Refining Reserve Flow Recommendations for the Mara River, Kenya and Tanzania

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Acknowledgments

This report on Refining Reserve Flow Recommendations for the Mara River, Kenya and Tanzania, and the work contained herein were facilitated by the Global Water for Sustainability (GLOWS) Program with financial support from the United States Agency for International Development-East Africa (USAID-EA). The Low-Flow EFA sampling was conducted by the Kenya Ministry of Water and Irrigation, with technical expertise from water resource managers from Lake Victoria South Catchment Management Authority in cooperation with scientists from University of Dar es Salaam and Florida International University. The effort was facilitated by the Worldwide Fund for Nature-Eastern and Southern Africa Regional Programme Office (WWF-ESARPO). The Mara River Water Resource Users' Association and local communities living near the EFA sites assisted with the fieldwork and sampling. The Long-term Monitoring was conducted by scientists from Florida International University in partnership with water resource managers from the Lake Victoria South Catchment Management Authority, scientists at the National Museums of Kenya, protected area authorities and managers from the Maasai Mara National Reserve and local students. We are grateful to all who participated in both activities for their dedicated work to this important effort, as well as to members of the Lake Victoria Basin Commission of the East African Community for their critical inputs and support.

Executive Summary

Both Kenyan and Tanzanian water laws call for determination and protection of reserve flows, defined as that quantity and quality of water necessary to satisfy basic human need and sustain aquatic ecosystems. In 2007 an Environmental Flow Assessment (EFA) was undertaken in the Mara River Basin, Kenya/Tanzania by the Global Water for Sustainability Program (GLOWS), in partnership with Kenyan and Tanzanian resource managers, and with funding from USAID – East Africa. This EFA brought together East African and international scientists with local water resource managers to make a first determination of the minimum sustainable flow levels required to provide for reserve flows in the Mara. The findings of the EFA were adopted and recommended for implementation by the Council of Ministers of the Lake Victoria Basin Commission of the East Africa Community (LVBC and WWF-ESARPO 2010).

After this assessment, the EFA team made two primary recommendations for future research and work in the basin:

- monitoring of critical low flows in the river, particularly in regards to water quality, to determine if minimum flow recommendations are sufficient or should be refined, and
- higher resolution temporal monitoring to determine the relationship between water quality and discharge.

From 2008-10, these recommendations were addressed through two approaches. First, a Low Flow EFA sampling event was held with a subset of the original EFA team to measure physical and biological characteristics of the river at critical low flow levels, revise hydraulic models and determine if minimum reserve requirements were sufficient. Second, Long-term Monitoring was conducted in the basin to monitor water quality and macroinvertebrate communities (as an indicator of ecosystem health) throughout the upper and middle basin every two weeks and to determine the relationship between water quality and discharge.

The Low Flow EFA took place in February 2009 when the river dropped to some of the lowest flow levels on record. Water quality at all three sites showed significant declines under these low flows, with very low levels of dissolved oxygen and elevated levels of conductivity and nutrients. A week after the Low Flow EFA was completed, a large and widespread fish die-off occurred in the middle-lower basin, illustrating the threat posed by these low flows to aquatic

ecosystem health. Flow levels during this sampling event were lower than both EFA reserve recommendations and Q95 flow recommendations at both EFA sites in the upper Mara. However, at the lowest EFA site on the border of Kenya and Tanzania, flow levels were below the lowest EFA reserve recommendations (for dry season flows during a drought year) but still above the Q95 flow level, meaning the river would be allowed to drop even further under default management practices.

Long-term Monitoring also identified several areas of concern in the basin. The Amala sub-catchment had greater declines in average monthly flow levels over the last 15 years, transported higher sediment load per unit catchment area and had generally lower water quality than the Nyangores sub-catchment, suggesting land degradation in this sub-catchment may be responsible for declines in water quantity and quality in the Mara. Overall, most water quality indicators suggested water quality declined from the upper catchment to the lower catchment. However, some indicators, such as *in situ* water quality measurements and macroinvertebrate sensitivity scores, showed an improvement from the middle catchment to the lowest site (EFA 3), suggesting the protected area of the Maasai Mara National Reserve may play an important role in allowing the river to recover. This recovery process may be threatened by inputs from the Talek River, as the Talek site just above the confluence with the Mara had the lowest water quality of any site monitored in the basin. Most alarmingly, water quality declined sharply from the upper to the lower site on the Talek, especially during low flows, suggesting tourism and urban development along this river may be at least partly responsible for its poor condition.

Overall, findings from the Low Flow EFA and Long-term Monitoring support the findings and recommendations of the 2007 EFA. Minimum recommended flow levels appear adequate to protect aquatic ecosystem health and provide for basic human need in the basin. However, during these assessments, new critical indicator species were identified, hydraulic rating curves were refined and hydrological data was updated for two of the EFA sites. These developments will need to be reviewed by the EFA team as a whole to determine whether adjustments to the original EFA prescriptions are warranted. This review will take place during Phase II of the EFA, which will be undertaken in 2011-12 to extend the EFA into the Tanzanian portion of the Mara River Basin.

Background

There is a growing awareness that minimum flow levels must be maintained in river channels to protect both the river itself and the people and wildlife that depend upon it. Both the Kenya Water Act (2002) and the Tanzania Water Act (2009) call for determination and protection of reserve flows to satisfy basic human needs and to protect the aquatic ecosystem. Environmental Flow Assessments (EFAs) have become the accepted way of determining minimum sustainable flow levels for a river. EFAs are structured, science-based approaches to determine how much water must be left in a river to protect the aquatic ecosystem and maintain Resource Quality Objectives (RQOs). In conjunction with available hydrological data showing how much water is available in the system, determination of how much must remain in the channel enables an estimate of that amount that can be allocated for abstraction, thus making EFAs a critical tool for water resource managers.

In 2006-07, an Environmental Flow Assessment (EFA) was conducted in the Mara River Basin, Kenya/Tanzania by the Global Water for Sustainability Program (GLOWS), in partnership with Kenyan and Tanzanian resource managers, and with funding from USAID – East Africa. This EFA was the first of its kind done in Kenya and only the second in East Africa. The EFA made a first assessment of minimum sustainable flow levels for the river using a multi-disciplinary approach based on rigorous field assessments, published information and expert opinion. The findings of that EFA were adopted and recommended for implementation by the Council of Ministers of the Lake Victoria Basin Commission of the East Africa Community (LVBC and WWF-ESARPO 2010).

Specialists engaged in the EFA also made recommendations for future work, which included the addition of data from critical low flows, and determination of impacts of flow level variation on water quality. From 2008-10, additional studies were undertaken on the Mara River to address these recommendations, determine the accuracy of EFA recommendations under variable flow conditions and provide additional data to the overall assessment of river health. This report synthesizes the findings of those studies and presents them in the context of the current EFA recommendations.

Introduction

The Mara River Basin, Kenya/Tanzania, is a critical, trans-boundary resource that sustains both the livelihoods of nearly one million people, many of whom are rural poor, who depend on the river for drinking water and ecosystem services, and the world-famous protected areas of the Maasai Mara National Reserve and Serengeti National Park. Increasing land use change, declining flow levels and degradation of ecosystem health in the Mara River led to the undertaking of an Environmental Flow Assessment (EFA)in 2006. The primary objective of this EFA was to determine reserve flows for the river from where it exits the Mau Forest to where it enters the Maasai Mara National Reserve and Serengeti National Park. The EFA was undertaken by East African and international scientists in conjunction with both Kenyan and Tanzanian water resource managers.

Analysis of field data and literature review were conducted by each specialist to determine the minimum sustainable flow levels required by each component of the ecosystem. Using this information, the specialists then reconvened to determine a modified flow regime that would sustain all components of the ecosystem and satisfy RQOs of the water resource managers. The specialists determined that, during years with normal rainfall, the river has sufficient flows to maintain the reserve and provide for abstraction. Recommended reserve flows account for 25-51% on average of recorded flows during maintenance years; however, the size of the reserve varies over the year, mirroring the natural high and low flows in the system. Much less water is available for abstraction during dry seasons than during wet seasons. During drought years, with below normal rainfall, the EFA found the reserve is currently not being met during several months of the year at sites in the upper and middle basin. The reserve is being met at the furthest downstream site; however, much less water is available for abstraction than during normal years.

The final report for the EFA prescribed reserve flows for different months of both normal and drought years for each of the three study sites (LVBC and WWF-ESARPO 2010; http://assets.panda.org/downloads/environmental_flows_assessment_mara_1.pdf). The report also included specific recommendations to help implement these reserve flows. The findings and recommendations of this EFA report were adopted by the Council of Ministers of the Lake Victoria Basin Commission of the East African Community in 2009 and recommended for implementation. Efforts to implement reserve flows are largely the responsibility of the water resource managers of both countries—the Lake Victoria South Catchment Management Authority of Kenya's Water Resources Management Authority, and the Lake Victoria Basin Water Office of Tanzania's Ministry of Water and Irrigation.

The EFA report also identified areas where further research was needed. The primary recommendations were

- monitoring of critical low flows in the river, particularly in regards to water quality, to determine if minimum flow recommendations are sufficient or should be refined, and
- higher resolution temporal monitoring to determine the relationship between water quality and discharge.

From the year 2008 to 2010, two primary approaches were used to address these recommendations. First, a smaller-scale low flow EFA was undertaken at the same sites as the original EFA with a limited group of specialists during critical low flows to determine the accuracy of the EFA's minimum flow recommendations. Secondly, a detailed long-term monitoring effort was undertaken at both EFA sites and additional sites throughout the basin to determine the relationship between flow and important ecological indicators and to look for critical low flow levels below which aquatic ecosystem health was threatened. This report presents methods and results from both the Low Flow EFA and the Long-term Monitoring. The findings of both studies support the reserve flows prescribed by the initial EFA and demonstrate that they are sufficient to maintain ecosystem health, while not allowing for additional abstraction. Furthermore, these studies identify critical indicators of aquatic ecosystem health that should be incorporated into future monitoring efforts.

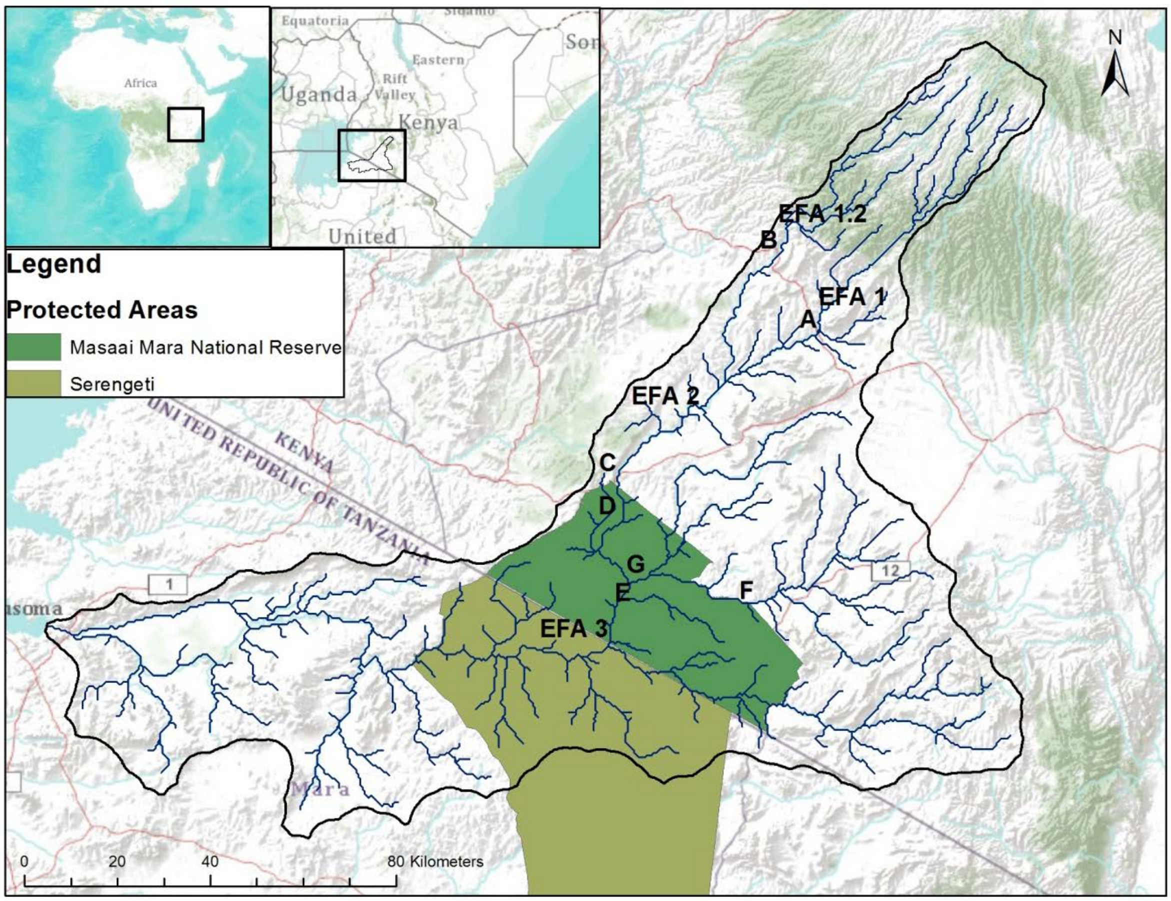
Methods

Low Flow EFA

From 21-24 February 2009, during some of the lowest flows on record for the Mara River, additional EFA sampling was conducted on the Mara River. Field assessments were done at all three original EFA sites – EFA 1: Amala River at Kapkimolwa, EFA 2: Mara River at Mara Safari Club and EFA 3: Mara River at the Kenya-Tanzania border – and one additional site, EFA

1.2: Nyangores River at Silibwet (Figure 1, Appendix 1). Sampling was conducted by a subset of specialists from the original EFA, targeting those river components most sensitive to small time-scale changes in flow level. Specialists included the hydraulics engineer, water quality specialist, aquatic entomologist and fish ecologist.

Figure 1: Map of the Mara River Basin showing sampling sites used during the low flow EFA and long-term monitoring.



Hydrological analysis was updated to include all up-to-date hydrological records for gauging stations at Amala River at Kapkimolwa (gauging station 1LB02) and Nyangores River at Bomet (gauging station 1LA03). Mara Mines gauging station stopped functioning in 1993 and was not restored until after the dates of these surveys, so no changes were made to the analyses that relied upon those records.

The hydraulics study aimed to refine the hydraulics analyses for the initial three study sites by including the lowest flow levels and to develop initial hydraulics rating curves for the new site.

This study adopted the same methodology as applied in the earlier EFA (LVBC and WWF-ESARPO 2010). Straight channels were selected that contained pools, riffles and runs, and 4-6 transects per reach were measured. Velocity was measured with a Flow-Tracker Acoustic Doppler Velocimeter, and water surface profiles were determined using a Total Station, Dumpy level or tape measure. Hydraulic analysis and modeling were undertaken using the Physical Habitat Simulation Model (PHABSIM) to determine relationships between discharge and ecologically relevant hydraulic parameters, such as depth, velocity, wetted perimeter, flow area and water surface width.

Water quality sampling was conducted at each site using *in situ* and laboratory methods. For *in situ* measurements, YSI 556 Multi-Probe System (Yellow Springs, Ohio) was used to measure temperature, conductivity and dissolved oxygen. A LaMotte 2020 turbidimeter was used to measure turbidity of the water. Water samples were collected and filtered through 45 µm cellulose nitrate filters. Before and after weights of the filter papers were used to determine total suspended solids in a known volume of sample. For laboratory analysis, filtered and non-filtered samples were collected in 60 mL HDPE bottles, a portion of which were preserved with sulfuric acid, and kept frozen until analysis. Samples were analyzed in the laboratory for dissolved organic carbon (DOC), ammonium, cations and anions, and a subset of the samples were analyzed for total nitrogen (TN), total phosphorous (TP), and phosphate.

Fish sampling was conducted at all four sites using a combination of gill nets and electroshocking. At each site, two sets of 100 m by 2 m multimesh gillnet panels were set parallel to river flow for 3 hours in deeper, wider sections of the river. A backpack electroshocker was used in shallower sections and along banks by wading for 30 minutes at each site. Fish were identified in the field using taxonomic guides (Bernacsek 1980, Eccles 1992, Skelton 1993, Witte and de Winter 1995), and total lengths and wet weights were measured. Fish were dissected to determine sex and gonad state was assessed using a five-point scale (Bagenal 1978). Catch per unit effort (CPUE, # fish captured/hour) and relative abundance and distribution of each taxa were determined, and the Shannon-Wiener Diversity Index (H’) (Shannon 1948) was calculated for each site.

Macroinvertebrates were sampled by kick-netting with a 500 µm rectangular-framed kick net (Ring size, 18" x 8"; net depth, 10"; Wildco, FL, USA). Kick-netting was done for 30 s in 4 replicates of 4 microhabitat types, including pools, riffled, runs and emergent vegetation, for a total of 16 samples per site. Depth and velocity were determined at each microhabitat sampling site. Macroinvertebrate samples were collected from the net and preserved using 70% ethanol until they could be sorted in the lab. Preserved specimens were then identified at the Entomology Lab, National Museums of Kenya, to family level and counted for abundance. Macroinvertebrates were classified according to sensitivity to water quality using the SASS 5 scoring protocol (Dickens and Graham 2002).

Long-term Monitoring

From 20 August 2008 through 22 August 2009, water quality monitoring was conducted at 11 sites throughout the Mara River Basin (Figure 1). EFA sites are referred to with numbers consistent with the original EFA, and new sites added for long-term monitoring are identified with letters. Sampling sites included two sites on each of three major tributaries – the Nyangores (EFA 1.2, Site B), Amala (EFA 1, Site A) and Talek (Sites F, G) Rivers – and five sites on the Mara River – two sites above (EFA 2, Site C) and three sites within (Sites D, E, EFA 3) the protected areas. Details for all sampling sites are located in Appendix 1. Water quality sampling was conducted in the same manner as during the Low Flow EFA, as described above. Results were analyzed according to site location in the basin and discharge levels.

Discharge data were collected from the Kenya Water Resources Management Authority (WRMA), Lake Victoria South Catchment (LVSC) office. Functioning staff gauges are located on the Nyangores River (gauging station 1LA03) at Site B and the Amala River (gauging station 1LB02) at EFA 1, and they are monitored on a daily or twice daily basis. Discharge data at EFA 2 was determined by adding together discharge from EFA 1 and Site B and dividing by a watershed correction factor of 0.94. The gauging station at Site C on the Mara River (gauging station 1LA04) no longer exists; however, determination of sediment loads at this site were important to facilitate comparisons with historical data collected at this site. Discharge data for Site C was extrapolated by using data from EFA 1 and Site B in the following watershed transformation,

$$A_{EFA1+B}/A_{C} = [Q_{EFA1+B}/Q_{C}]^{0.9}$$

where A is the watershed area contributing to each site and Q is the discharge. We obtained the watershed areas for EFA 1 and Sites B and C from McCartney (2009). We used a value of 0.9 for the exponent based on the assumption that the two watershed areas were fairly similar; it was not possible to obtain this value empirically due to limited data.

Variation in water quality data was examined by both site and date. Out of 24 sampling events, samples collected during the highest (August 2008) and lowest (March 2009) flows were used to compare across sites and flow levels. For the three sites where discharge measurements were obtained for the EFA (EFA 1, Site B and EFA 2), water quality parameters were analyzed in relation to flow level over the period of one year. Using discharge data for EFA 1, Site B and Site C (as described above), sediment rating curves were developed for these sites. Sediment rating curves can be used to determine total sediment load in a river over a period of time or to determine past sediment loads when only discharge data is available, assuming no significant changes in land use occurred (Campbell and Bauder 1940, Holdo et al. 2007). Sediment concentration was multiplied by discharge and a unit conversion factor to obtain the daily sediment flux using the following equation:

$$\text{Sediment flux (metric tons/day)} = \text{Sediment concentration (mg/L)} * Q\ (m^3/\text{sec}) * 0.0864$$

Both sediment flux and discharge measurements for each site were tested for normal distribution (Minitab 16). Data that weren’t normally distributed were log transformed or converted to ranks. Sediment rating curves were developed for all three sites by graphing sediment flux against discharge, using the data or transformed data that yielded a normal distribution. Sediment rating curve equations were applied to discharge data from WRMA for a period for which a solid year of record was available (July 2009 to June 2010) for Sites 2 and 3 to obtain total sediment load transported by the rivers during that time.

To compare spatial variability among all sites, including those for which discharge data was unavailable, sediment concentration was used instead of sediment flux. Average sediment concentration for each sampling location was analyzed in relation to the size of the contributing watershed and the percent watershed area under agricultural land use, using data from McCartney (2009).

Aquatic macroinvertebrates were sampled monthly at the four EFA sites (Figure 1; EFA 1, EFA 1.2, EFA 2, and EFA 3) to give a more detailed picture of ecological health in relation to flow. Macroinvertebrates were sampled as described above for the Low Flow EFA. Macroinvertebrate samples from all microhabitats were combined to yield one composite sample per site per sampling period. Each composite sample was analyzed for abundance, diversity and sensitivity to water quality using multiple metrics, and results were analyzed in relation to site location and discharge level.

To determine species richness, total numbers of taxa were counted at the family level for each composite sample. To describe differences in community composition as well as richness, diversity indices were calculated. The Simpson's Richness Index was calculated using Equation 1, to represent both the number and the relative abundance of taxa (Simpson 1949). The Simpson's Index ranges from 0 to 1, with high values indicating strong dominance and low diversity (Odum and Barrett 2005).

$$D = 1 - \frac{\sum_{i=1}^{s} n_i(n_i - 1)}{N(N-1)} \qquad \text{Equation 1}$$

The Shannon-Wiener Diversity Index was calculated using Equation 2 to reflect both species richness and evenness, with a higher value reflecting either the addition of new taxa or an increase in species evenness (Shannon 1948).

$$H = -\sum_{i=1}^{s} \frac{n_i}{N} \ln \frac{n_i}{N} \qquad \text{Equation 2}$$

Samples were also analyzed according to the sensitivity of macroinvertebrate taxa to declining water quality. To obtain an index of the proportion of sensitive taxa in the sample, the percent abundance of each sample comprised of Ephemeroptera, Plecoptera or Trichoptera (EPT) was calculated. The abundance of these orders was summed and presented as a proportion of the total number of individuals per site to give an overall %EPT Index, which is considered a good indicator of water quality (Resh and Jackson 1993, Bonada et al. 2006, Buss and Vitorino 2010). To provide an index of taxa less sensitive to water quality, we calculated the percent abundance of each sample comprised of Diptera and Annelida.

We also characterized the sensitivity of taxa according to the South African Scoring System (SASS) Version 5 Rapid Bioassessment Method for Rivers, which rates benthic macroinvertebrate taxa on a 1-15 scale, with higher numbers associated with increased sensitivity to poor water quality (Dickens and Graham 2002). The total SASS score for each sample was obtained by summing the sensitivity score for each documented taxa. The Average Score per Taxon (ASPT) was calculated by dividing the total SASS score by the total number of taxa documented in each sample.

We used one-way analysis of variance (ANOVA) to determine whether macroinvertebrate metrics varied significantly by site (Minitab 16). We tested the macroinvetebrate metrics data for normality and equal variance, and we tested the residuals for normal distribution. The following metrics met the assumptions of the model: Simpson and Shannon-Wiener indices, # taxa, SASS5 and ASPT. These were analyzed with one-way ANOVA and means were compared using Tukey's multiple comparisons. The metrics %EPT and %Diptera were not normally distributed, had unequal variances, and were analyzed with a Kruskal-Wallis test (Kruskal and Wallis 1952). Macroinvertebrate metrics also were used as dependent variables in stepwise multiple regression analyses with in-stream physiochemical parameters (temperature, conductivity, DO and turbidity) to determine which metrics were best explained by water quality (Sponseller et al. 2001). An alpha-to-remove value of 0.1 was used.

Results

Low Flow EFA

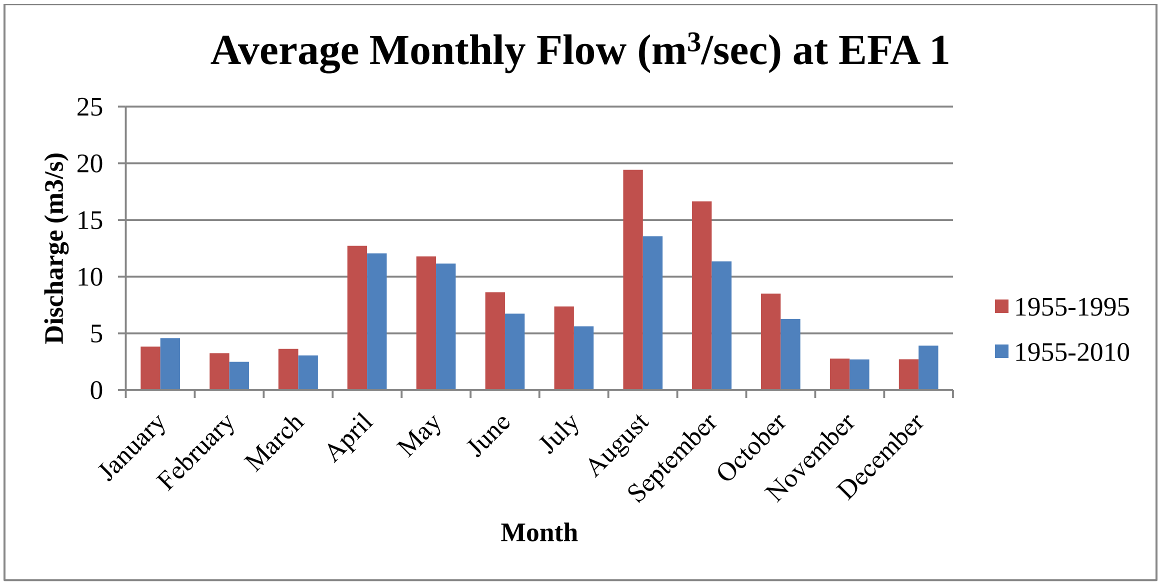
Hydrology

Hydrological analyses undertaken for the 2007 EFA were re-done using additional data available through 2010. Data from Amala River at Kapkimolwa (gauging station 1LB02) were available from 1955 through 2010. Data from Nyangores River at Bomet (1LA03) were available from 1963 through 2010.

