/03*	*29/5/04*	*3/6/04*	*10/6/04*
Temperature	C	25.19		*22.4*			*24.8*	*24.8*		*25*	*21*		*27.3*	*24.7*	*24.7*	*26.7*	*25.1*	*24.1*	*24.1*	*23.8*	*23.8*	
pH		6.93		*7.03*			*6.5*	*6.75*		*7.29*	*6.99*		*8*	*7.6*	*7.6*	*7.56*	*6.67*	*6.98*	*7.22*	*6.82*	*6.59*	*6.7*
Colour	(Pt/Co)		*330*	*330*		*200*		*200*	*100*	*100*	*NIL*	*500*										
Alkalinity	ppm	100	*86*	*86*	*66*	*53*	*68*	*53*	*70*	*70*	*60*	*66*	*74*	*110*	*110*	*80*	*76*	*80*	*80*			
Conductivity	$\mu S/cm^2$	232	*240*	*240*	*224*	*211*	*173.2*	*211*	*162*	*162*	*135.4*	*139.5*		*292*	*292*	*204*	*172*	*182.6*	*506*	*182.2*	*182*	*183*
TDS	g/L	0.15	*0.12*	*0.12*	*0.11*	*0.11*	*0.09*	*0.11*	*0.08*	*0.08*	*0.07*	*0.07*		*0.15*	*0.15*	*0.20*	*0.09*	*0.09*	*0.25*	*0.09*	*0.09*	*0.09*
Turbidity	NTU	7.1	*70*	*70*		*40*		*40*	*25*	*25*	*NIL*	*250*							*15.2*			
Total Suspended Solids	g/L	0.02													*0.00*				*5.21*			
T. Coliform	(per 100 mL)			*1400*			*100*			*60*						*40*	*200*					
F. Coliform	(per 100 mL)			*120*			*300*			*40*						*10*	*80*					
PV	(mg/L)				*34*	*16*	*5.2*	*16*	*31.2*	*31.2*	*10.6*			*14*	*14*		*37.5*					
Total Hardness	ppm	44		*48*			*111*	*63*		*25*	*15*		*19*	*50*	*50*	*43*	*40*	*39*				
Calcium Hardness	ppm	36		*13.6*			*18.8*	*12*		*16*	*4.4*		*6.4*	*14*	*14*	*8.8*	*11.2*	*9.2*				
Magnesium Hardness	ppm	8		*0.34*			*1.56*			*0.8*	*0.10*		*0.07*	*0.36*	*0.36*	*0.49*	*0.29*	*0.39*				

Table D1d: Continued

Chloride	(mg/L)		*19.14*	*19.14*	*14.18*	*16.31*	*23.38*	*16.31*	*16.31*	*16.31*			*17.73*	*26.92*	*26.92*	*13.49*	*12.76*	*17.02*	*14.18*			
BOD5	(mg/L)																*71.97*					
COD	(mg/L)																*114.24*					
Ammonium	mg/L	14.6																*0.053*				
Nitrite	(mg/L)																*0.01*	*0.02*	*0.23*			
Total Phos-phorous	(mg/L)														*0.34*		*0.17*	*0.10*	*3.14*			
Phosphate	mg/L	0.02													*0.08*		*0.08*	*0.02*	*0.00*			
Silica	(mg/L)																	*12.32*	*2.44*			

Notes

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