For EFA 1, including additional hydrological records from 1995-2010 collected at gauging station 1LB02 resulted in general declines in average monthly flow levels as compared to this 1955-1995 analysis (Figure 2). Lower averages were most pronounced in dry season flows in

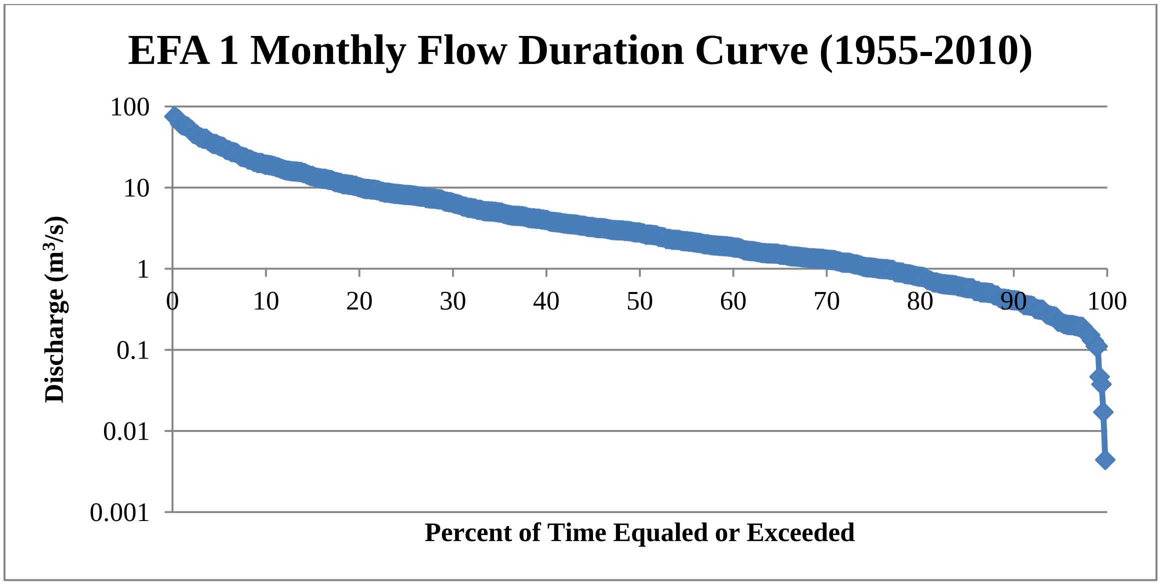
June and July and wet season flows from August to October. However, dry season flows in December and January actually showed a slight increase with the inclusion of recent data.

Figure 2: Average monthly flow at EFA 1 on the Amala River for hydrological records from 1955-2010



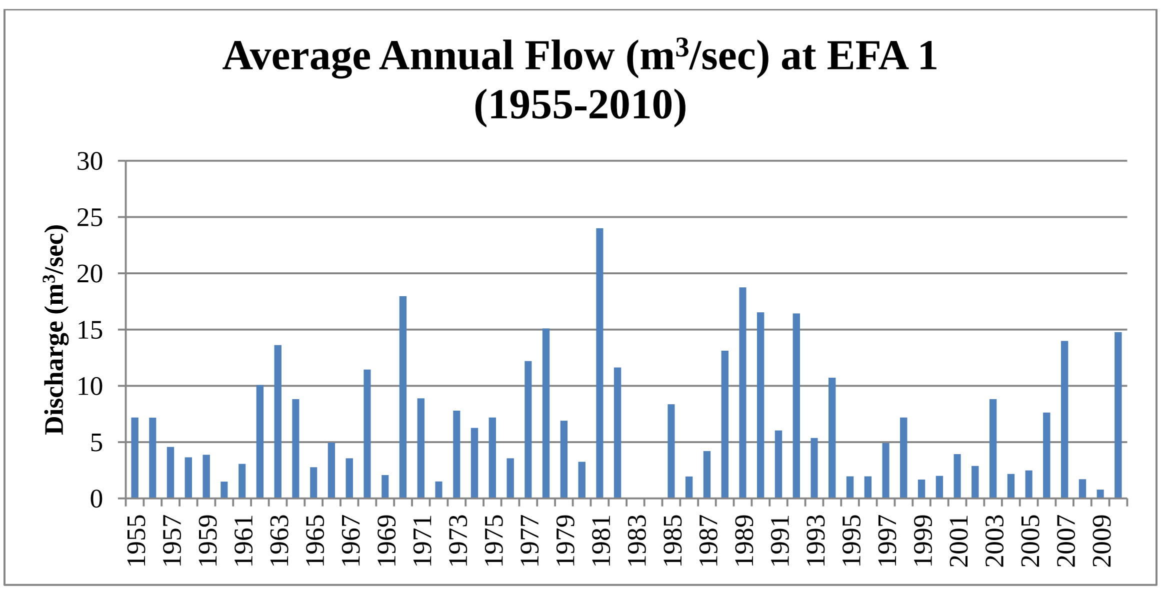
These declines in flow in turn caused the monthly flow duration curve (FDC), which shows the percent of time an average monthly flow is exceeded, to shift slightly downwards (Figure 3). In the original analysis, which included records from 1955-1995, a flow of 0.275 m^3/sec was exceeded 95% of the time. With the inclusion of data from 1995-2010, a flow of 0.217 m^3/sec is exceeded 95% of the time, suggesting the average flow levels in the river may have declined slightly in the past two decades.

Figure 3: Monthly flow duration curve for EFA 1 on the Amala River for hydrological records from 1955-2010



These declines in average monthly flow levels may be due to a number of extended droughts that occurred during the last 15 years as well as increased abstractions. Average annual flow over the period of record show average flow levels from 1995-2010 were generally lower than historically (Figure 4).

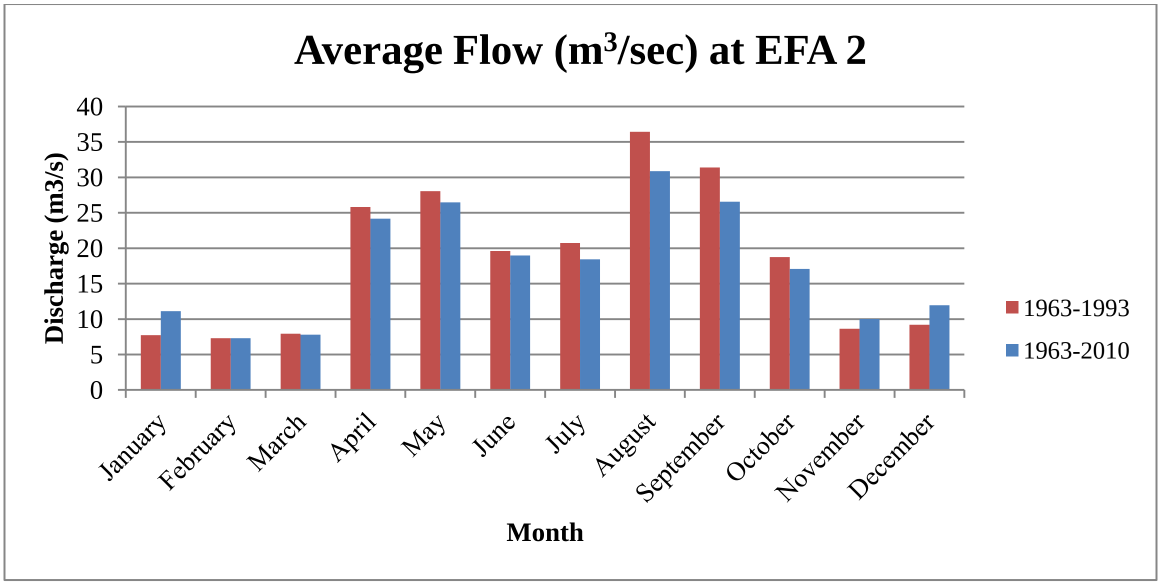
Figure 4: Average annual flow (m^3/sec) for EFA 1 on the Amala River from 1955-2010



Flow data at EFA 2 followed a similar pattern. When hydrological records from 1993-2010 were included, average monthly flow levels declined across months from April to October. As with

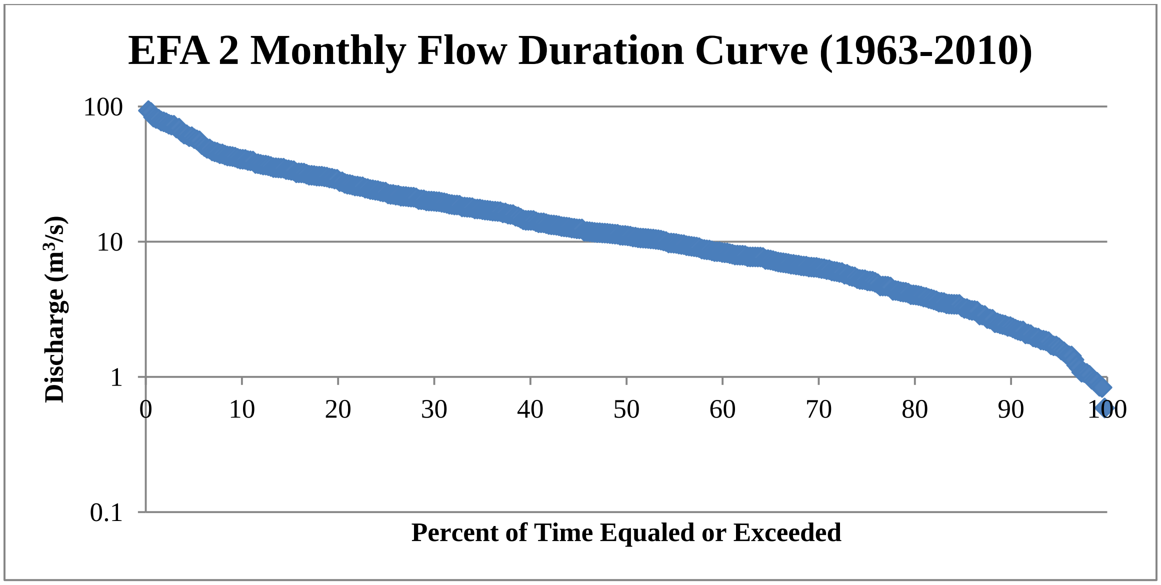
EFA 1, the largest declines were in August and September. However, flow levels in June and July didn't decline as much, and flow levels in February and March stayed fairly constant, suggesting that dry season flows haven't fallen in proportion with declines in wet season flows (Figure 5).

Figure 5: Average flow at EFA 2 on the Mara River for hydrological records from 1963-2010



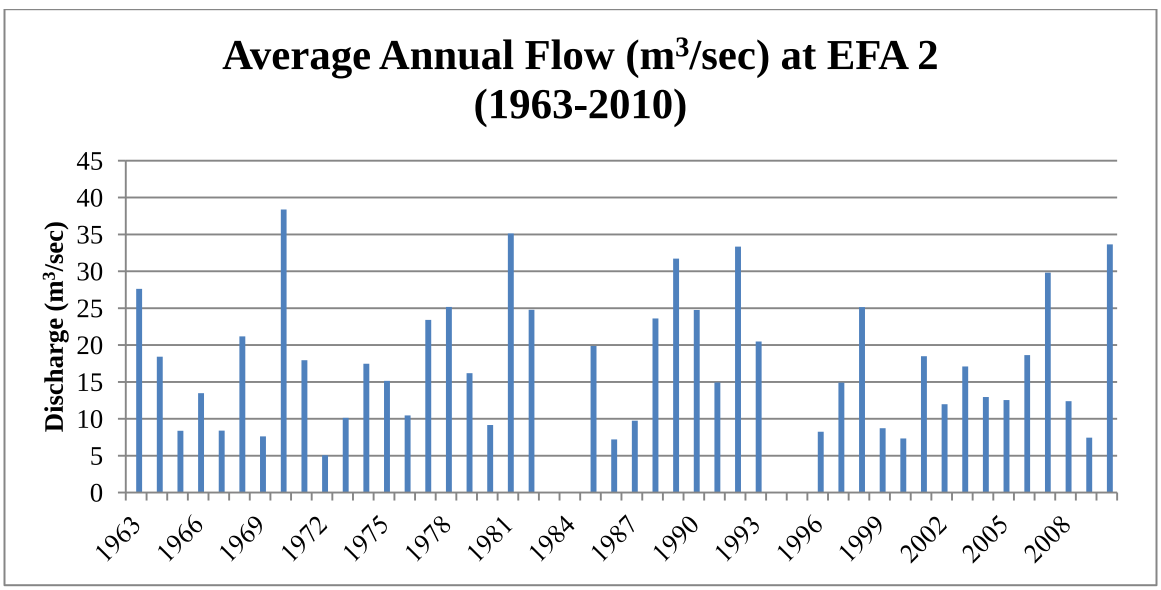
As a result of increased flows in some months and decreased flows in other months, the FDC for EFA 2 hardly shifted at all with inclusion of updated hydrological records (Figure 6). In the original FDC (1963-1993), a flow of 1.44 m^3/sec was exceeded 95% of the time. In the updated FDC (1963-2010) a flow of 1.53 m^3/sec is exceeded 95% of the time.

Figure 6: Monthly flow duration curve for EFA 2 on the Mara River for hydrological records from 1963-2010



Average annual flow data for EFA 2 also didn't show the same trend as for EFA 1 of lower than average flow levels from 1995 to present, suggesting the Amala sub-catchment may be experiencing greater declines in flows than the Nyangores (Figure 7).

Figure 7: Average annual flow (m^3/sec) for EFA 2 on the Mara River from 1963-2010



A more thorough analysis of the historical hydrological record will be necessary to determine which hydrological data most accurately represents normal flow levels in the river. For now, reserve flow recommendations and %FDC values given in this report will be based on the original hydrological analysis.

At EFA 1, discharge during the February 2009 sampling (0.2 m^3/sec) was at 97% on the monthly flow duration curve (FDC), meaning this flow level is exceeded 97% of the time. Default methods of prescribing reserve flows often only protect flows below Q95, that is, flows that are exceeded 95% of the time. At EFA 1, Q95 is 0.27 m^3/sec. The 2007 EFA recommendations for this site, during the dry season of drought years, was 0.3 m^3/sec. Flow levels in February 2009 were lower than both the EFA reserve recommendations and the default Q95 approach.

At EFA 2, discharge in February 2009 (1 m^3/sec) was also at 97% on the monthly FDC. Q95 at this site is 1.44 m^3/sec, and the EFA reserve recommendation for drought year dry season flow is 1.1 m^3/sec. Again, flow levels at this site in February 2009 fell below both EFA and Q95 recommendations.

At EFA 3, discharge (1.1 m^3/sec) was at 93% on the monthly FDC, and Q95 is 0.89 m^3/sec, meaning that flow levels had not reached the level at which the reserve should be protected according to Q95. However, the EFA reserve recommendation for drought year dry season flow at this site is 2 m^3/sec, meaning flow levels were already impinging on the reserve.

Hydraulics

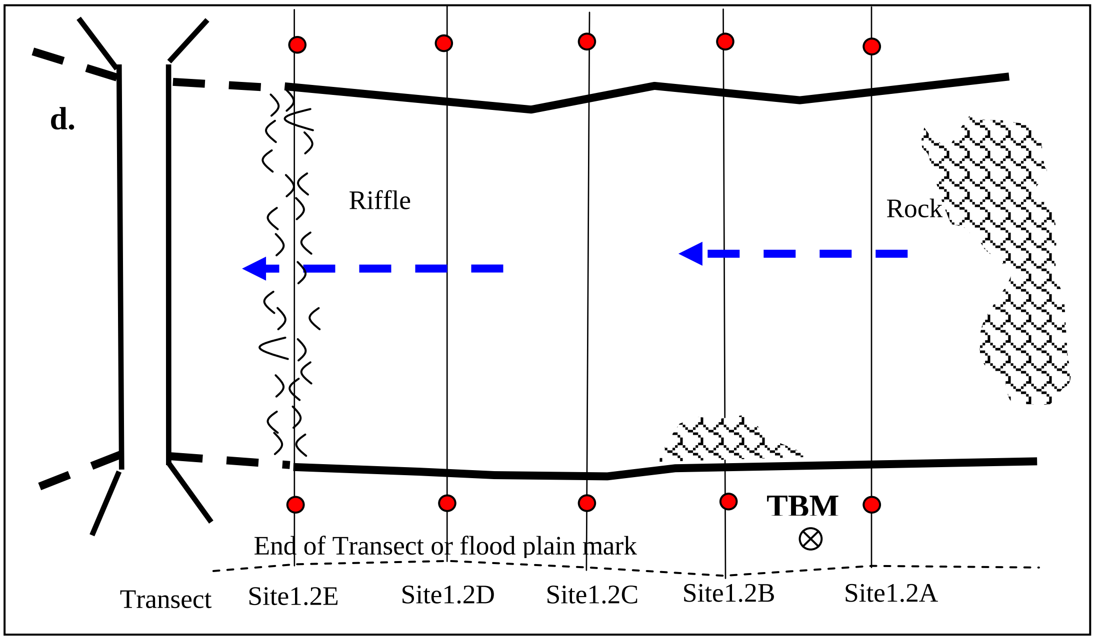
For the three original EFA sites, the same transects and Temporary Benchmark (TBM) were used as during the initial surveys. Site descriptions and graphs for the three original sites are available in the initial EFA report (LVBC and WWF-ESARPO 2010). Flow levels were significantly lower during the February 2009 sampling event than during either the March or July 2007 sampling events, which allowed the hydraulics engineer to re-calibrate hydraulic models using critical low-flow data (Table 1).

Table 1: Discharge at the EFA sites during 2007 and 2009 sampling events

EFA Site	Discharge (m^3/sec)		
	March 2007	July 2007	February 2009
EFA 1	1.2	7.9	0.2
EFA 1.2	-	-	0.6
EFA 2	6.8	16.9	1
EFA 3	7.5	15.9	1.1

For the new EFA site, EFA 1.2 on the Nyangores River, five transects and a TBM were established through a straight portion of the channel, with transects passing through riffles, pools and runs (Figure 8).

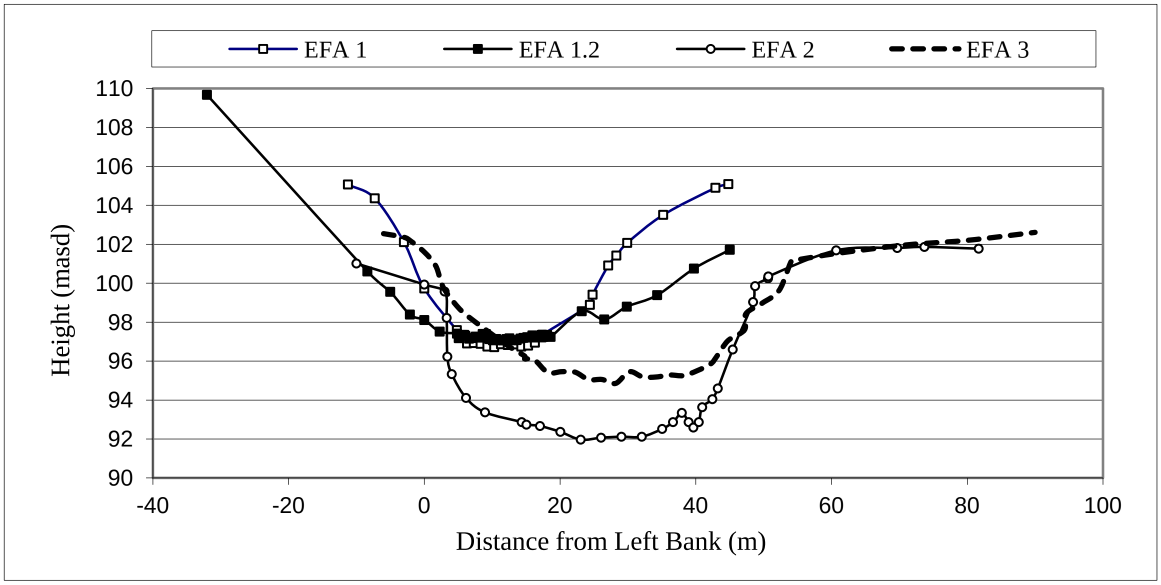
Figure 8: Diagram of survey reach at the new EFA site, EFA 1.2 on the Nyangores River, which had 5 transects over a 43.55 m length



Chainage	0.00	12.95	19.95	31.75	43.55

As in the earlier survey, the macro-channel at each site had similar shape and dimensions, all incised approximately 8 m below surrounding land level and with a width from 45 m at EFA 1 to 55 m at EFA 1.2, 2 and 3 (Figure 9).

Figure 9: Cross-sectional plots of selected transects (labeled with letter) at each study site



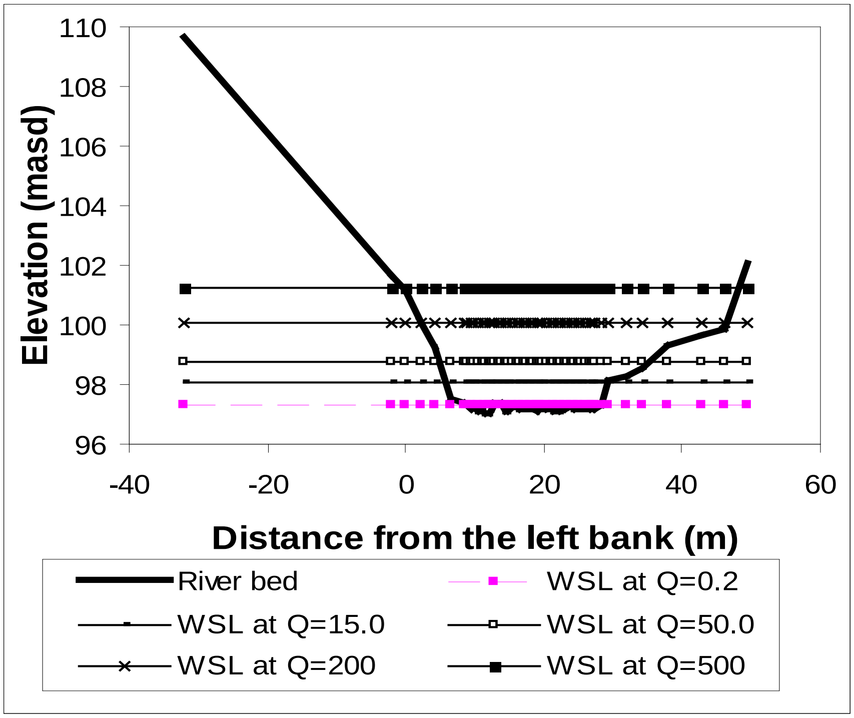
Flow parameters, including width of water surface, total area, total discharge, mean velocity and water surface level, were averaged for each study reach across all transects (Table 2). Average discharge during the 2007 survey was 1.2 m^3/sec and 7.9 m^3/sec at EFA 1, 6.8 m^3/sec and 16.9 m^3/sec at EFA 2, and 7.5 m^3/sec and 15.9 m^3/sec at EFA 3, in March and July, respectively. Discharge was on average 85% lower during the February 2009 sampling than during the March 2007 sampling, fulfilling the need for critically low flow levels to improve hydraulic rating models.

Table 2: Summary of average hydraulic characteristics measured at study sites during February 21-24, 2009 field visit

EFA site	Measured hydraulic average flow parameters				
	Total width of water surface, W (m)	Total area, A (m^2)	Total discharge, Q (m^3/s)	Cross section mean velocity, V_m (m/s)	Water Surface Level, WSL (masd)
Site 1	8.8	2.7	0.2	0.11	97.1
Site 1.2	17.5	4.7	0.6	0.19	97.4
Site 2	20.5	5.2	1.0	0.21	92.5
Site 3	19.0	8.2	1.1	0.11	95.8

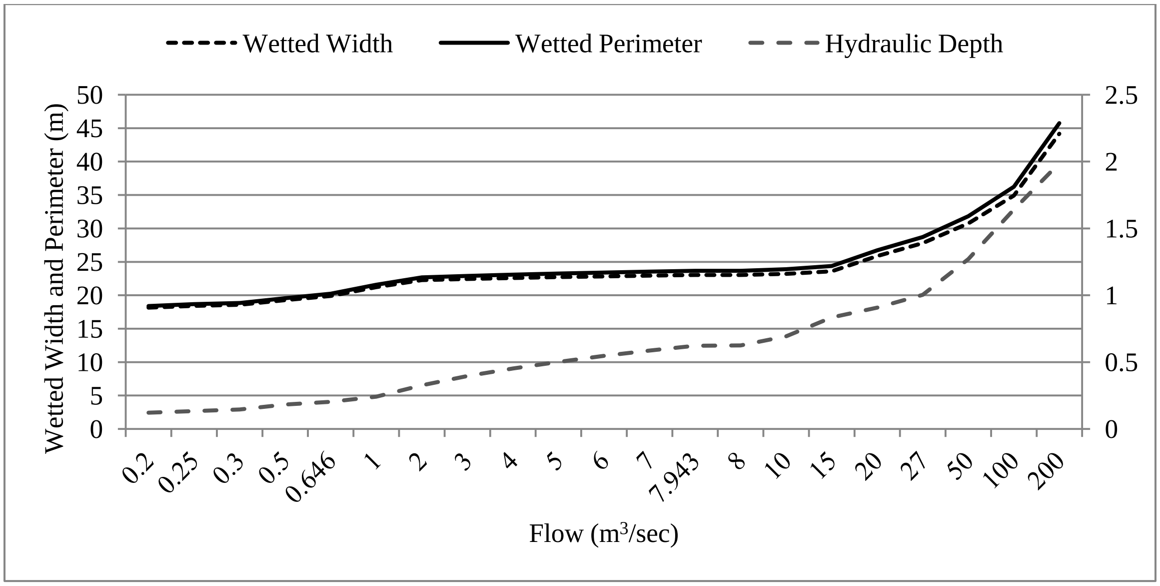
New hydraulic models were developed for EFA 1.2, which will need to be refined using data from surveys at medium and high flows. Model projections were used to develop relationships between discharge level and ecologically relevant hydraulic parameters, including water surface level (Figure 10), wetted width, wetted perimeter and velocity (Figure 11).

Figure 10: Simulation results of Water Surface Level (WSL) in meters above site datum (masd) as a function of discharge, Q (m^3/s) at EFA 1.2 on the Mara River.



Graphing flow parameters as a function of discharge allows determination of critical low flow levels. For example, wetted width and wetted perimeter are primary indicators of how much aquatic habitat is available at any particular discharge. At EFA 1.2, both wetted width and perimeter show inflection points at 0.3, 2 and 15 m^3/sec, suggesting that these flow levels occur where aquatic habitat availability significantly increases.

Figure 11: Simulated relationships between key ecological parameters (wetted width, wetted perimeter and hydraulic depth) and discharge at EFA 1.2 on the Nyangores River.

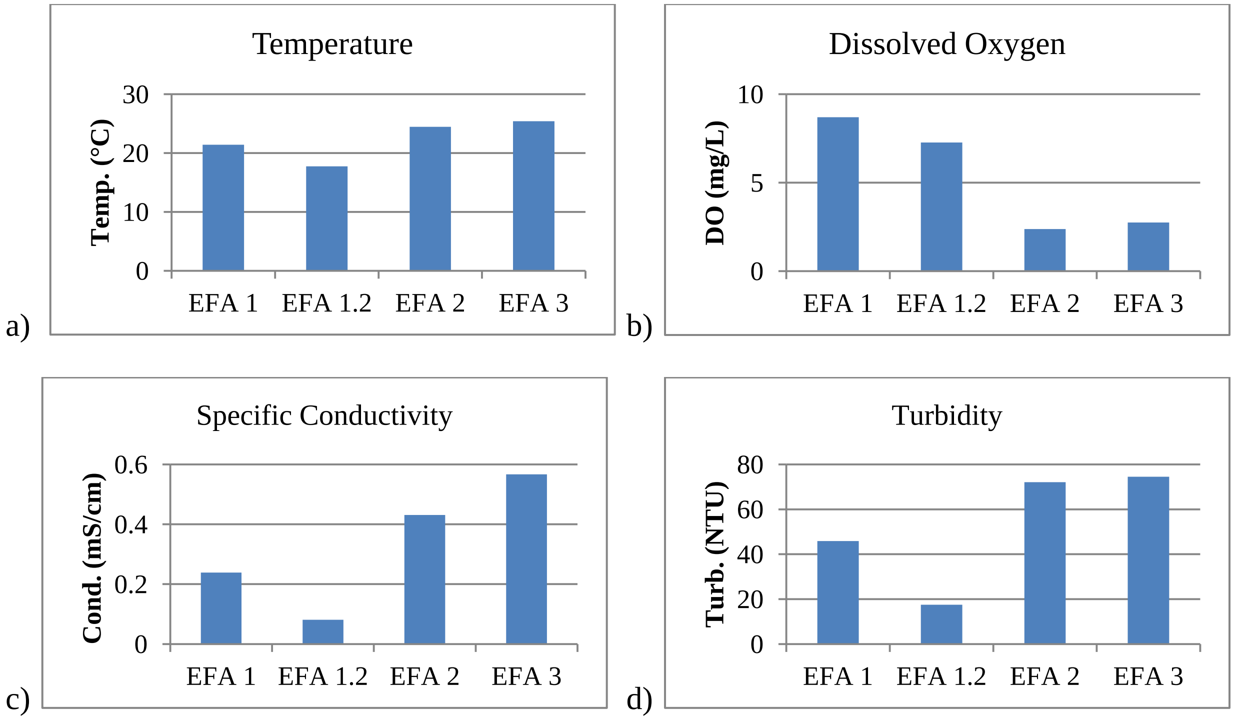


Results from the hydraulic simulation model for EFA 1.2, and results for the recalibrated hydraulic simulation models for EFA 1, 2 and 3 are in Appendix 2.

Water Quality

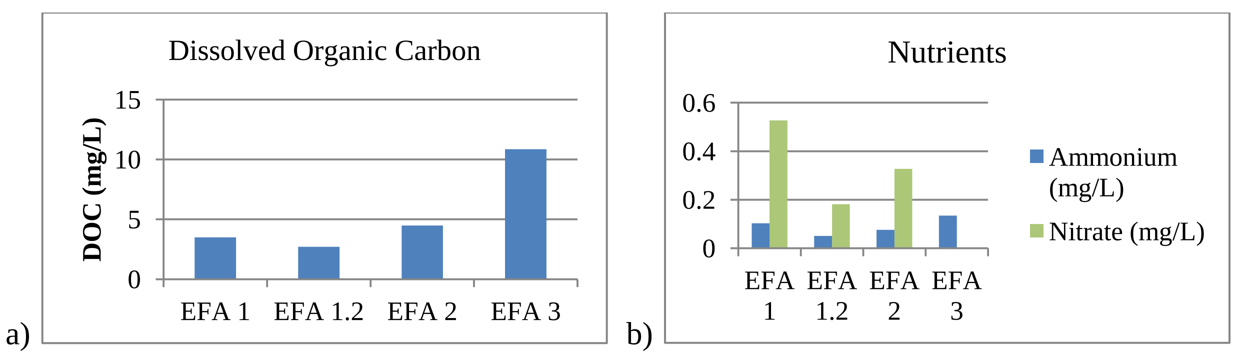
Water quality varied strongly among sampling sites (Figure 12). By all parameters, EFA 1 and 1.2 had the highest water quality, with lower temperatures, higher dissolved oxygen (DO), lower conductivity and lower turbidity than EFA 2 and 3. Some of the variability in these parameters could be confounded by the fact that EFA 1 and 1.2, on tributaries to the Mara, are different order streams than EFA 2 and 3, on the Mara itself. However, very low dissolved oxygen levels at EFA 2 (2.38 mg/L, 28.6% saturation) and EFA 3 (2.75 mg/L, 33.6% saturation) suggest water quality in the lower Mara was highly affected by very low flows during this sampling period. One week after this sampling event, a large, widespread fish die-off occurred in the Mara from EFA 2 through EFA 3, suggesting flows were below sustainable levels for healthy aquatic life.

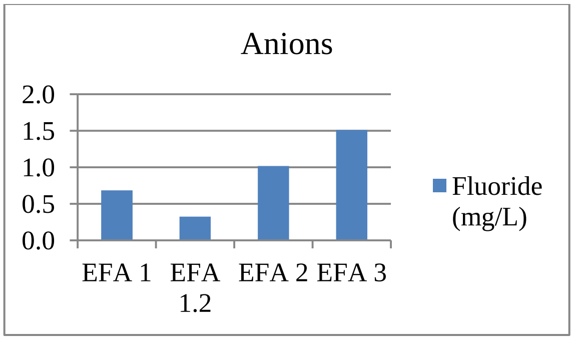
Figure 12: In situ water quality data for a) temperature, b) dissolved oxygen, c) conductivity and d) turbidity from four EFA sites during February 2009 sampling

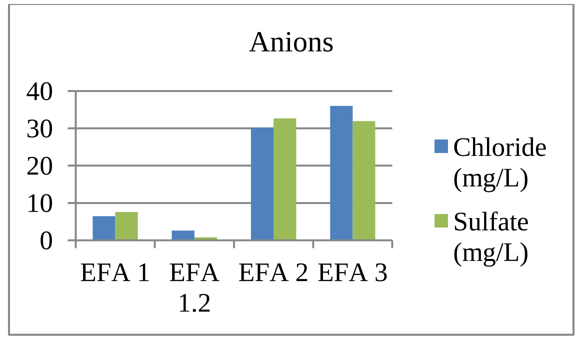


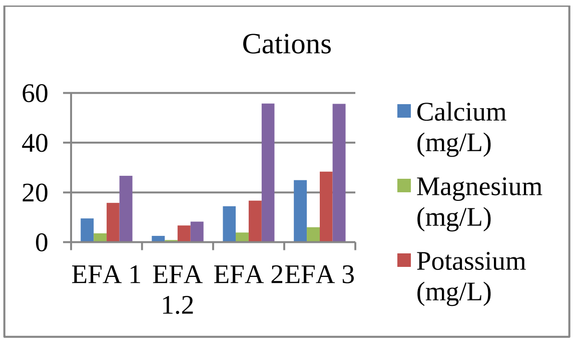
Water quality parameters measured in the laboratory followed similar patterns, with EFA 1.2 having the lowest values and EFA 2 and 3 generally having the highest values (Figure 13). However, in contrast to the *in situ* parameters, EFA 3 almost always had higher values than EFA 2, and for ammonium, EFA 1 had the second highest values.

Figure 13: Water quality data from laboratory analysis for a) dissolved organic carbon, b) nutrients, c-d) anions and e) cations from four EFA sites during February 2009 sampling



c) 

d) 

e) 

Water quality data from the Low Flow EFA sampling event can be found in Appendix 3.

Fish

A total of 229 individuals from 6 genera and 14 species of fish were captured during the 2009 sampling event, more than doubling the number of species captured during the 2006-07 sampling event, and increasing the total number of fish species described from the Mara River to 15 (Table 3). Photographs of all species can be found in Appendix 4. This increase in documented diversity was likely due to use of an electroshocker, in addition to gillnets, during sampling.

Table 3: Fish species documented in the Mara River during the 2007 and 2009 sampling events and their classifications into different ecological guilds.

Family	Species	Ecological Guild	2007 Survey	2009 Survey			
				EFA 1	EFA 1.2	EFA 2	EFA 3
CYPRINIDAE	*Labeo victorianus*	Lotic	✓	✓		✓	✓
	Labeo cylindricus	Lotic		✓		✓	✓
	Barbus oxyrhynchus	Pool		✓		✓	
	Barbus altianalis	Pool	✓	✓		✓	✓

	Barbus paludinosus	Pool		✓			✓
	Barbus cercops	Pool					✓
	Barbus kerstenii	Pool	✓			✓	
CLARIDAE	*Clarias liocephalus*	Lotic		✓	✓		
	Clarias gariepinus	Eurytopic	✓			✓	✓
MORMYRIDAE	*Mormyrus kannume*	Eurytopic	✓			✓	✓
BAGRIDAE	*Bagrus docmac*	Eurytopic				✓	
MOCHOKIDAE	*Chiloglanis somereni*	Riffle				✓	
CICHLIDAE	*Tilapia zillii*	Eurytopic					✓
	Haplochromis sp.	Eurytopic					✓
	Oreochromis sp.	Eurytopic	✓				

Across all sites, in both 2007 and 2009, the dominant species were *Barbus altianalis* (41%) and *Clarias liocephalus* (25%), followed by *Labeo victorianus* (15%) and *L. cylindricus* (14%). However, *Labeo* constituted the majority of the biomass (54%), followed by *Clarias* (19%), *Barbus* (15%) and *Mormyrus* (11%).

Catch per unit effort (CPUE, # individuals/hour) was used as an indicator of relative abundance across the four study sites. An ANOVA showed significant differences in CPUE across sites by electroshocker (p=0.006) but not by gillnets (p=0.406). EFA 1 and 2 had the highest CPUE for gillnets and electroshocking, respectively. EFA 1.2 had low CPUE for both methods because of the low abundance of *C. liocephalus*, which is the only species occurring at the site. A dam and natural waterfall just downstream of the study site prevents upstream migration of other fish species. EFA 3 had intermediate CPUE, although low sampling success could have been due to sampling challenges from large wildlife and channel incision that made thorough sampling difficult. Species diversity followed a different pattern than CPUE, with EFA 2 and EFA 3 having the highest and second highest values for both Shannon-Wiener diversity (which accounts for how many species are present) and evenness (which takes into account distribution of abundance across species) indices, respectively (Table 4). EFA 1 had slightly lower values. EFA

1.2, at which only one species, *C. liocephalus*, was documented, had values of 0 for both measurements.

Table 4: Catch per Unit Effort, Shannon-Wiener Diversity Index and associated Evenness for fish species in the Mara River from each EFA sampling site in 2009

Sampling site	**Catch per Unit Effort (CPUE) # indiv./hour**		**Shannon-Wiener Diversity Index**	**Evenness**
	Gillnet	Electroshocking		
EFA 1	5.3	118	1.38	0.77
EFA 1.2	0.33	66	0	0
EFA 2	3.33	154	1.84	0.84
EFA 3	2.7	52	1.87	0.85

For all species in which more than 50 individuals were captured, catch data were analyzed to determine proportion of reproductively active males and females. For 14 of the 15 species, over 23.5% of adult fishes carried ripe gonads, and there were a relatively large number of immature and juvenile fishes present, as well as males and females with recently spent gonads. These findings suggest the short rains that occurred in December 2008 and January 2009 had been sufficient to trigger spawning activity. Breeding activity in tropical fish species is often associated with rising water levels at the beginning of rainy seasons (Lowe-McConnell 1975, Welcomme 1985), and this has been observed in other river systems in the Lake Victoria Basin (Ochumba and Manyala 1992).

To determine flow requirements needed to sustain the fish component of the river system, fish species were characterized according to their ecological guild (Table 3) (Welcomme et al. 2006). The ecological guild classification approach used in this study grouped fish species according to preferred habitat requirements at various stages of their life cycles and how they are likely to respond to changing hydrology and geomorphology of the river. Fish in the Mara comprise two major communities, each consisting of different guilds. Rhithronic communities include the riffle guild and the pool guild. Potamonic communities include the lotic guild (longitudinal migrants), lentic guild (floodplain migrants) and eurytopic guild (tolerant of low dissolved oxygen). Riffle, pool and lotic guilds are most sensitive to changes in the flow regime that affect habitat availability, dissolved oxygen levels and mobility. Thus, species representing these communities are the best indicators of a suitable flow regime.

In the Mara, *Chiloglanis somereni*, which was only documented at EFA 2, is the most sensitive indicator, because it relies on riffle habitats. Riffle species usually require fast and well-oxygenated water, and they rely on riffle habitats which are the first habitats impacted by declining low flows. *Barbus sp.*, which were documented at EFA 1, 2 and 3, are also flow-sensitive indicators, because they fall in the pool guild. Species in the pool guild are impacted by changes in the flow regime which desiccate pools or result in extended low flows which drive pools to anoxia, or that otherwise change the balance between pools and riffles in the main channel. *Labeo spp.* and *Clarias liocephalus*, in the lotic guild, are also flow-sensitive indicators and were documented at all four sites, except EFA 1.2 where only *C. liocephalus* was encountered. Species in the lotic guild are often longitudinal migrants that move up and down the river channel and have one breeding season per year that is closely linked to peak flows. Thus, they are sensitive to damming of the river that prevents migration and to changes in timing or occurrence of high flow events. There are no representatives of the lentic guild in the Kenyan portion of the Mara Basin, which constitute non-migrant floodplain residents. The remaining species found in the Mara are in the eurytopic guild, which occupy the riparian zone and are generally tolerant of low dissolved oxygen. Species in this guild are fairly robust to changes in flow regime, and they may increase as other species decline in response; however, they may be negatively affected by declines in riparian vegetation. The vast majority (94.8%) of fish captured in the Mara during this survey comprise the most flow-sensitive guilds, suggesting the river is in fairly good condition. However, maintenance of reserve flows is critical to maintenance of the native fish fauna in the river (Table 5).

Table 5: Representative fish species in major environmental guilds in the Mara River

Fish community type	Ecological guild	Representative fish genera/species in the Mara	Percent of the total catch	Sensitivity to flow
Rhithronic communities	Riffle guild	*Chiloglanis*	1.7	Critical
	Pool guild	*Barbus*	40.7	High
Potamonic communities	Lotic guild	*Labeo, Clarias liocephalus*	52.4	Very high
	Lentic guild	No representative species in the Mara	-	High
	Eurytopic guild	*Clarias gariepinus, Tilapia, Oreochromis, Haplochromis, Mormyrus*	5.2	Low

Recommended reserve flows for the fish component of the river system were reviewed after the 2009 sampling event. Although discharge during the 2009 sampling event fell below recommended reserve flows for dry season low flows at all three original sites, two flow-sensitive species – *C. somereni* and *C. liocephalus* – were documented in the river for the first time during this sampling event. The occurrence of these species suggests the February 2009 flow levels were sufficient for minimal survival conditions, at least for short periods of time. However, they may not be sustainable in the longer term. In particular, *Chiloglanis* are generally known to require fast flowing water >0.3 m/s during most phases of their life cycle (Africa 2008). Taking into account both earlier data as well as these new species occurrences and their flow requirements, the fisheries scientist used the revised hydraulic models to prescribe minimum flow recommendations to sustain the fish component of the river (Table 6). Some of the reserve recommendations were adjusted up or down due to either new findings or different outcomes from the hydraulic models; however, these changes to reserve recommendations would need to be reviewed and vetted by the entire EFA team of specialists before formally adjusting reserve flow recommendations for the whole river system.

Table 6: Recommended reserve flows to satisfy fish requirements during various flow building blocks, as determined after the 2007 and 2009 sampling events

Year	**Flow Category**	**EFA 1 (2007)**	**EFA 1 (2009)**	**EFA 1.2 (2007)**	**EFA 1.2 (2009)**	**EFA 2 (2007)**	**EFA 2 (2009)**	**EFA 3 (2007)**	**EFA 3 (2009)**
Maintenance Year	Dry season low flows	1.0	1.25	-	2.00	4.0	1.00	6.0	7.00
	Wet season low flows	2.0	2.00	-	4.00	6.0	6.84	15.0	15.00
	Wet season floods **	12.0	12.00	-	13.00	16.0	16.00	90.0	90.00
Drought Year	Dry season low flows	0.3	0.30	-	0.8	1.0	0.40	2.0	1.40
	Wet season low flows	1.0	1.25	-	2.00	4.0	1.00	6.0	7.00
	Wet season floods **	4.0	4.00	-	8.00	12.0	12.00	20.0	20.00

** For these flow categories the prescribed flows are required to occur twice in January-February for one-time breeders and 2-3 times per year for repeat breeders.

Macroinvertebrates

Macroinvertebrate surveys from 2009 yielded much higher levels of diversity than documented in 2007; however, this was likely due to extensive improvements in sampling methodology and increased sampling time. Increased taxon richness and sensitivity of taxa should not be interpreted as an improvement in water quality during the very low flows of 2009. The among-site differences also showed a different pattern than that found in 2007. EFA 1.2 had the highest taxon richness and number of sensitive taxa, corresponding to the highest water quality rating on the SASS5 scale, followed closely by EFA 1. EFA 2 had the lowest taxon richness and sensitivity scores, resulting in a poor SASS5 score for water quality and habitat diversity. However, EFA 3 seemed to have recovered partially, with increased taxa and sensitivity (Table 7).

Table 7: Macroinvertebrate data from February 2009 sampling at four EFA sites with SASS5 sensitivity scores, average score per taxon (ASPT) and site classification

EFA Site	# Taxa	SASS 5 Score	ASPT	Classification
1	19	109	5.74	Water quality good; habitat diversity reduced
1.2	17	106	6.24	Water quality good; habitat diversity high
2	13	57	4.38	Some deterioration in water quality and habitat diversity
3	14	72	5.14	Borderline water quality and habitat diversity

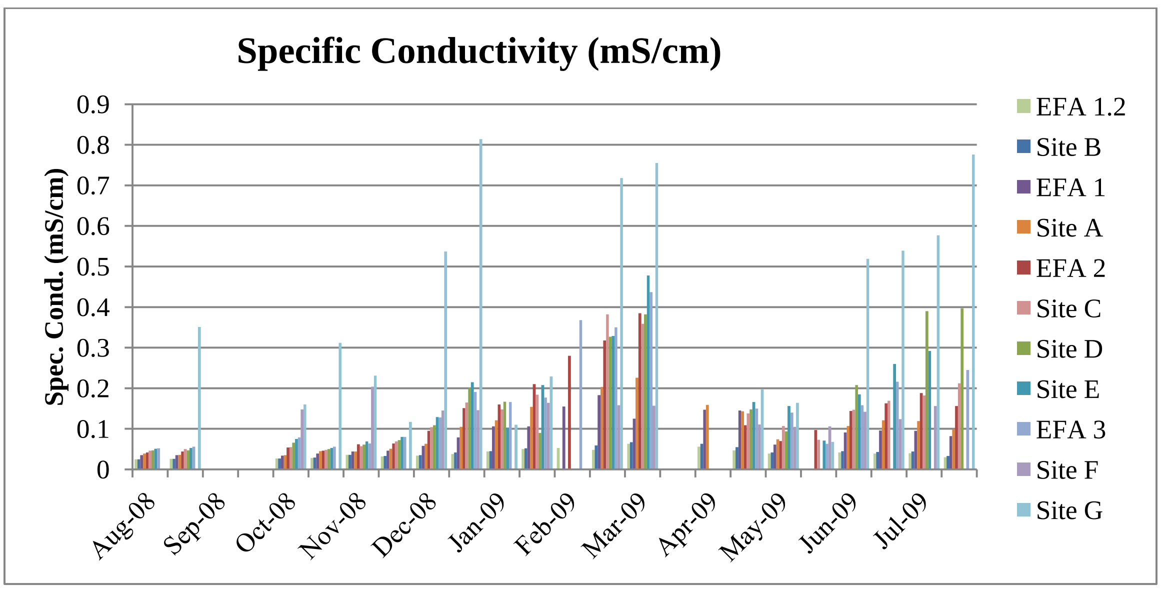
The most sensitive taxa documented at EFA 1 were Perlidae (Plecoptera) and Lepidoptera, both with a SASS score of 12, followed by Leptophlebiidae (Ephemeroptera), with a SASS score of 9. The most sensitive taxon at EFA 1.2 was Heptageniidae (Ephemeroptera), with a SASS score of 13, followed by Perlidae (Plecoptera) and Lepidoptera, both with a SASS score of 12. In contrast, the most sensitive taxon at EFA 2 was Corduliidae (Odonata), with a SASS score of 8, followed by Gomphidae (Odonata) and Hydropsychidae (Trichoptera), both with a SASS score of 6. At EFA 3, the most sensitive taxa were Lepidoptera, with a SASS score of 12, and Leptophlebiidae (Ephemeroptera), with a SASS score of 9. These data suggest that not only was overall sensitivity of macroinvertebrates variable by site, but also maximum sensitivity documented at those sites. Macroinvertebrate populations can be highly variable over space and time, and long-term monitoring is necessary to determine the consistency of these patterns.

Long-term Monitoring

Water Quality – In Situ Measurements

Water quality measured at 11 sites throughout the basin bimonthly over one year followed two general patterns—decreasing water quality from upstream to downstream and decreasing water quality in response to low flows. Specific conductivity showed both trends markedly, with levels rising from the upper to lower sites by 60-70% during seasons with high flows, and by over 500% during seasons with low flows (Figure 14).

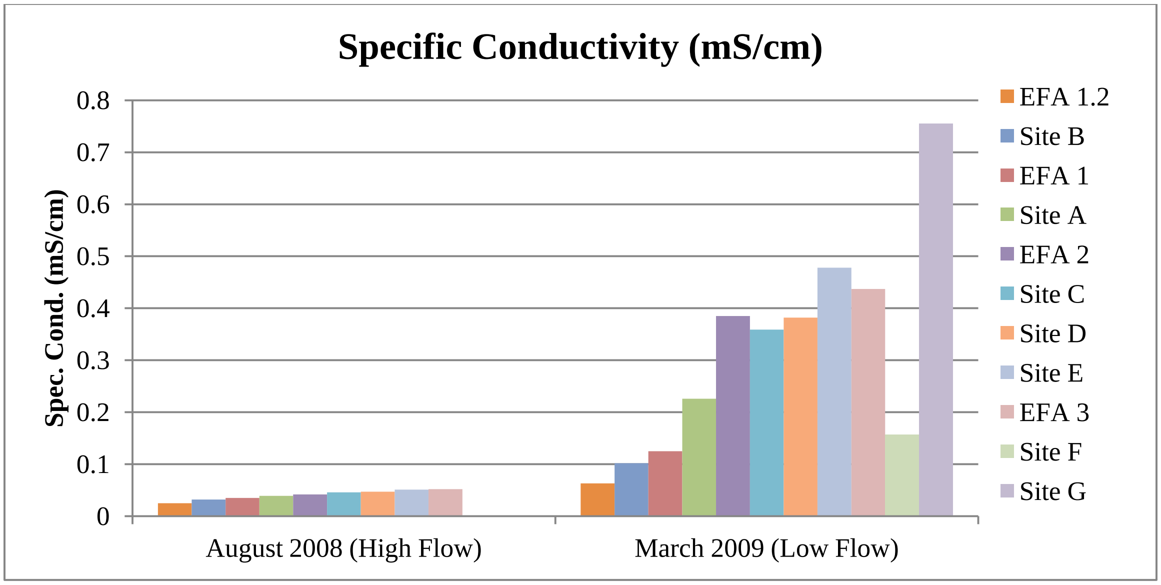
Figure 14: Specific conductivity (mS/cm) for 11 long-term monitoring sites in the Mara Basin, arranged upstream to downstream, from August 2008-August 2009



These patterns are easier to see when a high flow month (August 2008) is compared directly to a low flow month (March 2009) (Figure 15). Sites F and G are from the Talek River, which enters the Mara inside the Masai Mara National Reserve. Data wasn't available for these sites during August 2008. However, data from March 2009 shows 381% increase in conductivity from the upstream to downstream sites on the Talek. This increase may be due to high pollution loads from urban settlements and tourism facilities along the river, although it may also be due to the influence of saline tributaries feeding the Talek between these sampling sites. Interestingly, Site

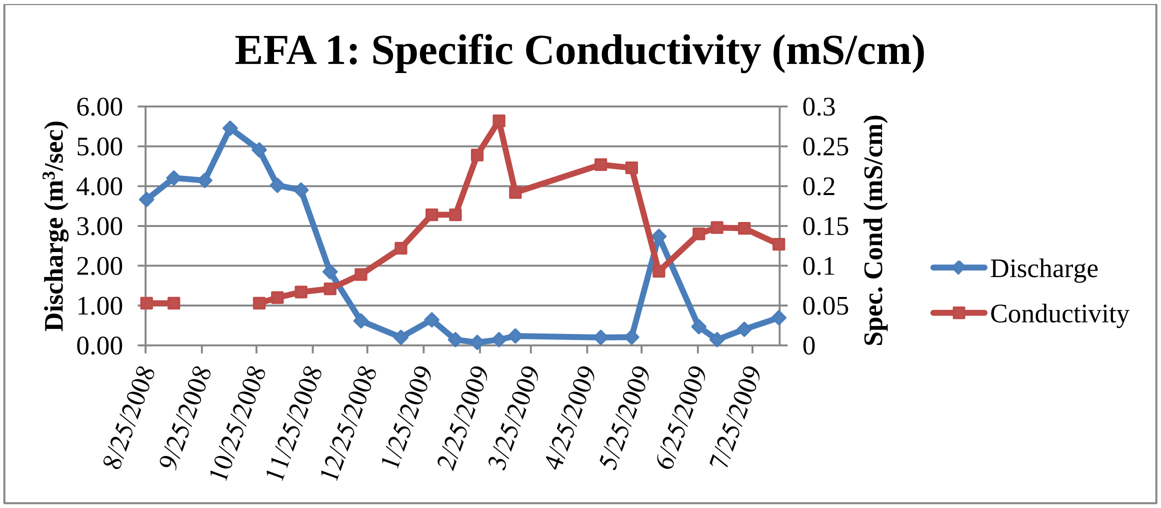
E, just below the confluence of the Talek River, shows a rise in conductivity that seems to be diluted by the EFA 3 sampling point.

Figure 15: Specific conductivity (mS/cm) for 11 long-term monitoring sites in the Mara Basin, arranged upstream to downstream, during a period of high flow (August 2008) and low flow (March 2009)

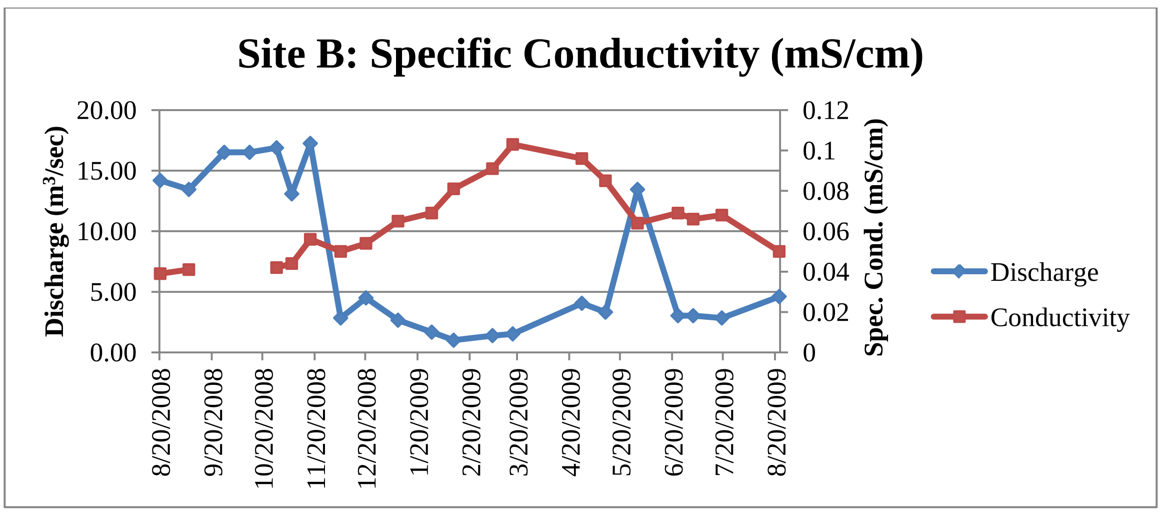


To examine the relationship between specific conductivity and flow level in greater detail, we graphed conductivity measurements with discharge measurements for the 3 sites for which we had gauging data (EFA 1, Site B and EFA 2). At all sites, conductivity clearly increased with decreasing flow levels, with the lowest levels during August 2008 and highest levels during March 2009. At EFA 1, there was a 432% increase, at Site B there was a 164% increase and at EFA 2 there was an 812% increase from lowest to highest levels (Figure 16).

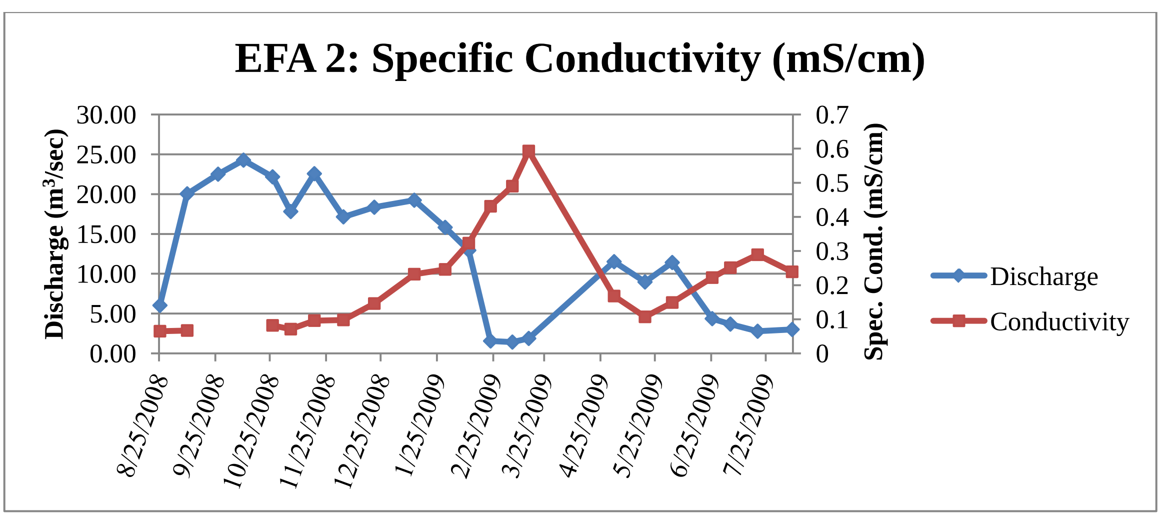
Figure 16: Specific conductivity (mS/cm) and discharge measured twice monthly from August 2008-August 2009 at a) EFA 1, b) Site B and c) EFA 2.



a)



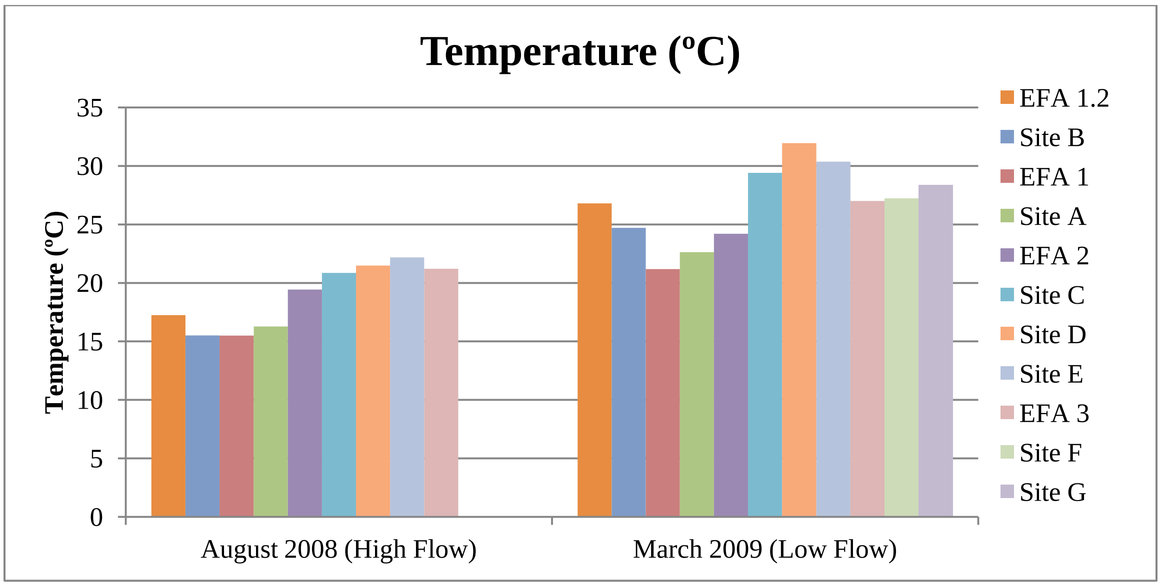
b)



c)

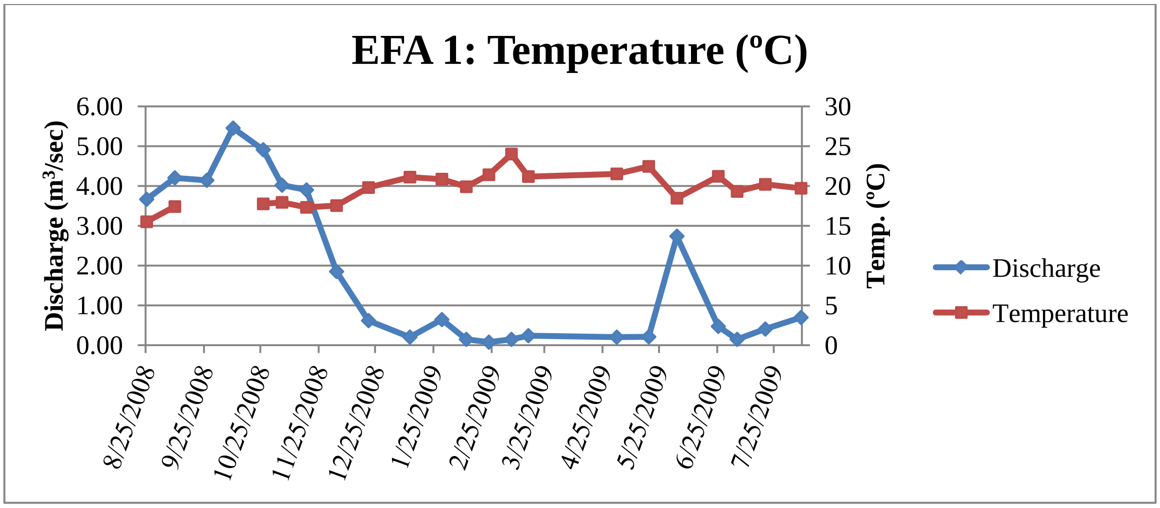
Temperature is also very important to aquatic organisms, and increased temperature levels can cause stress, particularly in conjunction with higher concentration of pollutants. Temperature is typically lower in upper catchments of rivers, where a higher degree of canopy cover provides shading that keeps a river cooler. Temperature also can be affected by flow levels, as lower flows allow higher infiltration of sunlight. In the Mara, temperature increased slightly from upper to lower sites, and it increased at all sites from high flows to low flows (Figure 17).

Figure 17: Temperature (ºC) for 11 long-term monitoring sites in the Mara Basin, arranged upstream to downstream, during a period of high flow (August 2008) and low flow (March 2009)

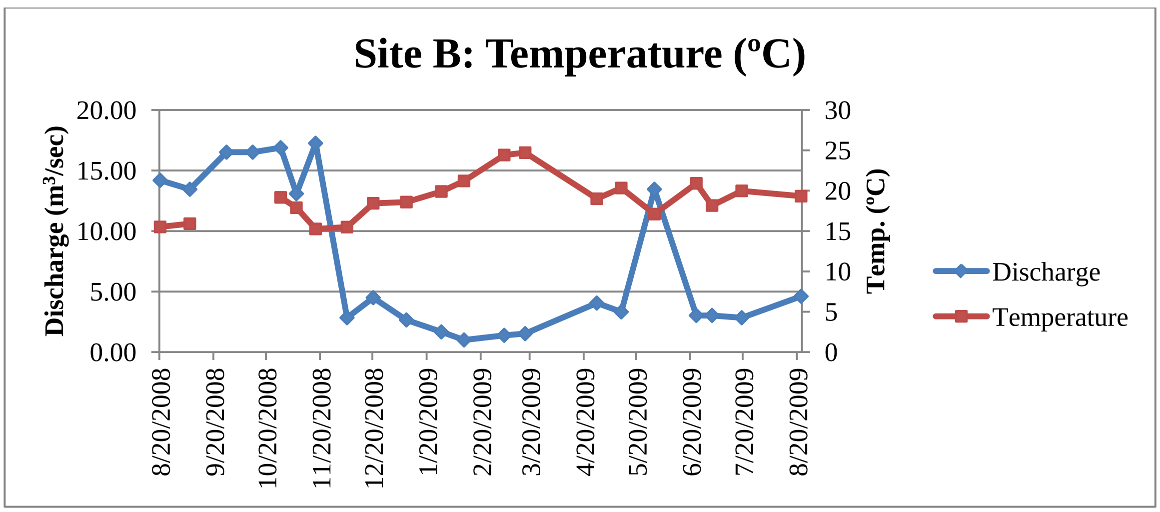


Comparing temperature to discharge levels shows the effect that flow level has on temperature in the Mara. As with conductivity, lowest temperature levels occurred during high flows in August 2008, and highest temperature levels occurred during low flows in March 2009 (Figure 18).

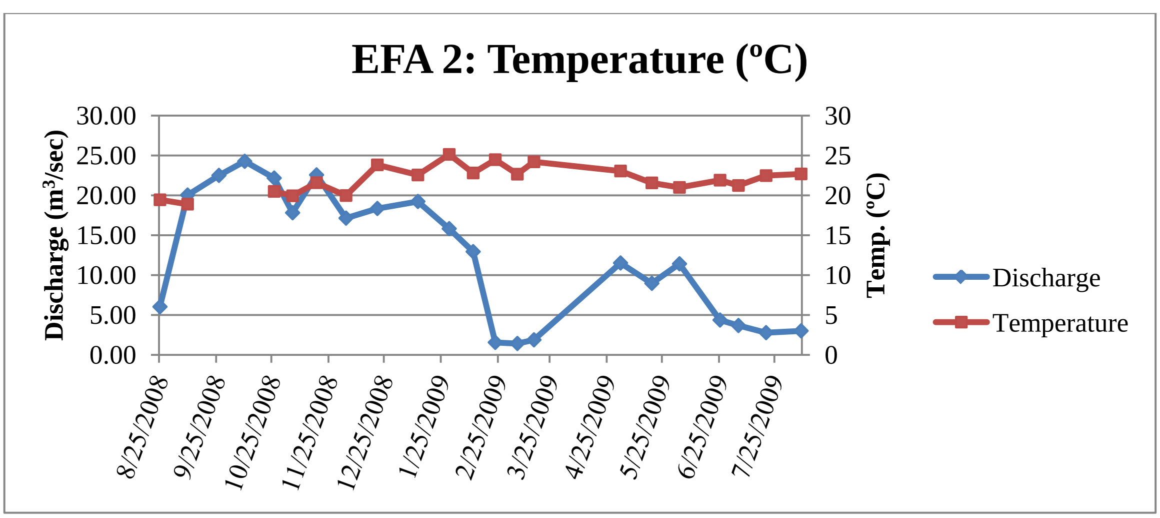
Figure 18: Temperature (ºC) and discharge measured twice monthly from August 2008-August 2009 at a) EFA 1, b) Site B and c) EFA 2.



a)



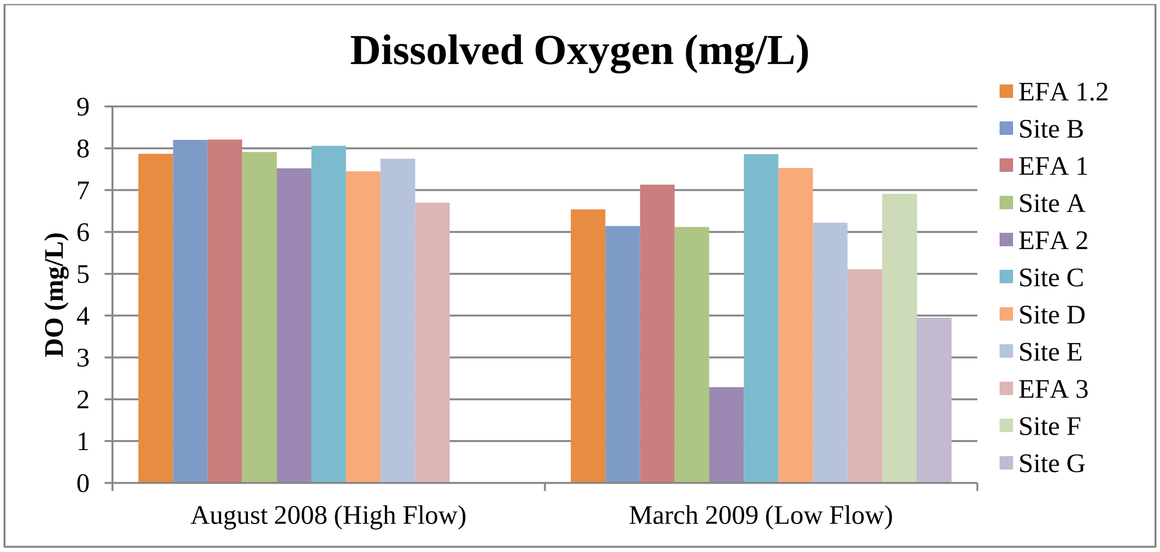
b)



c)

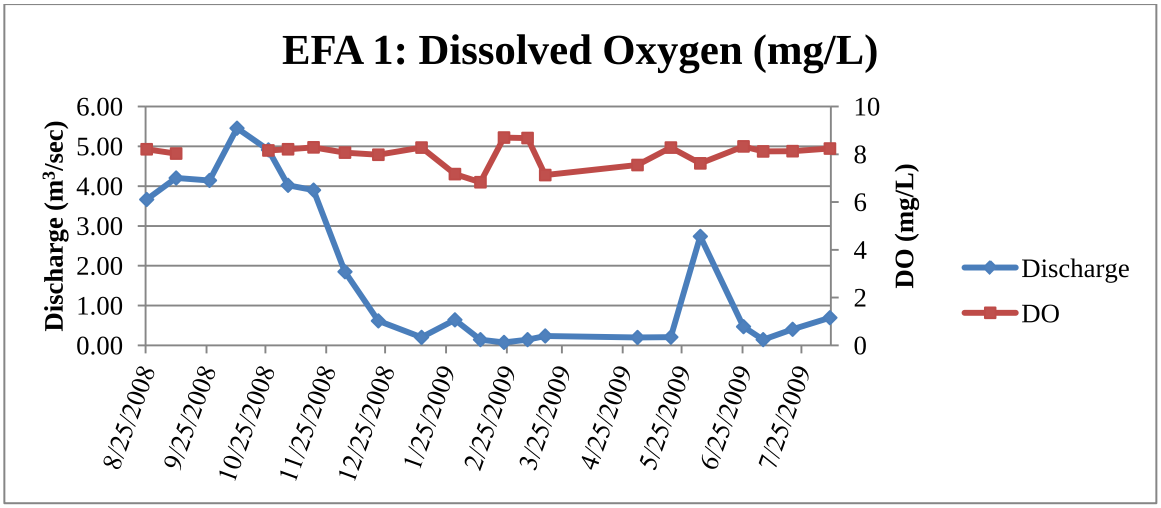
Dissolved oxygen (DO) levels are a primary indicator of aquatic ecosystem health because most aquatic organisms rely on relatively high levels for survival and reproduction. Dissolved oxygen decreased by 15% from upstream (EFA 1.2) to downstream (EFA 3) sites during high flows, and decreased by 22% during low flows (Figure 19). In March 2009, however, the lowest DO was documented at EFA 2, a 65% decline from upstream levels.

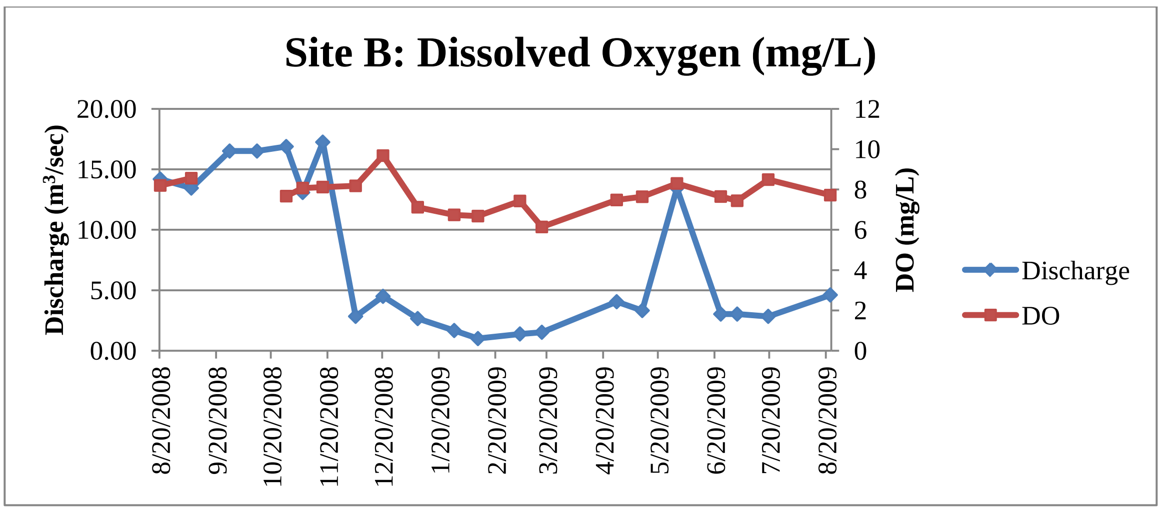
Figure 19: Dissolved oxygen (mg/L) for 11 long-term monitoring sites in the Mara Basin during a period of high flow (August 2008) and low flow (March 2009)

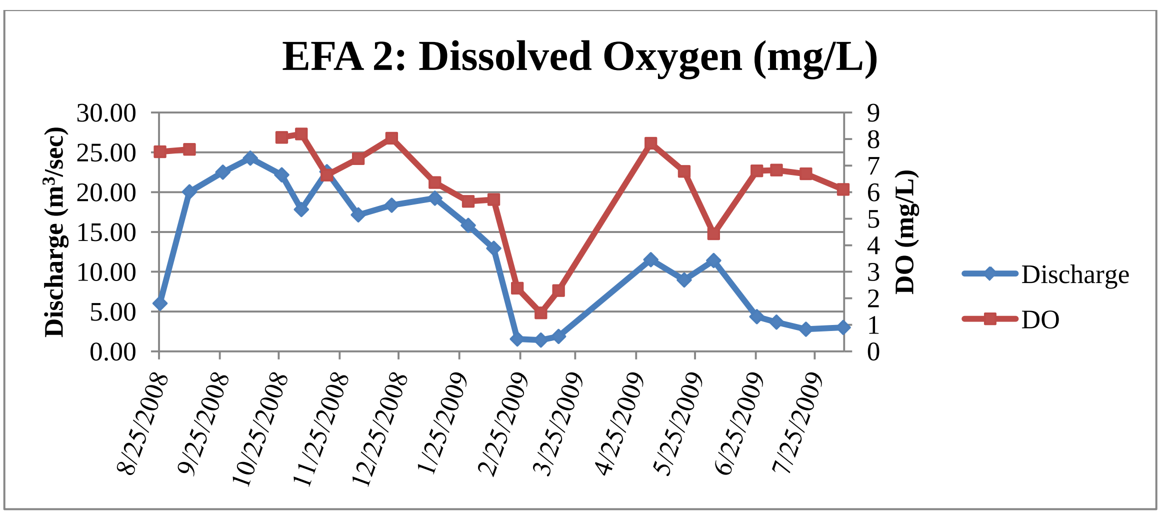


DO levels are heavily influenced by flow level, as lower flows simultaneously lead to higher concentrations of nutrient inputs and lower rates of re-aeration. In the Mara, highest and lowest DO levels didn't occur during the exact same months for each site, but DO generally followed the same trend as discharge (Figure 20). From August levels to March levels, DO declined by 13% at EFA 1, by 25% at Site B and by 81% at EFA 2. EFA 2 had the greatest decline between high and low flow levels for both conductivity and DO.

Figure 20: Dissolved oxygen (mg/L) and discharge measured twice monthly from August 2008-August 2009 at a) EFA 1, b) Site B and c) EFA 2.

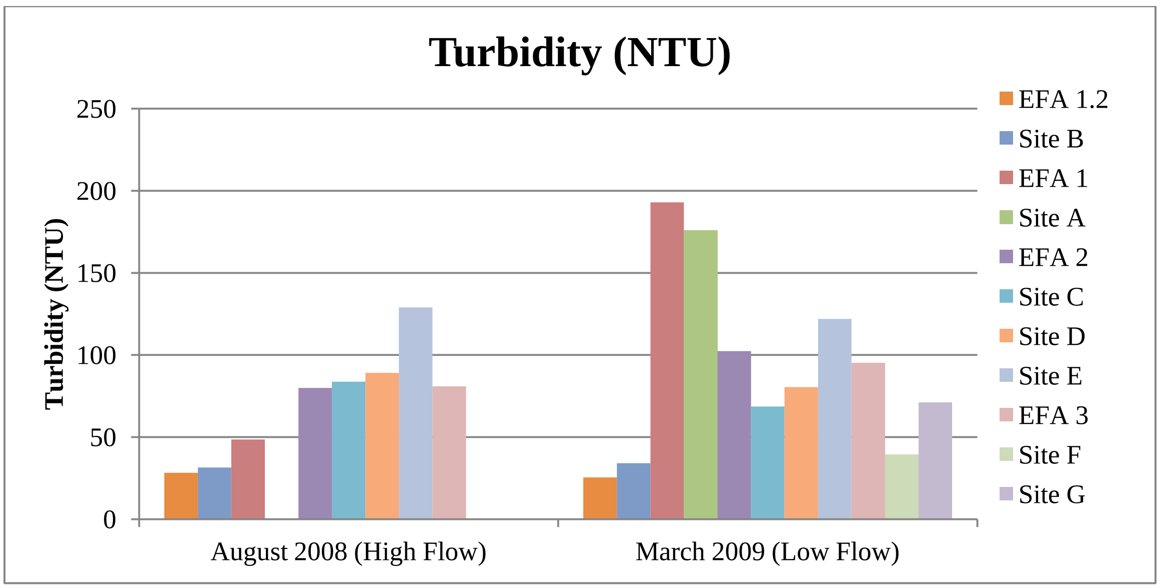
a) 

b) 

c) 

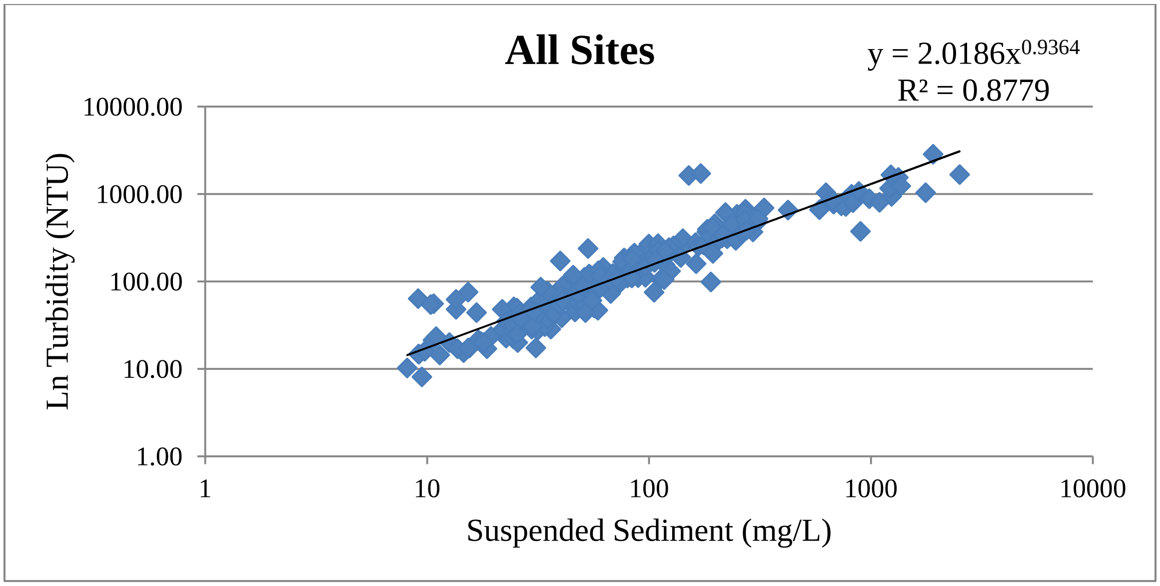
Turbidity levels are a primary concern in the Mara River due to their negative influence on aquatic ecosystem health and their tendency to bind potentially harmful contaminants. Patterns in turbidity levels through the basin and over time were less clear than for other parameters (Figure 21). In general, turbidity did increase from upstream to downstream sites, generally doubling under high flow conditions. However, turbidity is determined by rainfall events occurring at a short time scale and it usually peaks at the onset of rains, and thus turbidity data are highly variable depending on sample collection time. The relationship with flow level is also unclear, as higher turbidity loads would be expected under high flows. However, very low flows resulted in low dilution levels and larger effects from any small rainfall events, which may explain the more variable data from March 2009.

Figure 21: Turbidity (NTU) for 11 long-term monitoring sites in the Mara Basin during a period of high flow (August 2008) and low flow (March 2009)



Analysis of suspended sediment loads in the Mara Basin showed a strong, linear relationship between turbidity and suspended sediment concentration across all eleven sampling sites in the Mara River Basin ($R^2 = 0.8779$, Figure 22). This relationship is useful because it allows turbidity, which is easier to measure in the field, to be used to determine suspended sediment loads.

Figure 22: Relationship between turbidity (NTU) and suspended sediment (mg/L) for all 11 sampling sites in the Mara River Basin, 2008-2010



The relationship between sediment flux and discharge was determined for three sites for which discharge was available or could be determined- EFA 1 on the Amala River (Figure 23), Site B on the Nyangores River (Figure 24), and Site C on the Mara River (Figure 25). Site C was used instead of EFA 2 for this analysis to allow future comparison with historical sediment load data collected during earlier studies. For all three sites, there was a positive relationship between sediment flux and discharge.

Figure 23: Sediment rating curve for EFA 1 on the Amala River, with log-transformed sediment flux (tons/day) versus log-transformed discharge (m^3/sec).

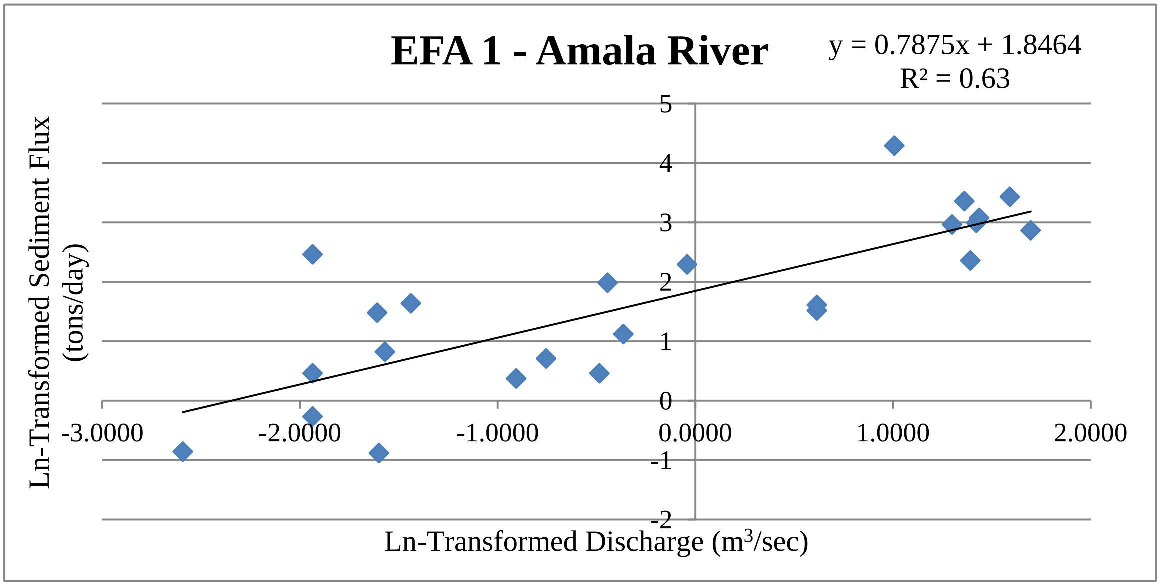


Figure 24: Sediment rating curve for Site B on the Nyangores River, with ranked sediment flux (tons/day) versus ranked discharge (m^3/sec).

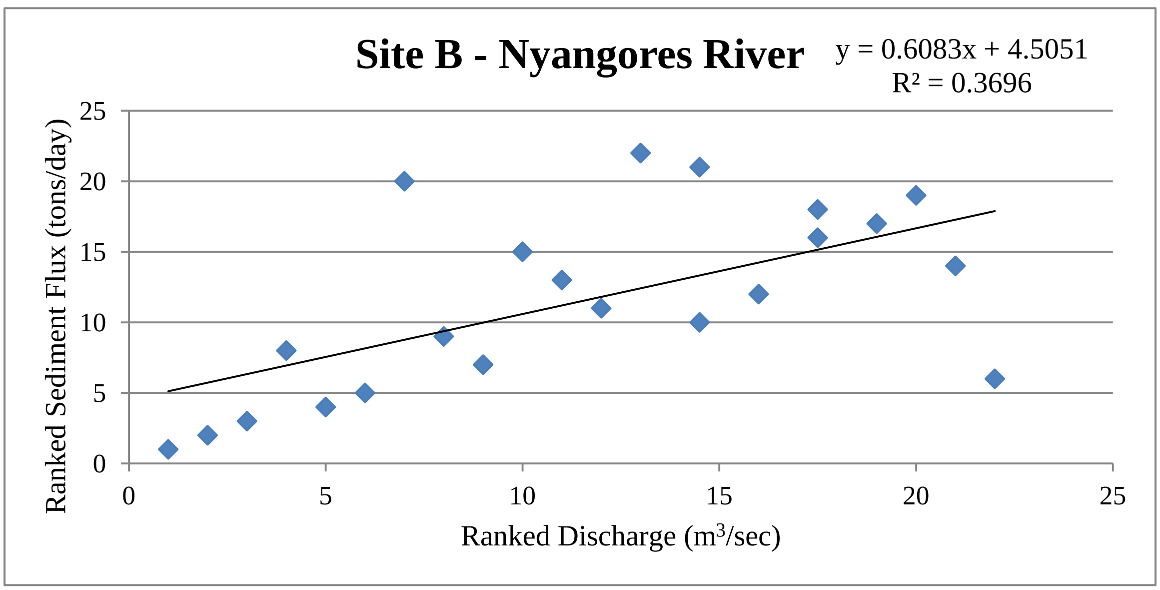
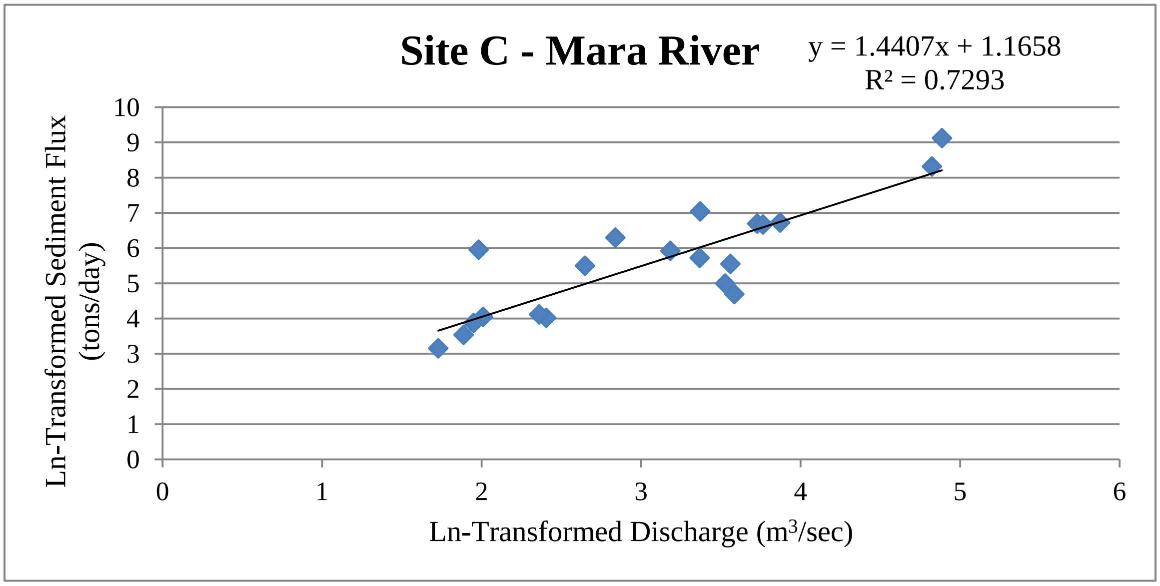
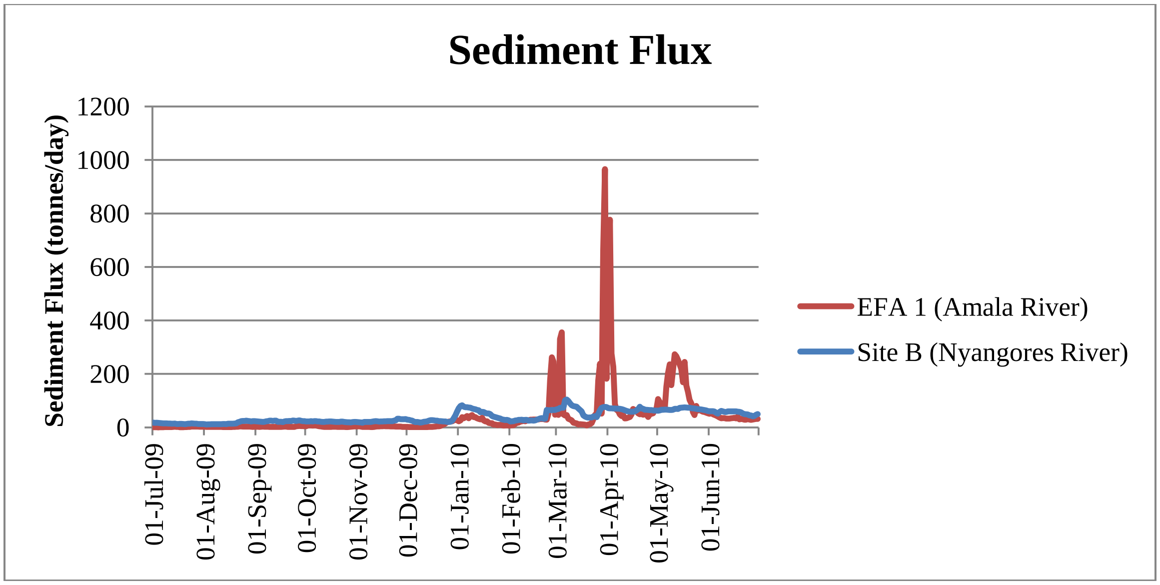


Figure 25: Sediment rating curve for Site C on the Mara River, with log-transformed sediment flux (tons/day) versus log-transformed discharge (m^3/sec).



When sediment rating curves were applied to discharge data from July 2009 to June 2010, EFA 1 and Site B showed very different patterns in sediment flux that largely mirrored differences in discharge (Figure 26). However, when daily sediment flux was summed over this annual period of record, total transported sediment load for the two rivers was nearly equal, with the Nyangores River at Site B transporting 14,299 metric tons/year and the Amala River at EFA 1 transporting 14,686 metric tons/year.

Figure 26: Total sediment flux (metric tons per day) for EFA 1 on the Amala River and Site B on the Nyangores River from July 2009 to June 2010.



Average sediment concentrations varied markedly across the eleven sampling sites (Table 8). Sediment concentration per unit watershed area was fairly consistent throughout the basin, except in the Amala sub-catchment, which had values twice as high as the Nyangores or Mara sub-catchments. The highest value was at EFA 1, the sampling point farthest upstream in the Amala River. These elevated values were associated with higher percentage of watershed area under agricultural land use.

Table 8: Average sediment concentrations at eleven sampling locations in the Mara River Basin and their relationship with watershed area and land use characteristics

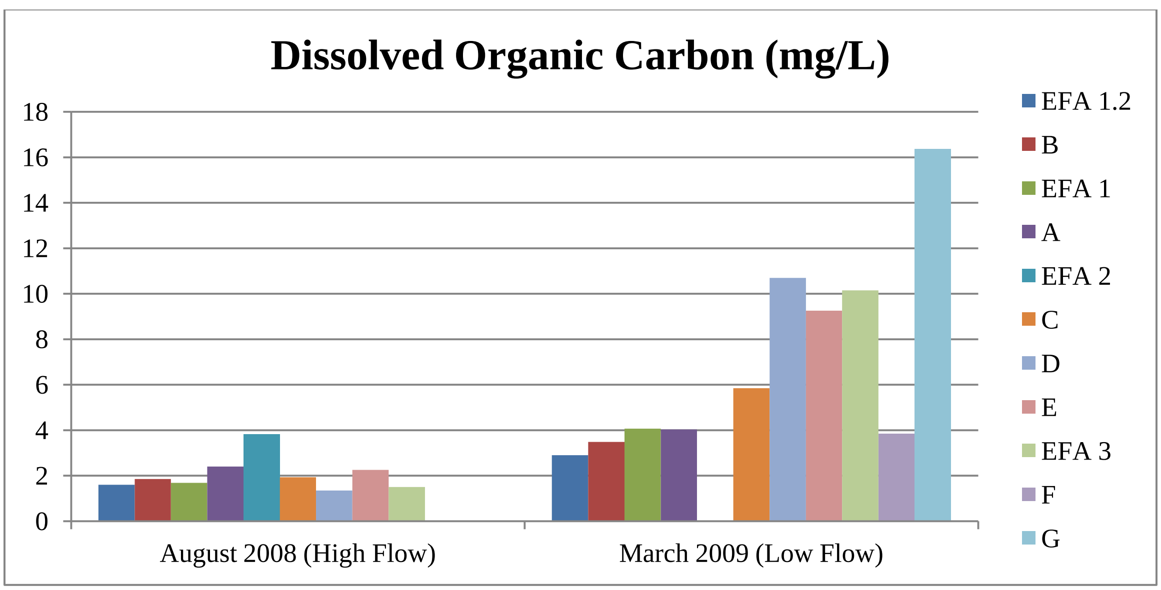
Site	**Sediment Concentration** (mg/L) Mean (SE)	**Watershed Area** (km^2)	**Sediment Concentration per Unit Area** (mg/L/km^2)	**Percent Watershed in Agriculture** (%)
EFA 1.2 – Silibwet	48.3 (7.39)	661	0.07	49
B – Bomet Bridge	60.4 (11)	697	0.09	51
EFA 1 – Kapkimolwa	134.0 (37.9)	699	0.19	63
A – Mulot	125.4 (31.4)	992	0.13	68
EFA 2 – Ngerende	193.2 (50.7)	2514	0.08	62
C – Old Mara Bridge	230.7 (37.6)	2978	0.08	56

D – Governor's Slough	346.0 (84.2)	-	-	-
E – Mara at Talek	438.2 (88.2)	-	-	-
F – Talek at Mara Simba	352.5 (64.9)	-	-	-
G – Talek at Naibor	416.0 (77.7)	-	-	-
EFA 3 – New Mara Bridge	500.4 (83.9)	6493	0.08	27

Water Quality – Laboratory Analyses

Water samples collected in the field were analyzed in the laboratory for a number of parameters. Results from these parameters followed the same pattern as *in situ* water quality parameters, increasing from upstream to downstream and during low flows. Dissolved organic carbon (DOC) originates from incompletely decomposed organic material, and levels can be elevated by high levels of organic input such as sewage. DOC levels didn't rise from upstream to downstream during high flows, but during low flows, they increased by 220% from EFA 1.2 to EFA 3 (Figure 27). On the Talek, levels increased by 325 % during low flows.

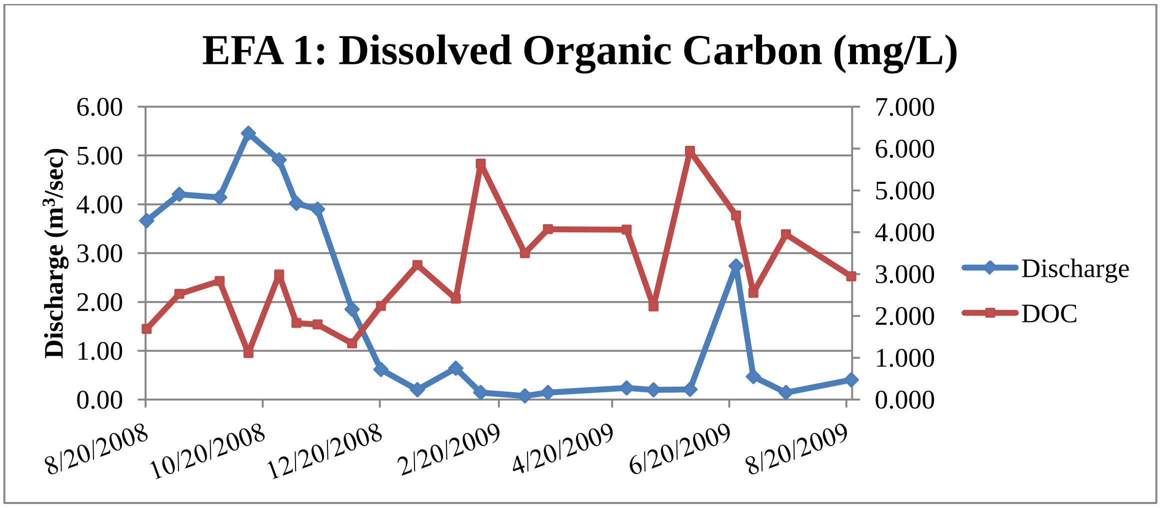
Figure 27: Dissolved organic carbon (mg/L) for 11 long-term monitoring sites in the Mara Basin, arranged upstream to downstream, during a period of high flow (August 2008) and low flow (March 2009)



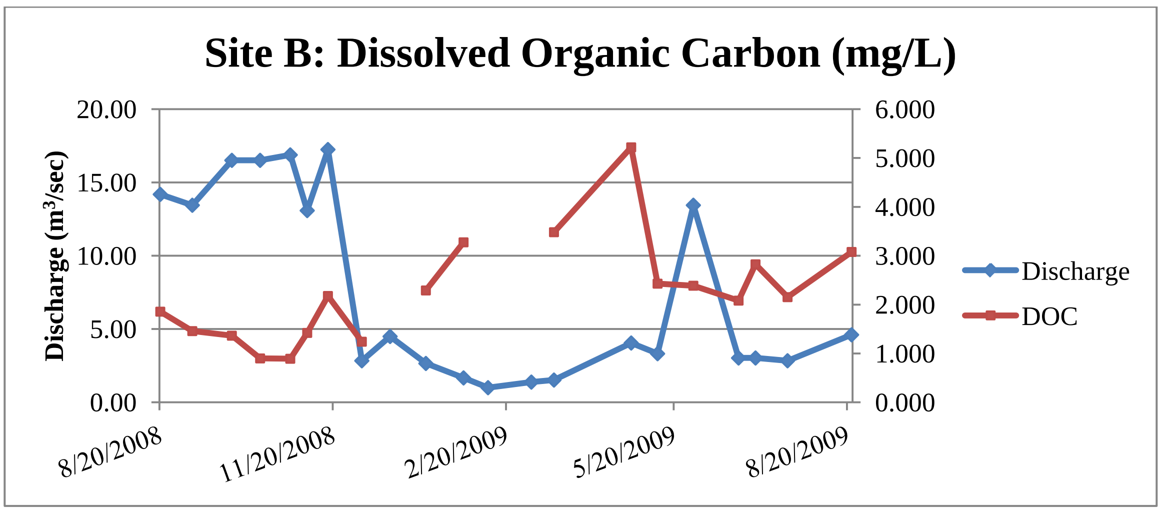
In addition to increasing from upstream to downstream during low flows, DOC levels also increased at each site in response to decreasing flow levels. From high flows in August to low flows in March, DOC levels increased 141% at EFA 1, 88% at Site B and 101% at EFA 2 (Figure 28). DOC levels weren't only correlated with discharge levels, however, and the highest levels did not always occur during the lowest flows.

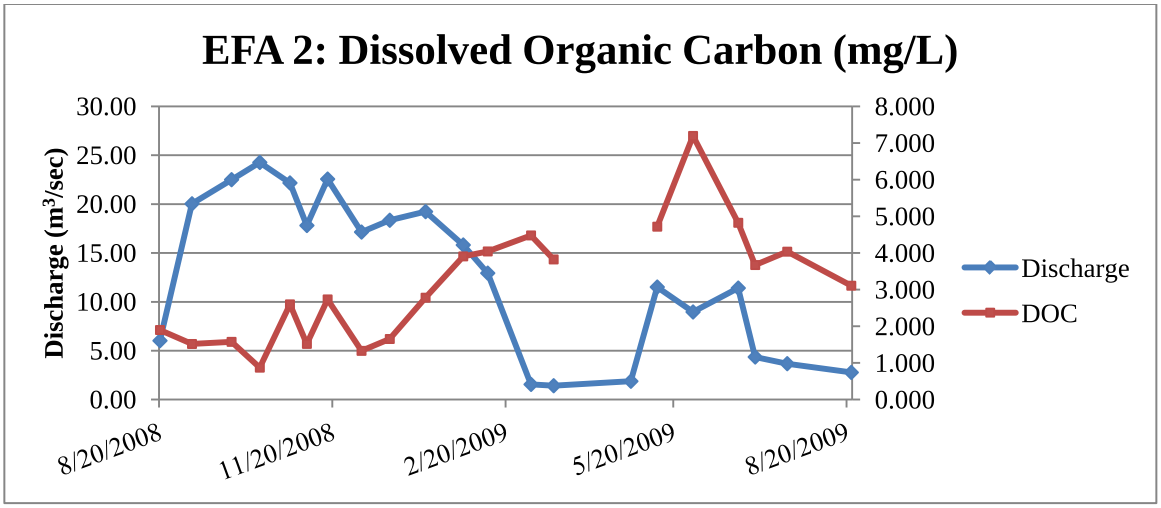
Figure 28: Dissolved organic carbon (mg/L) and discharge measured twice monthly from August 2008-August 2009 at a) EFA 1, b) Site B and c) EFA 2

a)



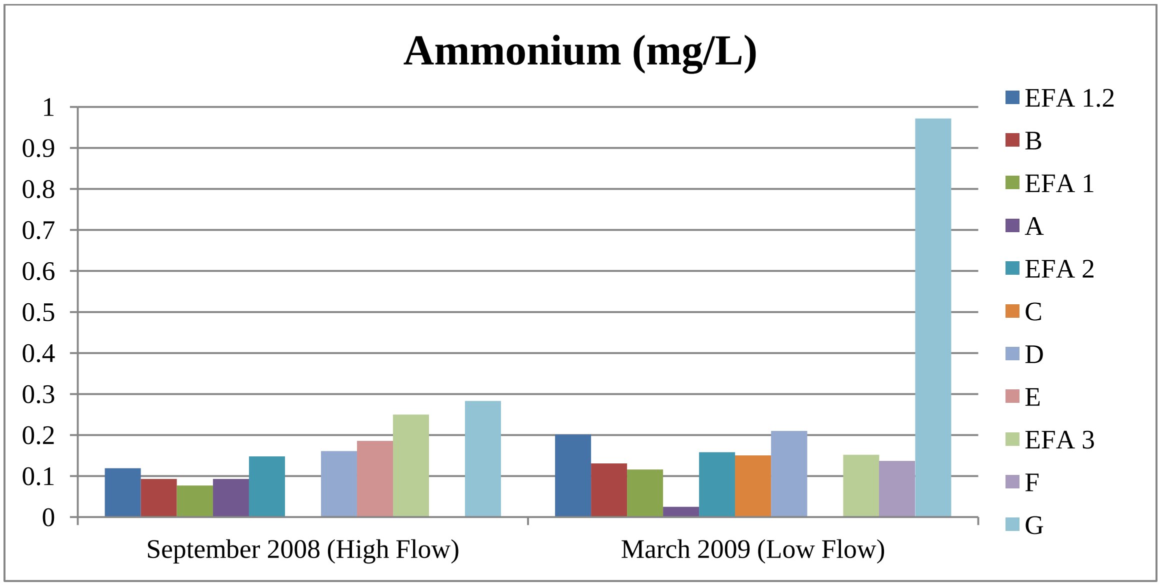
b)



c) 

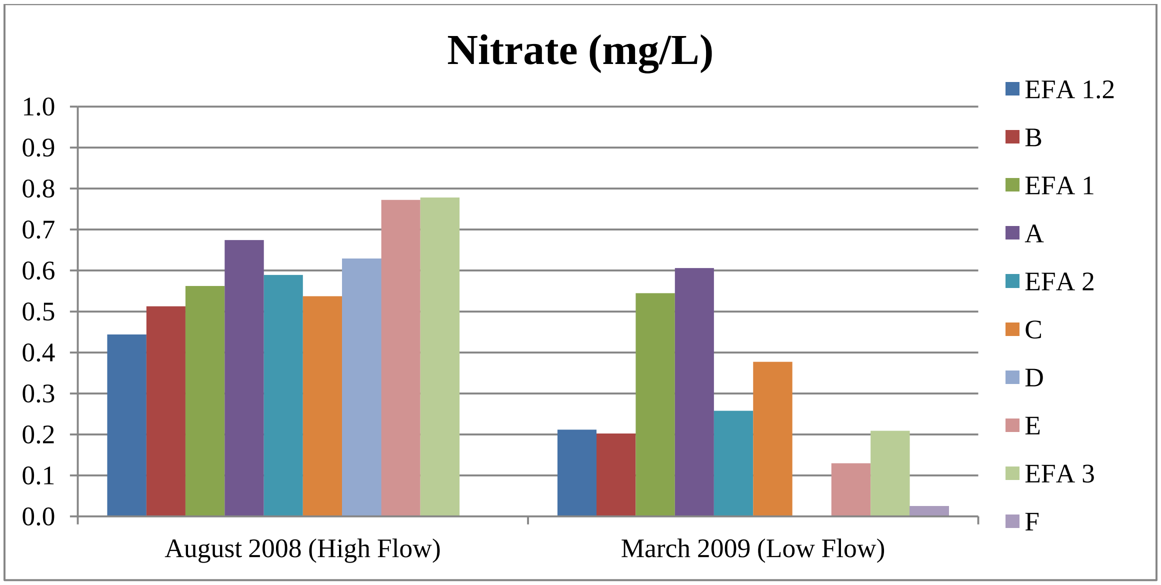
Ammonium is produced by decomposition of nitrogenous organic matter, and levels can be elevated by over-application of fertilizer or breakdown of sewage. Ammonium levels in the Mara didn't show a distinct pattern either from upstream to downstream or in relation to high or low flow levels (Figure 29). However, on the Talek River levels increased 600% from upstream to downstream during low flows.

Figure 29: Ammonium (mg/L) for 11 long-term monitoring sites in the Mara Basin, arranged upstream to downstream, during a period of high flow (September 2008) and low flow (March 2009)



Nitrates are formed from the oxidation of ammonia and are typically elevated by the same nitrogen inputs that elevate ammonium levels. Interestingly, although nitrates showed an increase from upstream to downstream in the basin during high flows, they decreased at all sites under low flows (Figure 30). This decrease could be due to a reduction in loading from watershed runoff during the dry season.

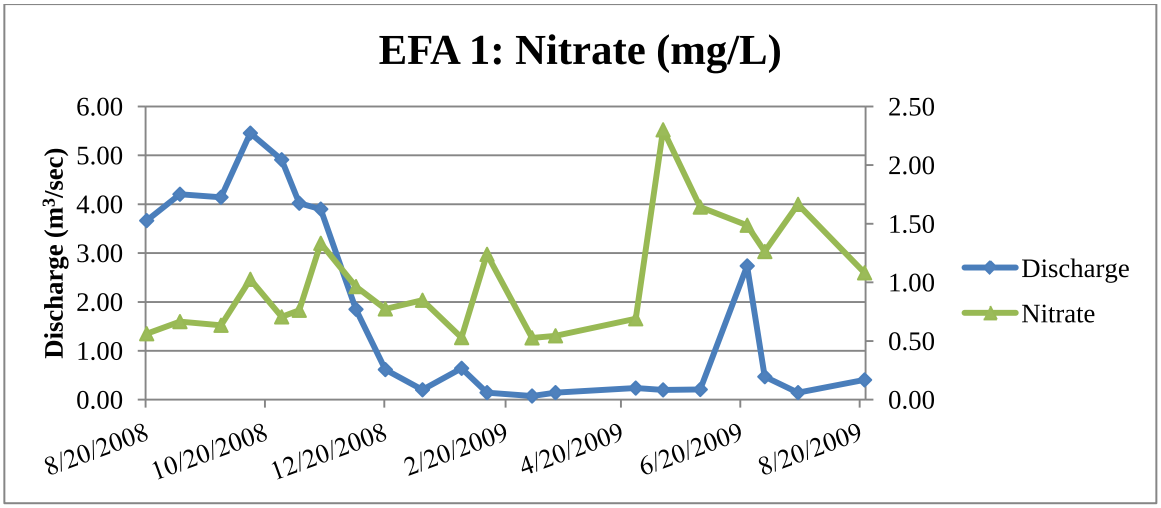
Figure 30: Nitrate (mg/L) for 11 long-term monitoring sites in the Mara Basin, arranged upstream to downstream, during a period of high flow (August 2008) and low flow (March 2009)



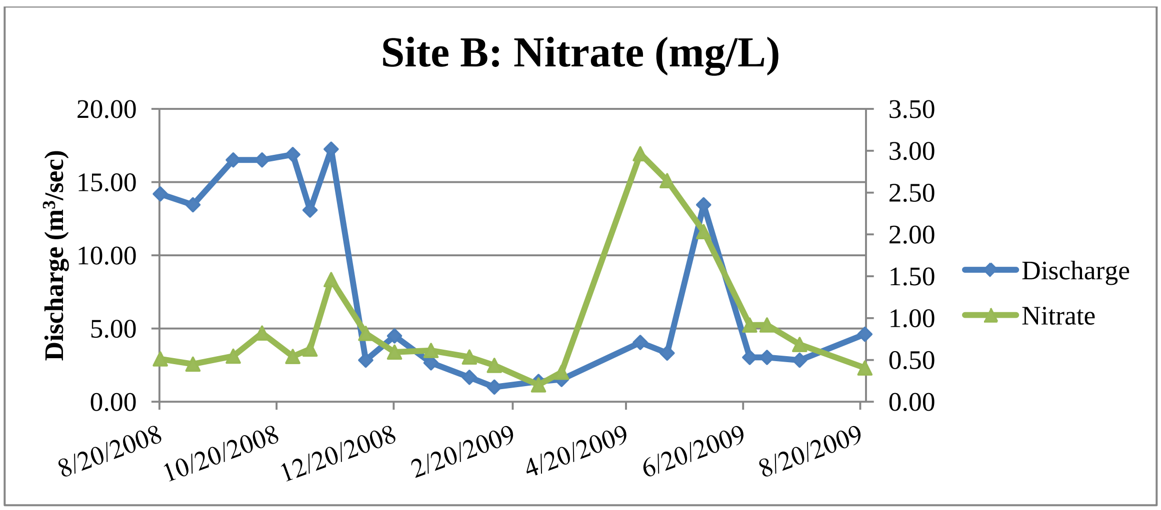
When graphed over the course of a year, nitrate and discharge levels are loosely correlated, with nitrate slightly elevated during high flows and lower during low flows (Figure 31). Most noticeably, all three sites for which discharge data was available showed a significant peak in nitrate at the end of April/beginning of May. At two of the sites, this peak preceded rising river levels, suggesting high rainfall levels were not the only cause. This time of year may correlate with high use of fertilizer in the basin, or the first rains after the dry season may wash disproportionately large loads into the river.

Figure 31: Nitrate (mg/L) and discharge measured twice monthly from August 2008-August 2009 at a) EFA 1, b) Site B and c) EFA 2

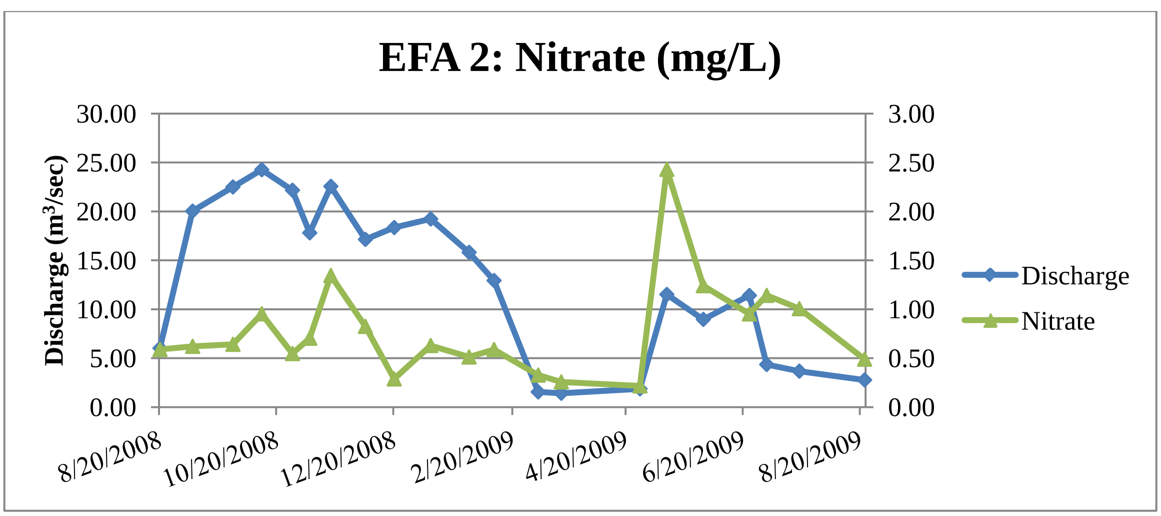
a)



b)

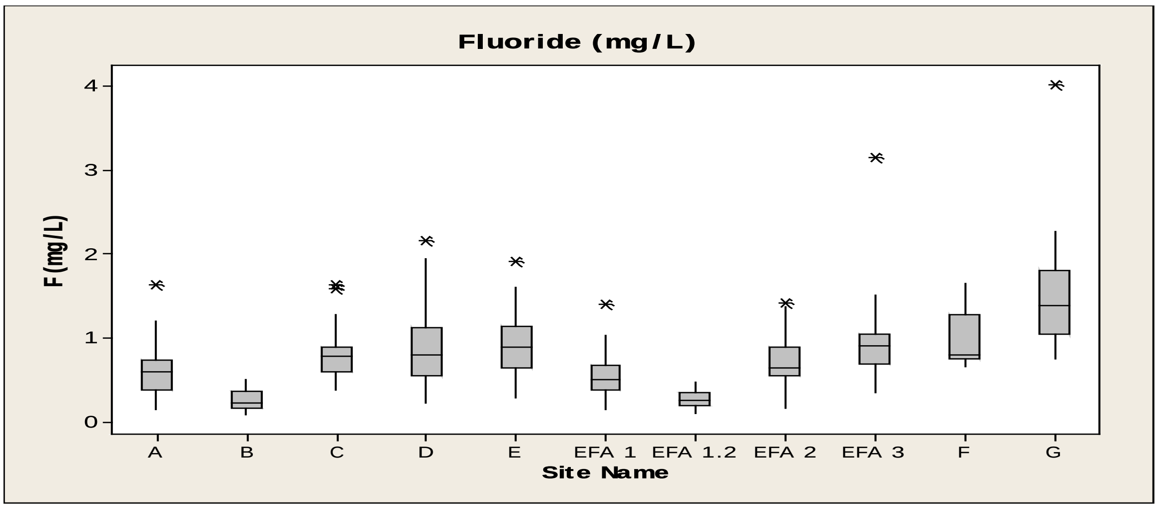


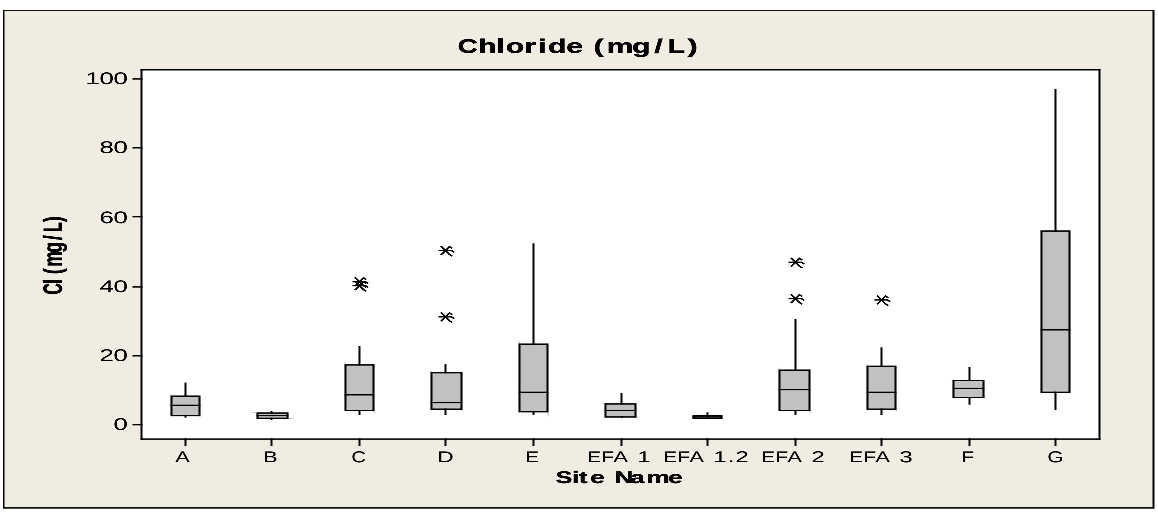
c)

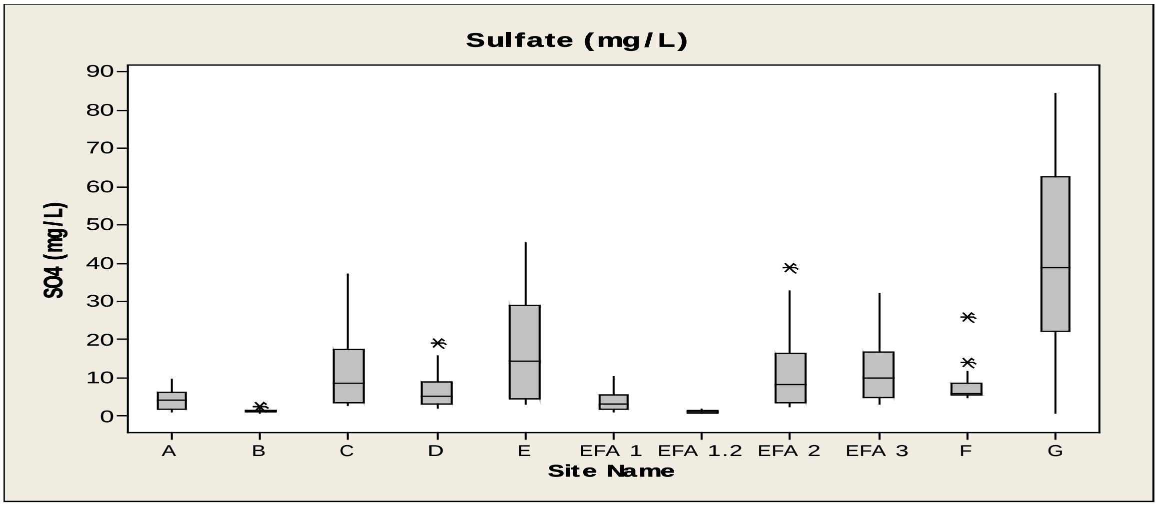


Conductivity levels that were measured *in situ* reflect the concentration of anions and cations in the river. The actual concentration of these anions and cations were measured from water samples in the lab. Major anions in the river—including fluoride, chloride and sulfate—play a critical role in biogeochemical reactions. Values for these anions were within normal ranges for aquatic systems (Figure 32).

Figure 32: Mean values and interquartile ranges for major anions including a) fluoride, b) chloride and c) sulfate at 11 long-term monitoring sites in the Mara River Basin from August 2008-August 2009

a) 

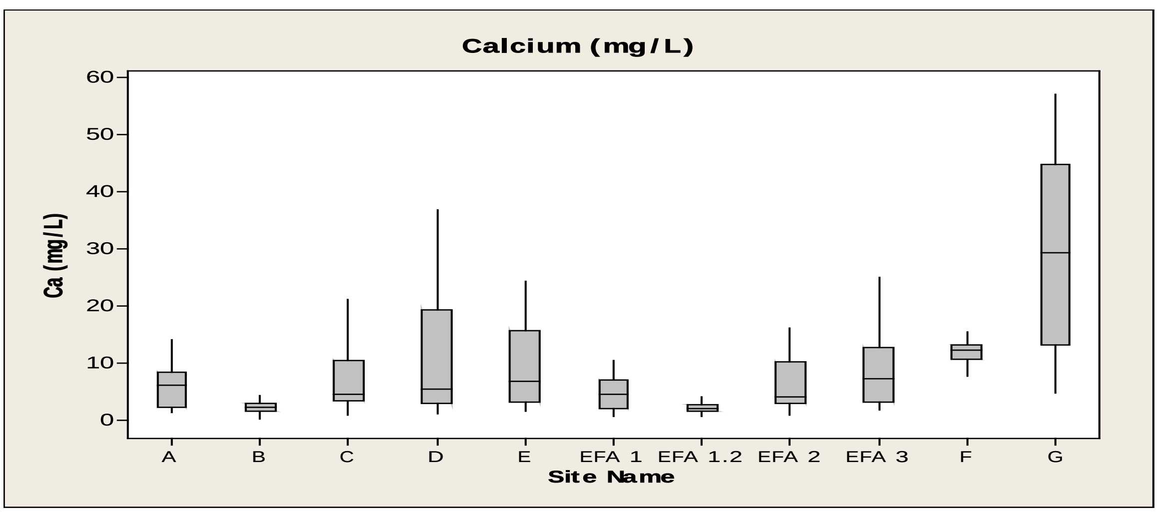
b) 



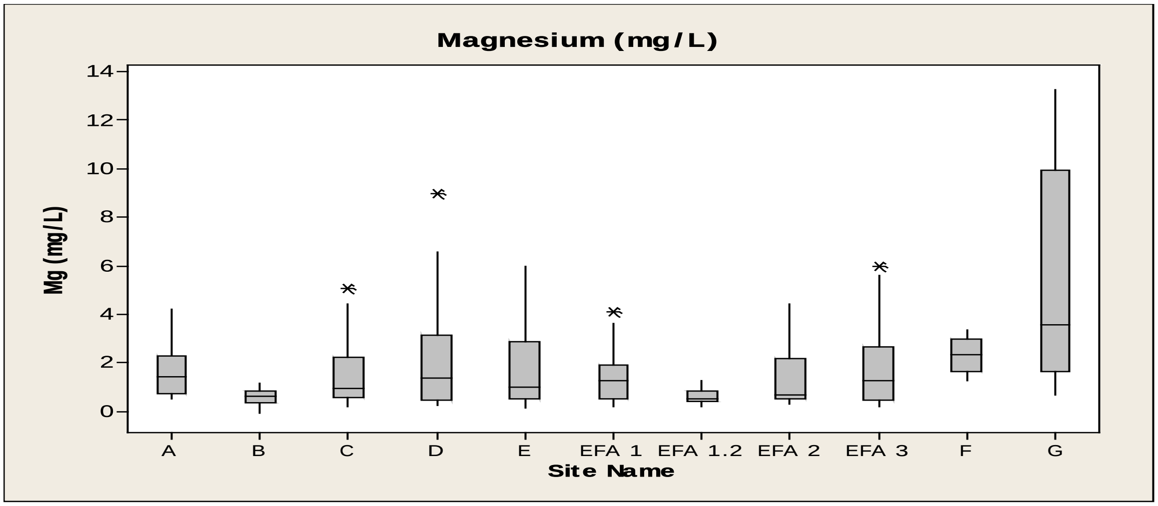
c)

Major cations in the river include calcium, magnesium, potassium and sodium. These elements also occur naturally in the system and play an important role in biogeochemical processes. Cation levels within the Mara were within normal ranges (Figure 33).

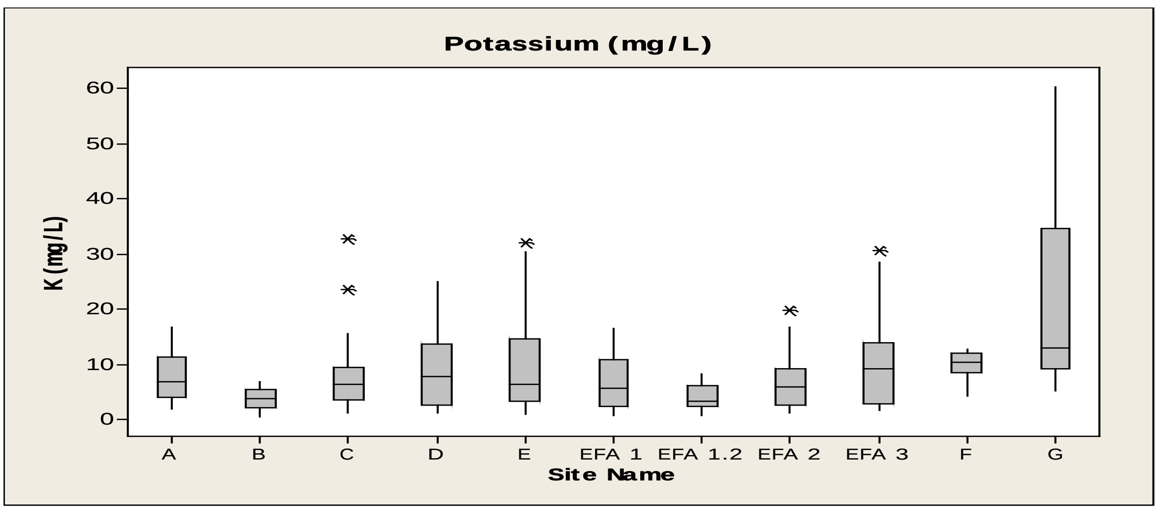
Figure 33: Mean values and interquartile ranges for major cations including a) calcium, b) magnesium, c) potassium and d) sodium at 11 long-term monitoring sites in the Mara River Basin from August 2008-August 2009



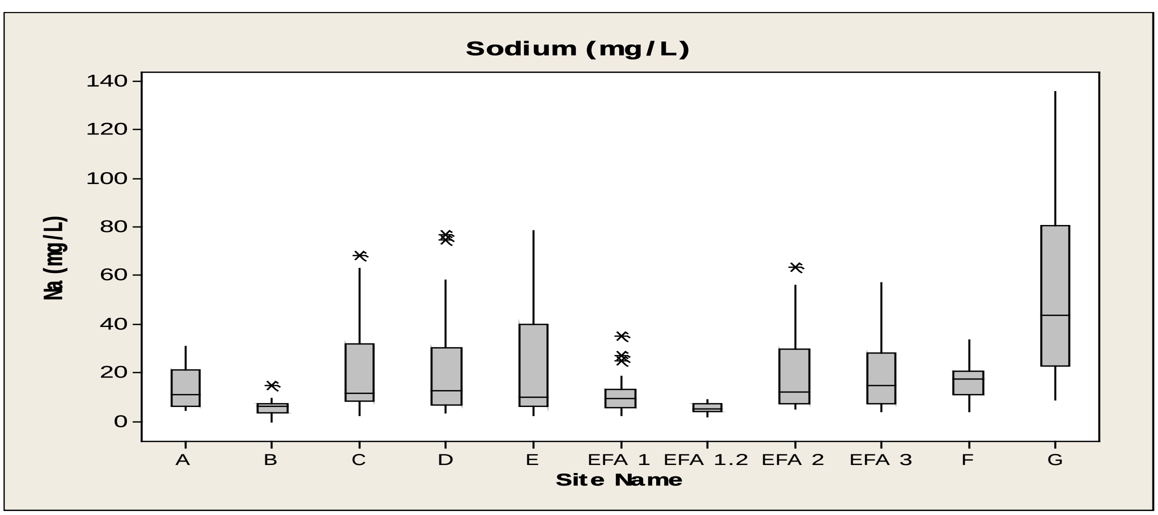
a)



b)



c)



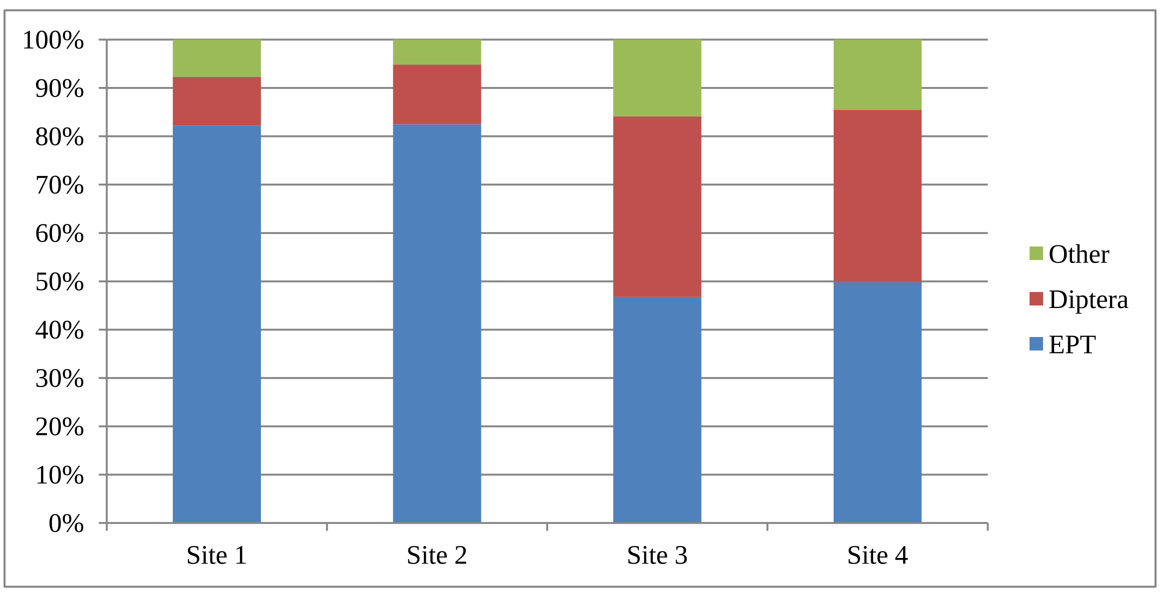
d)

Water quality data from the long-term monitoring can be found in Appendix 5.

Macroinvertebrates

Between September 2008 and August 2009, 121,282 individual benthic macroinvertebrates were collected and identified; they comprised 12 orders and 38 families. Macroinvertebrate indicators followed the same general pattern as water quality, declining from upstream to downstream sites, although several metrics showed an increase from EFA 2 to EFA 3 (Table 9). Number of taxa ($p = 0.006$), SASS5 ($p = 0.000$) and ASPT ($p = 0.011$) all declined significantly from upstream to downstream, with EFA 1 and 1.2 being most similar and EFA 2 and EFA 3 being most similar (Table 9). %EPT also declined significantly from upstream to downstream ($p = 0.001$), primarily due to a decline in Ephemeroptera; in contrast, %Diptera significantly increased ($p = 0.003$) (Table 9, Figure 34). In contrast to sensitivity indicators, diversity indicators increased from upstream to downstream. The Simpson's Diversity Index increased significantly ($p = 0.041$) and the Shannon-Wiener Diversity Index increased, although not significantly ($p = 0.074$), from upstream to downstream sites (Table 9). However, Shannon-Wiener Diversity Index values at all sites are considered low and indicative of disturbed conditions.

Figure 34: Relative proportion of macroinvertebrate taxa collected at each site calculated for EPT (Ephemeroptera, Plecoptera and Trichoptera) as an index of sensitive taxa, Diptera as an index of less sensitive taxa and Other, representing groups with intermediate sensitivity



Stepwise multiple regression analysis between macroinvertebrate metrics and physiochemical parameters generally incorporated two variables. Both number of taxa and SASS5 increased with decreasing conductivity (p = 0.072 and p = 0.002) and decreasing turbidity (p = 0.005 and p = 0.045) (adj. R^2 = 26.51 and adj. R^2 = 31.52). ASPT increased only with decreasing conductivity (p = 0.000, adj. R^2 = 35.29). %EPT increased with decreasing conductivity (p = 0.023) and increasing DO (p = 0.017) (adj. R^2 = 56.09). These results suggest conductivity, turbidity and DO are suitable indicators to monitor to determine status of ecological health in the Mara River.

Macroinvertebrates also varied within each site depending on flow level. Total number of taxa, total SASS sensitivity score (Figure 35) and average sensitivity score per taxon (ASPT) (Figure 36) all declined at 3 of the 4 EFA sites during low flows as compared to high flows. Those parameters only increased at EFA 1.2, which was in the best ecological health of all four sites, even under low flow conditions. Increases may have resulted from the ability to conduct more thorough sampling under low flow conditions.

Figure 35: Total SASS sensitivity score for macroinvertebrates documented at four EFA sites during a high flow (September 2008) and low flow (February 2009) month

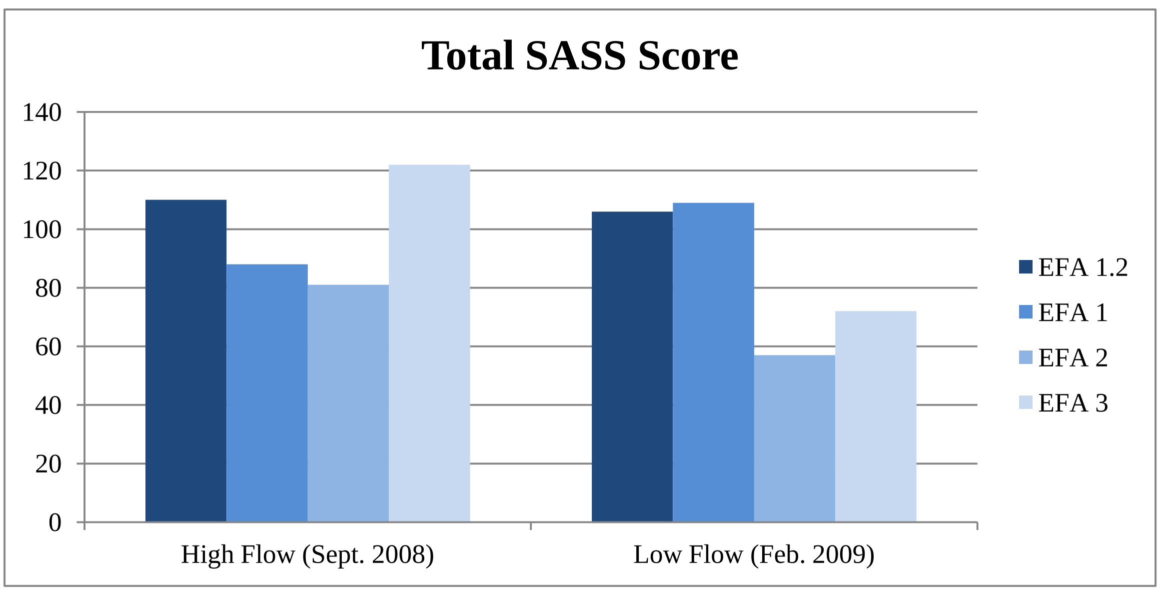
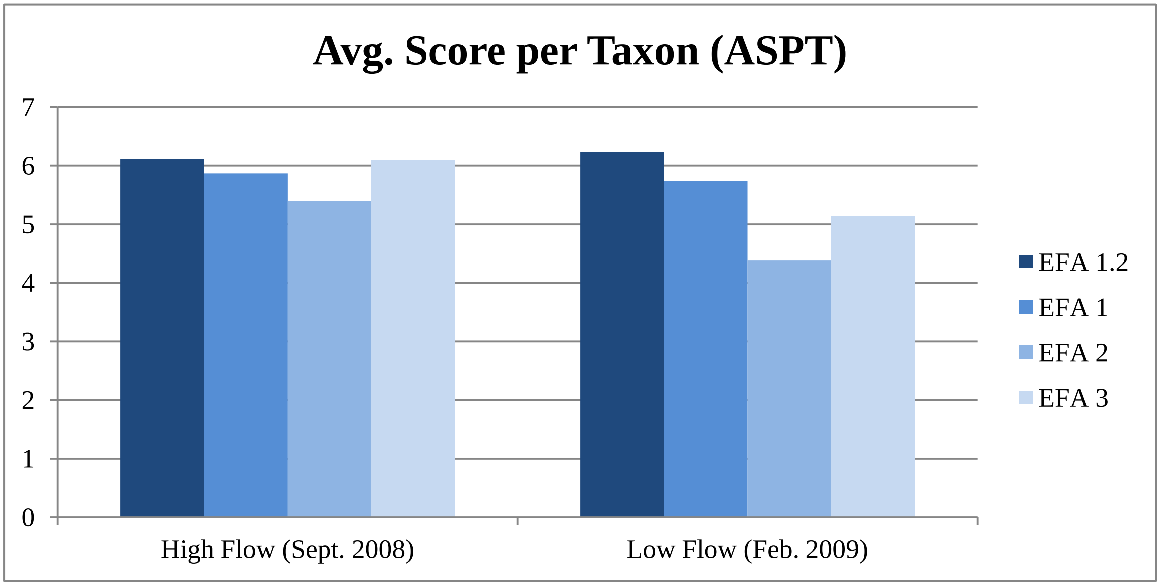


Figure 36: Average score per taxon (ASPT) for macroinvertebrates documented at four EFA sites during a high flow (September 2008) and low flow (February 2009) month



Overall characteristics of the catchment areas, water quality and macroinvertebrate metrics for each of the four EFA sites (EFA 1, EFA 1.2, EFA 2 and EFA 3) averaged across the year of sampling are summarized in the table below (Table 9).

Table 9: Characteristics of the four study sites in the Mara River Basin, including elevation, population, area, percent of upstream watershed under different land use categories, water quality parameters and macroinvertebrate metrics. Site characteristics data adapted from McCartney (2010)

		EFA 1.2		EFA 1		EFA 2		EFA 3	
Site Characteristics	Elevation (meters above sea level)	1975		1875		1683		1484	
	Human Population	62306		67527		326360		383756	
	Population Density (pop/km²)	94.26		96.61		129.82		59.1	
	Catchment Area (km²)	661		699		2514		6493	
	Land Use %								
	Agriculture	49%		63%		62%		27%	
	Bushland	0%		0%		10%		52%	
	Forest	41%		34%		21%		10%	
	Grassland	0%		0%		0%		6%	
	Plantation	0%		0%		0%		1%	
	Woodland	10%		3%		6%		4%	
		Mean	**Stn Dev**	**Mean**	**Stn Dev**	**Mean**	**Stn Dev**	**Mean**	**Stn Dev**
Water Quality	Temperature (°C)	19.37	3.10	19.70	1.65	21.71	1.96	23.76	1.41
	Conductivity (mS/cm)	0.066	0.020	0.144	0.093	0.234	0.152	0.284	0.184
	Dissolved Oxygen (% saturation)	83.69	3.25	87.44	6.09	67.94	21.02	59.26	18.48
	Turbidity (NTU)	28.13	12.14	167.30	325.40	103.70	140.50	178.90	286.90
	Suspended Sediment (mg/L)	32.55	13.02	172.60	245.20	172.60	232.60	299.30	330.40
Macroinvertebrate Metrics	Total Abundance	5397	2611	2474	848	1528	2197	2237	2270
	# of Taxa	18.78	1.72	16.30	2.41	13.82	3.74	14.80	3.77
	Simpson Diversity Index	0.49	0.11	0.43	0.15	0.54	0.12	0.60	0.17
	Shannon Wiener Div. Index	1.11	0.20	0.98	0.30	1.18	0.21	1.29	0.35
	% EPT	82%	8%	82%	12%	46%	28%	50%	27%
	% Ephemeroptera	72%	10%	75%	12%	44%	26%	40%	30%
	% Plecoptera	0%	0%	0%	0%	1%	2%	0%	0%
	% Trichoptera	10%	6%	7%	5%	1%	1%	10%	13%
	% Diptera	10%	8%	12%	9%	37%	26%	36%	19%
	% Annelida	4%	8%	2%	5%	4%	5%	2%	2%
	SASS 5	108.00	11.42	86.60	11.71	65.27	22.69	74.80	26.98
	ASPT	5.75	0.28	5.35	0.59	4.65	0.75	4.94	0.77

Discussion

The Low Flow EFA sampling event captured the Mara River at critical low flow levels that were below the EFA reserve recommendations for all three sites. Although sensitive biological indicators still occurred at all sites, ecologically relevant hydraulic parameters, such as depth, velocity and wetted width, were below levels needed to sustain them in the long-term. Depth was small enough to begin precluding movement by some organisms through the river channel, velocity was too low to sustain sufficient DO levels, even in riffles, and riparian vegetation was exposed and potentially without access to water. Water quality, which varies at shorter time scales, was significantly impacted at these flow levels, with very low DO levels and higher conductivity levels. The very low DO levels at both EFA 2, 17-27% saturation in March 2009, and EFA 3, 34-41% in February 2009, are a significant matter of concern. A week after the February 2009 survey was completed, a large and widespread fish die-off occurred from EFA 2 to EFA 3, further showing that aquatic ecosystem health was threatened at these flow levels. Dead fish were otherwise healthy-looking adults across a range of taxa (Figure 37). In February 2010, fish die offs were also reported when the river was under baseflow conditions.

During this sampling event, EFA 2 was just slightly under the lowest reserve flow recommendation for this site, suggesting the drought year dry season flow recommendation for this site should possibly be increased. EFA 3 was nearly half the lowest reserve flow recommendation for this site at this time, which suggests the EFA recommendations are more appropriate for this site. However, EFA 3 was still above Q95 flow recommendations, meaning the river would be allowed to fall even lower under default management practices, which supports the development and implementation of EFA recommendations for river management.

Figure 37: Dead fish resulting from a large fish die-off in the lower Mara in February 2009

Long-term monitoring highlighted areas of concern in the basin, as well as the importance of flow level to maintenance of water quality. The Amala sub-catchment had higher peak sediment flux, transported higher sediment load per unit catchment area and generally had lower water quality than Nyangores sub-catchment, suggesting land use change in this area may be causing problems to water quality in the basin. Hydrological data also suggests the Amala has had greater declines in flow levels over the past 15 years as compared to the Nyangores, suggesting changes in the Amala sub-catchment may also be threatening water quantity in the basin.

Both water quality and macroinvertebrate indicators suggested EFA 2 was in the poorest ecological condition of all sites surveyed in the basin, particularly under very low flow conditions. However, some water quality parameters and macroinvertebrate sensitivity improved by EFA 3, which may be due to the role of the protected area of the Maasai Mara National Reserve in allowing the river to recover. Significant declines in water quality were also noted along the Talek River from the upstream to downstream site. In fact, the downstream site on the Talek (Site G) had the poorest water quality of all surveyed sites. More focused monitoring will be needed to determine the role of urban and tourism developments in causing these changes. Because this tributary enters the Mara inside the National Reserve, it could impede the ability of the river to recover in this region.

Long-term monitoring also captured the wide degree of change occurring within sites over the course of a year with variable flow levels. Conductivity and DO levels responded most strongly to declining flow levels. These were two of the three parameters with significant predictive capacity for determining sensitivity of macroinvertebrate fauna at a given site. Indeed, diversity and sensitivity of macroinvertebrate taxa also declined under low flow conditions at 3 of the 4 sampling sites. Turbidity had a less clear relationship with flow level, as it generally varies on a shorter time-scale. More frequent monitoring, ideally by an in-situ turbidity meter, will be necessary to develop a better understanding of sediment dynamics in this system.

Overall, the data from the Low Flow EFA and Long-Term Monitoring support the findings and recommendations of the 2007 EFA. However, significantly low water quality at EFA 2 suggests low flow recommendations for this site may need to be reviewed. In addition, some new critical indicator species were identified and hydraulics rating curves for EFA 1, 2 and 3 were refined using low flow values. The findings of these assessments need to be reviewed by all members of the EFA team in order to determine whether adjustments to the original EFA prescriptions are warranted, as EFA recommendations arose under consideration of all components of the river system. The EFA team should also consider the hydrological data available for the period of record to determine whether or not reserve flow recommendations should be adjusted based on updated average monthly flow values that may incorporate high levels of abstraction. Review and analysis of reserve flow prescriptions will take place during Phase II of the EFA in Tanzania.

The report from the 2007 EFA made eight recommendations for implementation and monitoring of reserve flows, one of which was continued monitoring of river flow levels and ecological health to refine reserve flow recommendations (LVBC and WWF-ESARPO 2010). This report details the work undertaken from 2008-10 to contribute to this recommendation thus far, and recommends that ongoing monitoring be continued into the future and extended throughout the basin to the degree possible. Working with local communities and resource managers to monitor the rivers in their regions is one effective way to approach this goal. Ultimately, accuracy of reserve flow recommendations will be determined by continued health of the river and the people and nature that depend upon it.

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Appendix 1: Sampling site names and locations

Site Name	**Location**	**Site Coordinates** Lat. and Long. (Degree, Minute, Second)
EFA 1	Kapkimolwa Bridge	0°54'2.16"S 35°26'13.50"E
Site A	Mulot Bridge	0°56'40.29"S 35°25'25.90"E
EFA 1.2	Silibwet Bridge	0°44'20.84"S 35°21'43.48"E
Site B	Bomet Bridge	0°47'26.31"S 35°20'45.49"E
EFA 2	Ngerende Island near Mara Safari Club	1° 5'39.36"S 35°11'50.18"E
Site C	Old Mara Bridge	1°13'18.08"S 35° 2'27.74"E
Site D	Oxbow by Governor's Camp	1°18'28.68"S 35° 2'5.02"E
Site E	Mara at the Talek Confluence	1°26'4.31"S 35° 3'48.87"E
EFA 3	New Mara Bridge	1°32'50.42"S 35° 1'4.90"E
Site F	Talek at Mara Simba	1° 29' 41.419" S 35° 18' 6.473" E
Site G	Talek upstream of Naibor Camp	1°25'3.24"S 35° 2'58.71"E

Appendix 2: Simulated stream flow hydraulics for cross-sections of EFA sites

Simulated stream flow hydraulics for various cross sections at EFA 1.2 on the Nyangores River

Cross section	Stream Discharge (m^3/s)	Water Surface Level (masd)	Average Velocity (m/s)	Hydraulic depth (m)	Wetted Width (m)	Wetted perimeter (m)	Cross section Area (m^2)
BBM1.2E	0.200	97.294	0.090	0.122	18.157	18.402	2.220
	0.250	97.308	0.101	0.134	18.414	18.669	2.476
	0.300	97.321	0.110	0.146	18.586	18.853	2.717
	0.500	97.364	0.142	0.183	19.266	19.572	3.529
	0.646	97.390	0.160	0.203	19.901	20.227	4.038
	1.000	97.442	0.196	0.241	21.223	21.579	5.113
	2.000	97.541	0.275	0.327	22.274	22.678	7.275
	3.000	97.613	0.338	0.396	22.448	22.904	8.885
	4.000	97.672	0.392	0.452	22.590	23.089	10.213
	5.000	97.725	0.438	0.502	22.718	23.256	11.414
	6.000	97.772	0.481	0.547	22.832	23.404	12.485
	7.000	97.815	0.520	0.587	22.936	23.539	13.469
	7.943	97.853	0.554	0.623	23.028	23.658	14.342
	8.000	97.855	0.556	0.625	23.033	23.664	14.388
	10.000	97.928	0.622	0.693	23.209	23.894	16.076
	15.000	98.083	0.761	0.835	23.584	24.381	19.702
	20.000	98.237	0.852	0.907	25.867	26.736	23.466
	27.000	98.401	0.968	1.003	27.795	28.727	27.885
	50.000	98.780	1.281	1.270	30.748	31.838	39.040
	100.000	99.342	1.743	1.642	34.925	36.241	57.359
	200.000	100.096	2.278	1.988	44.178	45.739	87.809
BBM1.2D	0.200	97.295	0.038	0.315	16.786	17.025	5.292
	0.250	97.309	0.045	0.328	16.847	17.092	5.531
	0.300	97.322	0.052	0.340	16.903	17.154	5.753
	0.500	97.366	0.077	0.380	17.089	17.359	6.494
	0.646	97.392	0.093	0.404	17.204	17.486	6.947
	1.000	97.445	0.127	0.449	17.530	17.829	7.865
	2.000	97.546	0.207	0.533	18.153	18.485	9.671
	3.000	97.620	0.272	0.593	18.608	18.963	11.026
	4.000	97.680	0.329	0.641	18.980	19.355	12.163
	5.000	97.735	0.379	0.683	19.314	19.706	13.201
	6.000	97.783	0.424	0.721	19.610	20.018	14.136
	7.000	97.827	0.467	0.755	19.881	20.302	15.004
	7.943	97.865	0.503	0.784	20.120	20.554	15.779
	8.000	97.867	0.506	0.786	20.132	20.567	15.820
	10.000	97.942	0.577	0.842	20.590	21.049	17.334
	15.000	98.099	0.726	0.958	21.560	22.069	20.652
	20.000	98.253	0.832	1.068	22.508	23.067	24.045
	27.000	98.418	0.956	1.016	27.807	28.436	28.246
	50.000	98.804	1.235	1.171	34.578	35.367	40.481
	100.000	99.390	1.607	1.584	39.277	40.268	62.227

	200.000	100.181	2.095	2.154	44.312	45.563	95.466
	0.200	97.295	0.029	0.397	17.444	17.764	6.918
	0.250	97.309	0.035	0.409	17.518	17.843	7.166
	0.300	97.322	0.041	0.421	17.586	17.917	7.398
	0.500	97.366	0.061	0.459	17.813	18.160	8.172
	0.646	97.392	0.075	0.482	17.950	18.308	8.646
	1.000	97.446	0.104	0.527	18.225	18.604	9.607
	2.000	97.547	0.174	0.613	18.753	19.171	11.491
	3.000	97.622	0.232	0.674	19.139	19.586	12.903
	4.000	97.683	0.284	0.724	19.456	19.927	14.086
	5.000	97.738	0.330	0.768	19.740	20.233	15.162
	6.000	97.787	0.372	0.807	19.993	20.504	16.131
	7.000	97.832	0.411	0.842	20.224	20.753	17.028
	7.943	97.871	0.446	0.873	20.428	20.972	17.828
	8.000	97.873	0.448	0.874	20.438	20.983	17.871
	10.000	97.949	0.515	0.933	20.830	21.404	19.431
	15.000	98.109	0.657	1.008	22.658	23.299	22.846
	20.000	98.265	0.750	1.026	26.011	26.738	26.677
	27.000	98.434	0.862	1.074	29.157	29.979	31.326
	50.000	98.826	1.142	1.295	33.824	34.768	43.786
	100.000	99.416	1.527	1.665	39.331	40.441	65.474
	200.000	100.211	2.021	2.191	45.164	46.495	98.946
BBM1.2B	0.200	97.298	0.148	0.117	11.620	11.849	1.355
	0.250	97.313	0.163	0.125	12.233	12.487	1.530
	0.300	97.327	0.177	0.133	12.755	13.028	1.699
	0.500	97.371	0.218	0.168	13.598	13.920	2.291
	0.646	97.398	0.243	0.186	14.318	14.663	2.660
	1.000	97.451	0.290	0.223	15.499	15.857	3.451
	2.000	97.554	0.386	0.295	17.570	17.950	5.175
	3.000	97.629	0.461	0.359	18.118	18.517	6.513
	4.000	97.691	0.523	0.412	18.567	18.983	7.642
	5.000	97.746	0.576	0.457	18.969	19.400	8.675
	6.000	97.794	0.624	0.497	19.325	19.769	9.609
	7.000	97.839	0.668	0.533	19.651	20.108	10.480
	7.943	97.879	0.705	0.565	19.939	20.406	11.260
	8.000	97.881	0.708	0.566	19.954	20.422	11.302
	10.000	97.956	0.779	0.626	20.507	20.995	12.833
	15.000	98.117	0.925	0.747	21.703	22.234	16.216
	20.000	98.272	1.008	0.790	25.121	25.705	19.837
	27.000	98.441	1.106	0.844	28.907	29.560	24.407
	50.000	98.835	1.357	1.105	33.352	34.143	36.856
	100.000	99.428	1.712	1.491	39.163	40.110	58.399
	200.000	100.226	2.177	2.050	44.806	45.978	91.862
BBM1.2A	0.200	97.379	0.198	0.094	10.712	11.034	1.008
	0.250	97.399	0.203	0.098	12.617	12.971	1.233
	0.300	97.413	0.211	0.098	14.531	14.906	1.419
	0.500	97.458	0.234	0.133	16.018	16.439	2.133
	0.646	97.484	0.253	0.156	16.375	16.820	2.549

	1.000	97.539	0.287	0.201	17.300	17.793	3.479
	2.000	97.648	0.364	0.278	19.731	20.275	5.492
	3.000	97.729	0.421	0.341	20.911	21.473	7.130
	4.000	97.796	0.467	0.392	21.842	22.417	8.563
	5.000	97.855	0.506	0.439	22.509	23.097	9.873
	6.000	97.908	0.542	0.482	22.982	23.583	11.075
	7.000	97.955	0.574	0.520	23.411	24.023	12.185
	7.943	97.998	0.603	0.554	23.789	24.411	13.182
	8.000	98.000	0.604	0.556	23.810	24.433	13.238
	10.000	98.082	0.657	0.620	24.542	25.184	15.212
	15.000	98.254	0.766	0.751	26.068	26.752	19.572
	20.000	98.411	0.843	0.879	27.009	27.760	23.736
	27.000	98.588	0.934	0.921	31.385	32.229	28.895
	50.000	99.005	1.149	1.172	37.114	38.124	43.503
	100.000	99.627	1.478	1.666	40.619	41.872	67.672
	200.000	100.463	1.901	2.159	48.738	50.183	105.209

Simulated stream flow hydraulics after recalibration for various cross sections at EFA 1 on the Amala River

Cross section	**Stream Discharge (m3/s)**	**Water Surface Level (masd)**	**Average Velocity (m/s)**	**Hydraulic depth (m)**	**Wetted Width (m)**	**Wetted perimeter (m)**	**Cross section Area (m^2)**
BBM1F	0.177	97.064	0.156	0.203	5.605	5.683	1.136
	0.200	97.094	0.152	0.194	6.787	6.870	1.318
	0.250	97.127	0.161	0.209	7.419	7.508	1.554
	0.300	97.158	0.167	0.223	8.040	8.156	1.792
	0.500	97.257	0.184	0.254	10.715	10.951	2.723
	1.000	97.399	0.222	0.331	13.622	14.008	4.509
	1.250	97.316	0.367	0.272	12.504	12.811	3.402
	2.000	97.574	0.287	0.482	14.444	14.991	6.964
	3.000	97.714	0.332	0.598	15.111	15.787	9.033
	4.000	97.848	0.359	0.666	16.708	17.449	11.136
	5.000	97.970	0.376	0.704	18.890	19.649	13.307
	6.000	98.060	0.399	0.766	19.638	20.426	15.047
	7.000	98.140	0.421	0.828	20.094	20.918	16.638
	7.943	97.936	0.627	0.693	18.282	19.036	12.675
	8.000	98.211	0.443	0.891	20.272	21.152	18.071
	11.000	98.405	0.499	1.062	20.757	21.790	22.051
	27.000	99.201	0.678	1.654	24.100	25.553	39.851
BBM1E	0.177	97.065	0.029	0.518	11.740	12.015	6.086
	0.200	97.095	0.031	0.545	11.814	12.119	6.438
	0.250	97.128	0.037	0.575	11.881	12.227	6.830
	0.300	97.159	0.042	0.603	11.945	12.328	7.199
	0.500	97.258	0.060	0.693	12.100	12.622	8.386
	1.000	97.399	0.099	0.828	12.196	12.929	10.100
	1.250	97.317	0.137	0.751	12.121	12.746	9.105

	2.000	97.574	0.163	0.982	12.481	13.413	12.257
	3.000	97.714	0.214	1.096	12.798	13.871	14.023
	4.000	97.848	0.253	1.154	13.693	14.808	15.798
	5.000	97.970	0.285	1.207	14.508	15.660	17.518
	6.000	98.060	0.318	1.248	15.110	16.289	18.851
	7.000	98.140	0.349	1.284	15.644	16.848	20.081
	7.943	97.936	0.466	1.192	14.281	15.422	17.029
	8.000	98.211	0.377	1.316	16.119	17.344	21.209
	11.000	98.405	0.450	1.405	17.415	18.699	24.461
	27.000	99.201	0.638	1.494	28.327	29.738	42.319
BBM1D	0.177	97.066	0.075	0.227	10.437	10.571	2.374
	0.200	97.095	0.074	0.255	10.539	10.692	2.687
	0.250	97.128	0.082	0.285	10.652	10.826	3.038
	0.300	97.160	0.089	0.313	10.758	10.952	3.370
	0.500	97.259	0.112	0.400	11.125	11.443	4.454
	1.000	97.402	0.164	0.510	11.955	12.479	6.094
	1.250	97.322	0.242	0.454	11.388	11.842	5.169
	2.000	97.582	0.238	0.618	13.589	14.152	8.400
	3.000	97.729	0.286	0.717	14.613	15.222	10.474
	4.000	97.871	0.317	0.810	15.575	16.230	12.608
	5.000	98.000	0.340	0.892	16.458	17.155	14.687
	6.000	98.100	0.367	0.954	17.132	17.861	16.351
	7.000	98.189	0.391	1.010	17.743	18.500	17.915
	7.943	98.019	0.530	0.904	16.586	17.289	14.997
	8.000	98.271	0.413	1.059	18.297	19.080	19.381
	11.000	98.498	0.464	1.195	19.842	20.698	23.712
	27.000	99.483	0.588	1.885	24.351	25.738	45.896
BBM1C	0.177	97.127	0.167	0.125	8.509	8.658	1.061
	0.200	97.147	0.162	0.133	9.300	9.458	1.238
	0.250	97.174	0.166	0.153	9.868	10.036	1.505
	0.300	97.200	0.170	0.175	10.064	10.241	1.764
	0.500	97.292	0.184	0.253	10.758	10.964	2.720
	1.000	97.434	0.231	0.370	11.700	12.024	4.332
	1.250	97.394	0.323	0.333	11.604	11.862	3.866
	2.000	97.619	0.304	0.524	12.549	13.048	6.571
	3.000	97.768	0.354	0.654	12.971	13.616	8.480
	4.000	97.909	0.387	0.779	13.250	14.040	10.326
	5.000	98.038	0.415	0.893	13.505	14.428	12.054
	6.000	98.139	0.447	0.980	13.705	14.731	13.425
	7.000	98.231	0.477	1.058	13.886	15.006	14.686
	7.943	98.101	0.616	0.947	13.629	14.616	12.902
	8.000	98.314	0.505	1.128	14.050	15.257	15.847
	11.000	98.544	0.575	1.319	14.507	15.950	19.139
	27.000	99.529	0.757	1.857	19.207	21.373	35.659
BBM1B	0.177	97.163	0.158	0.198	5.644	5.762	1.117
	0.200	97.182	0.163	0.207	5.911	6.055	1.224
	0.250	97.211	0.178	0.222	6.331	6.515	1.402
	0.300	97.237	0.191	0.244	6.437	6.652	1.572

	0.500	97.329	0.230	0.324	6.715	7.036	2.174
	1.000	97.477	0.308	0.406	8.001	8.537	3.249
	1.250	97.470	0.391	0.399	8.001	8.524	3.196
	2.000	97.670	0.407	0.530	9.266	9.869	4.913
	3.000	97.821	0.466	0.561	11.485	12.146	6.438
	4.000	97.960	0.488	0.615	13.337	14.039	8.196
	5.000	98.086	0.503	0.694	14.332	15.066	9.948
	6.000	98.188	0.525	0.756	15.128	15.886	11.438
	7.000	98.279	0.545	0.826	15.541	16.373	12.845
	7.943	98.190	0.693	0.757	15.143	15.902	11.468
	8.000	98.363	0.565	0.890	15.911	16.811	14.159
	11.000	98.594	0.613	1.056	17.004	18.318	17.952
	27.000	99.572	0.734	1.757	20.946	23.575	36.807
BBM1A	0.177	97.163	0.180	0.144	6.826	7.003	0.981
	0.200	97.182	0.180	0.152	7.334	7.526	1.113
	0.250	97.211	0.187	0.171	7.827	8.041	1.336
	0.300	97.237	0.194	0.195	7.919	8.151	1.545
	0.500	97.329	0.219	0.277	8.239	8.532	2.285
	1.000	97.477	0.281	0.379	9.382	9.806	3.558
	1.250	97.470	0.357	0.377	9.288	9.704	3.497
	2.000	97.670	0.333	0.447	13.458	14.059	6.015
	3.000	97.821	0.372	0.589	13.699	14.447	8.066
	4.000	97.960	0.401	0.717	13.921	14.803	9.984
	5.000	98.086	0.425	0.832	14.127	15.225	11.759
	6.000	98.188	0.455	0.923	14.295	15.687	13.197
	7.000	98.279	0.482	1.005	14.448	16.106	14.515
	7.943	98.190	0.601	0.925	14.298	15.696	13.225
	8.000	98.363	0.509	1.078	14.587	16.487	15.729
	11.000	98.594	0.575	1.278	14.971	17.541	19.138
	27.000	99.572	0.787	2.131	16.097	20.470	34.300

Simulated stream flow hydraulics after recalibration for various cross sections at EFA 2 on the Mara River

Cross section	Stream Discharge (m3/s)	Water Surface Level (masd)	Average Velocity (m/s)	Hydraulic depth (m)	Wetted Width (m)	Wetted perimeter (m)	Cross section Area (m^2)
BBM2D	1.000	92.482	0.496	0.178	11.332	11.437	2.016
	1.035	92.485	0.505	0.179	11.444	11.552	2.050
	1.450	92.515	0.602	0.191	12.618	12.759	2.410
	2.180	92.557	0.729	0.200	14.958	15.152	2.989
	2.530	92.572	0.786	0.204	15.790	16.004	3.220
	4.000	92.621	0.985	0.219	18.511	18.787	4.060
	6.842	92.912	0.588	0.377	30.900	31.535	11.642
	7.510	92.700	1.309	0.230	24.986	25.362	5.735
	7.920	92.706	1.345	0.233	25.286	25.669	5.887
	8.000	92.707	1.353	0.234	25.306	25.690	5.912

	16.896	93.068	1.017	0.509	32.664	33.341	16.614
BBM2C	1.000	92.504	0.485	0.198	10.446	10.547	2.064
	1.035	92.507	0.493	0.199	10.556	10.656	2.101
	1.450	92.544	0.576	0.208	12.111	12.219	2.515
	2.180	92.596	0.677	0.213	15.095	15.216	3.219
	2.530	92.616	0.715	0.217	16.292	16.418	3.537
	4.000	92.688	0.822	0.236	20.585	20.728	4.865
	6.842	92.925	0.617	0.383	28.935	29.242	11.088
	7.510	92.819	0.925	0.298	27.224	27.425	8.116
	7.920	92.832	0.935	0.308	27.455	27.661	8.468
	8.000	92.835	0.937	0.310	27.499	27.707	8.537
	16.896	93.097	1.035	0.516	31.623	32.095	16.323
BBM2B	1.000	92.524	0.171	0.352	16.591	16.655	5.841
	1.035	92.529	0.175	0.355	16.654	16.719	5.913
	1.450	92.574	0.217	0.386	17.317	17.388	6.685
	2.180	92.638	0.278	0.423	18.514	18.614	7.831
	2.530	92.664	0.305	0.437	19.022	19.134	8.308
	4.000	92.752	0.395	0.460	22.015	22.171	10.123
	6.842	92.957	0.457	0.593	25.244	25.554	14.969
	7.510	92.897	0.557	0.555	24.267	24.517	13.480
	7.920	92.910	0.573	0.564	24.489	24.753	13.814
	8.000	92.913	0.576	0.566	24.532	24.799	13.879
	16.896	93.168	0.818	0.720	28.673	29.191	20.656
BBM2A	1.000	92.574	0.368	0.142	19.083	19.101	2.716
	1.035	92.578	0.370	0.146	19.131	19.150	2.794
	1.450	92.621	0.400	0.185	19.633	19.663	3.624
	2.180	92.685	0.445	0.240	20.450	20.497	4.902
	2.530	92.710	0.465	0.260	20.897	20.950	5.435
	4.000	92.801	0.540	0.330	22.476	22.550	7.412
	6.842	92.995	0.569	0.482	24.926	25.050	12.020
	7.510	92.956	0.679	0.451	24.536	24.649	11.057
	7.920	92.970	0.693	0.463	24.684	24.801	11.421
	8.000	92.973	0.696	0.465	24.712	24.831	11.491
	16.896	93.240	0.906	0.640	29.130	29.286	18.653

Simulated stream flow hydraulics after recalibration for various cross sections at EFA 3 on the Mara River

Cross section	Stream Discharge (m3/s)	Water Surface Level (masd)	Average Velocity (m/s)	Hydraulic depth (m)	Wetted Width (m)	Wetted perimeter (m)	Cross section Area (m^2)
BBM3D	1.056	95.820	0.128	0.316	26.101	26.406	8.248
	2.000	95.929	0.180	0.415	26.850	27.187	11.134
	2.220	95.950	0.190	0.433	26.995	27.337	11.699
	2.240	95.952	0.191	0.435	27.008	27.352	11.754
	2.320	95.959	0.194	0.441	27.056	27.402	11.943
	2.410	95.967	0.198	0.448	27.111	27.459	12.159

	2.660	95.988	0.209	0.467	27.256	27.610	12.730
	2.960	96.012	0.221	0.488	27.421	27.782	13.386
	3.200	96.031	0.230	0.505	27.552	27.918	13.909
	3.300	96.038	0.234	0.511	27.600	27.968	14.102
	3.810	96.074	0.252	0.542	27.847	28.226	15.100
	4.690	96.130	0.281	0.592	28.149	28.563	16.669
	5.120	96.155	0.295	0.615	28.230	28.672	17.374
	5.230	96.161	0.298	0.621	28.249	28.698	17.543
	5.290	96.164	0.300	0.624	28.259	28.712	17.628
	5.690	96.185	0.312	0.643	28.321	28.796	18.222
	6.000	96.201	0.321	0.658	28.360	28.851	18.675
	6.120	96.207	0.325	0.664	28.375	28.872	18.846
	6.570	96.230	0.337	0.686	28.432	28.951	19.499
	6.590	96.231	0.337	0.687	28.435	28.954	19.527
	6.800	96.241	0.343	0.696	28.460	28.989	19.812
	6.920	96.246	0.347	0.701	28.472	29.006	19.954
	7.471	96.177	0.415	0.636	28.301	28.768	17.996
	8.030	96.296	0.376	0.748	28.596	29.178	21.381
	8.230	96.305	0.380	0.756	28.618	29.209	21.638
	9.360	96.352	0.407	0.800	28.735	29.371	22.986
	15.000	96.548	0.523	0.981	29.221	30.046	28.666
	15.882	96.620	0.516	1.047	29.399	30.294	30.776
BBM3C	1.056	95.821	0.091	0.473	24.542	24.698	11.615
	2.000	95.935	0.138	0.560	25.887	26.065	14.500
	2.220	95.957	0.147	0.535	28.178	28.358	15.082
	2.240	95.959	0.148	0.536	28.242	28.422	15.140
	2.320	95.966	0.151	0.539	28.465	28.646	15.344
	2.410	95.974	0.155	0.542	28.720	28.902	15.579
	2.660	95.996	0.164	0.551	29.390	29.574	16.206
	2.960	96.021	0.175	0.565	30.002	30.189	16.941
	3.200	96.040	0.183	0.579	30.294	30.483	17.528
	3.300	96.047	0.186	0.584	30.402	30.592	17.748
	3.810	96.084	0.202	0.610	30.955	31.151	18.884
	4.690	96.142	0.227	0.650	31.816	32.020	20.692
	5.120	96.168	0.238	0.668	32.201	32.408	21.516
	5.230	96.174	0.241	0.672	32.294	32.502	21.716
	5.290	96.177	0.242	0.675	32.340	32.549	21.817
	5.690	96.199	0.253	0.690	32.665	32.877	22.523
	6.000	96.215	0.260	0.704	32.770	32.988	23.064
	6.120	96.221	0.263	0.709	32.801	33.021	23.268
	6.570	96.245	0.273	0.730	32.919	33.149	24.047
	6.590	96.246	0.274	0.731	32.924	33.154	24.081
	6.800	96.257	0.278	0.741	32.975	33.210	24.421
	6.920	96.262	0.281	0.745	33.001	33.238	24.594
	7.471	96.201	0.331	0.691	32.697	32.909	22.593
	8.030	96.313	0.305	0.791	33.257	33.515	26.307
	8.230	96.323	0.309	0.799	33.303	33.565	26.615
	9.360	96.371	0.331	0.842	33.544	33.826	28.238
	15.000	96.574	0.427	1.017	34.549	34.914	35.138

	15.882	96.621	0.432	1.057	34.784	35.169	36.784
BBM3B	1.056	95.822	0.080	0.528	25.025	25.289	13.207
	2.000	95.945	0.122	0.634	25.808	26.112	16.356
	2.220	95.968	0.131	0.653	25.929	26.242	16.941
	2.240	95.970	0.132	0.655	25.941	26.254	16.997
	2.320	95.978	0.135	0.662	25.981	26.297	17.194
	2.410	95.987	0.138	0.669	26.028	26.347	17.419
	2.660	96.009	0.148	0.689	26.150	26.478	18.014
	2.960	96.035	0.158	0.711	26.290	26.627	18.697
	3.200	96.056	0.166	0.729	26.400	26.744	19.238
	3.300	96.064	0.170	0.735	26.441	26.788	19.441
	3.810	96.103	0.186	0.738	27.774	28.132	20.495
	4.690	96.164	0.211	0.790	28.115	28.542	22.208
	5.120	96.191	0.223	0.815	28.179	28.639	22.978
	5.230	96.198	0.226	0.822	28.194	28.662	23.164
	5.290	96.201	0.227	0.825	28.202	28.674	23.260
	5.690	96.224	0.238	0.846	28.256	28.756	23.915
	6.000	96.242	0.246	0.863	28.298	28.819	24.415
	6.120	96.249	0.249	0.869	28.311	28.840	24.602
	6.570	96.274	0.260	0.890	28.440	28.985	25.317
	6.590	96.275	0.260	0.891	28.448	28.993	25.348
	6.800	96.286	0.265	0.900	28.521	29.070	25.663
	6.920	96.292	0.268	0.904	28.559	29.110	25.826
	7.471	96.243	0.306	0.864	28.301	28.823	24.450
	8.030	96.347	0.293	0.948	28.926	29.496	27.415
	8.230	96.357	0.297	0.955	28.991	29.564	27.700
	9.360	96.409	0.320	0.996	29.336	29.927	29.214
	15.000	96.626	0.420	1.161	30.778	31.443	35.746
	15.882	96.634	0.441	1.167	30.829	31.496	35.979
BBM3A	1.056	95.822	0.120	0.628	13.974	14.317	8.770
	2.000	95.957	0.186	0.712	15.074	15.459	10.728
	2.220	95.981	0.200	0.717	15.476	15.866	11.092
	2.240	95.983	0.201	0.716	15.531	15.922	11.127
	2.320	95.991	0.206	0.715	15.731	16.124	11.253
	2.410	96.001	0.211	0.714	15.957	16.352	11.398
	2.660	96.025	0.226	0.712	16.555	16.955	11.792
	2.960	96.053	0.241	0.690	17.774	18.181	12.264
	3.200	96.074	0.253	0.673	18.807	19.222	12.662
	3.300	96.082	0.257	0.669	19.159	19.576	12.818
	3.810	96.124	0.279	0.652	20.939	21.370	13.654
	4.690	96.189	0.310	0.637	23.716	24.169	15.105
	5.120	96.218	0.324	0.634	24.960	25.423	15.814
	5.230	96.225	0.327	0.633	25.262	25.728	15.992
	5.290	96.229	0.329	0.633	25.418	25.884	16.084
	5.690	96.254	0.340	0.634	26.389	26.865	16.728
	6.000	96.273	0.348	0.638	27.002	27.487	17.231
	6.120	96.280	0.351	0.640	27.232	27.721	17.423
	6.570	96.306	0.362	0.649	27.967	28.468	18.161
	6.590	96.308	0.362	0.650	27.991	28.494	18.194

	6.800	96.319	0.367	0.656	28.241	28.750	18.525
	6.920	96.326	0.370	0.659	28.372	28.884	18.699
	7.471	96.289	0.422	0.642	27.543	28.037	17.685
	8.030	96.384	0.394	0.689	29.621	30.165	20.404
	8.230	96.395	0.397	0.694	29.842	30.391	20.714
	9.360	96.450	0.418	0.722	31.011	31.590	22.388
	15.000	96.679	0.485	0.804	38.463	39.135	30.922
	15.882	96.637	0.542	0.769	38.131	38.792	29.309

Appendix 3: Water quality data from the Low Flow EFA sampling event in February 2009

In Situ Parameters

Site Name	Date	Temperature (ºC)	Specific Conductivity (mS/cm)	Total Dissolved Solids (mg/L)	Dissolved Oxygen (% saturation)	Dissolved Oxygen (mg/L)	Turbidity
EFA 1	2/21/2009	21.41	0.239	0.155	98.4	8.7	45.9
EFA 1.2	2/22/2009	17.76	0.081	0.053	76.4	7.27	17.5
EFA 2	2/23/2009	24.47	0.431	0.28	28.6	2.38	72.1
EFA 3	2/24/2009	25.41	0.567	0.368	33.6	2.75	74.5

Laboratory Analyses

Site Name	Date	DOC (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)
EFA 1	2/21/2009	3.499	0.68	6.48	0.53	7.59	< 0.1	0.103	9.571	3.577	15.76	26.70
EFA 1.2	2/22/2009	2.709	0.32	2.60	0.18	0.81	< 0.1	0.051	2.494	0.858	6.736	8.23
EFA 2	2/23/2009	4.479	1.02	30.22	0.33	32.67	< 0.1	0.076	14.46	3.85	16.702	55.74
EFA 3	2/24/2009	10.86	1.51	35.99	0.00	31.94	< 0.1	0.135	24.912	5.976	28.368	55.65

Appendix 4: Photos of 15 fish species documented in the Mara River during 2007 and 2009 EFA sampling events (Photos by R. Tamatamah, unless specified otherwise)

CYPRINIDAE

Labeo cylindricus

Labeo victorianus

Barbus altianalis

Barbus paludinosus

Barbus kerstenii

Barbus oxyrhynchus

Barbus cercops

CLARIDAE

Clarias gariepinus

Clarias liocephalus

MORMYRIDAE

Mormyrus kannume

BAGRIDAE

Bagrus docmak

MOCHOKIDAE

Chiloglanis somereni

CICHLIDAE

Haplochromis sp. (Photo by E. Schraml)

Oreochromis sp.

Tilapia zillii (Photo by A. Azeroual)

Appendix 5: Water quality data from Long-term Monitoring in the Mara River Basin, August 2008-August 2009

In Situ Parameters

Site Name	Location	Date	Temp (ºC)	Specific Conductivity (mS/cm)	Total Dissolved Solids (mg/L)	Dissolved Oxygen (% saturation)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
EFA 1	Kapkimolwa Bridge	8/20/2008	15.5	0.053	0.035	82.3	8.21	48.5
EFA 1	Kapkimolwa Bridge	9/5/2008	17.41	0.053	0.035	83.8	8.03	38.7
EFA 1	Kapkimolwa Bridge	9/27/2008						10.7
EFA 1	Kapkimolwa Bridge	10/12/2008						35
EFA 1	Kapkimolwa Bridge	10/28/2008	17.75	0.053	0.034	85.7	8.16	67.2
EFA 1	Kapkimolwa Bridge	11/5/2008	17.94	0.06	0.039	86.6	8.21	33.9
EFA 1	Kapkimolwa Bridge	11/16/2008	17.31	0.067	0.044	86.3	8.29	42.3
EFA 1	Kapkimolwa Bridge	12/5/2008	17.53	0.071	0.046	84.4	8.07	29.6
EFA 1	Kapkimolwa Bridge	12/20/2008	19.8	0.089	0.058	87.5	7.98	21.9
EFA 1	Kapkimolwa Bridge	1/8/2009	21.11	0.122	0.079	93.1	8.28	17
EFA 1	Kapkimolwa Bridge	1/28/2009	20.86	0.164	0.106	80.3	7.17	125
EFA 1	Kapkimolwa Bridge	2/10/2009	19.9	0.164	0.106	75	6.83	1239
EFA 1	Kapkimolwa Bridge	2/21/2009	21.41	0.239	0.155	98.4	8.7	45.9
EFA 1	Kapkimolwa Bridge	3/5/2009	24.01	0.282	0.183	103.3	8.68	41.9
EFA 1	Kapkimolwa Bridge	3/17/2009	21.18	0.192	0.125	80.3	7.13	193
EFA 1	Kapkimolwa Bridge	4/28/2009	21.52	0.227	0.147	85.6	7.55	142
EFA 1	Kapkimolwa Bridge	5/11/2009	22.46	0.223	0.145	95.6	8.28	85.5
EFA 1	Kapkimolwa Bridge	5/29/2009	18.46	0.093	0.061	81.3	7.62	142
EFA 1	Kapkimolwa Bridge	6/23/2009	21.21	0.14	0.091	93.8	8.33	
EFA 1	Kapkimolwa Bridge	7/1/2009	19.31	0.148	0.096	88.1	8.12	87.7
EFA 1	Kapkimolwa Bridge	7/12/2009	20.2	0.147	0.095	89.8	8.13	29.8
EFA 1	Kapkimolwa Bridge	8/21/2009	19.71	0.127	0.082	90.1	8.24	29.4
Site A	Mulot Bridge	8/28/2008	16.28	0.06	0.039	80.6	7.91	
Site A	Mulot Bridge	9/5/2008	17.01	0.055	0.036	83.5	8.07	46.4
Site A	Mulot Bridge	9/27/2008						10.38
Site A	Mulot Bridge	10/12/2008						40.4
Site A	Mulot Bridge	10/28/2008	18.45	0.054	0.035	85.2	7.99	74
Site A	Mulot Bridge	11/6/2008	19.3	0.069	0.045	83.1	7.66	
Site A	Mulot Bridge	11/16/2008	17.62	0.068	0.044	86.9	8.29	46.2

Site Name	Location	Date	Temp (ºC)	Specific Conductivity (mS/cm)	Total Dissolved Solids (mg/L)	Dissolved Oxygen (% saturation)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
Site A	Mulot Bridge	12/5/2008	18.91	0.078	0.051	86.9	8.07	29.9
Site A	Mulot Bridge	12/20/2008	21.33	0.097	0.063	84	7.44	25.6
Site A	Mulot Bridge	1/8/2009	20.4	0.161	0.105	72.8	6.56	19.4
Site A	Mulot Bridge	1/28/2009	21.02	0.186	0.121	70	6.24	47.7
Site A	Mulot Bridge	2/10/2009	19.71	0.236	0.154	63.9	5.84	282
Site A	Mulot Bridge	3/5/2009	21.79	0.312	0.203	64.2	5.63	73.6
Site A	Mulot Bridge	3/16/2009	22.63	0.348	0.226	70.9	6.12	176
Site A	Mulot Bridge	4/28/2009	23.07	0.244	0.159	80.5	6.89	189
Site A	Mulot Bridge	5/11/2009	21.56	0.221	0.143	82.3	7.25	85.4
Site A	Mulot Bridge	5/29/2009	18.54	0.114	0.074	92.1	8.62	272
Site A	Mulot Bridge	6/23/2009	21.98	0.164	0.107	78.5	6.86	
Site A	Mulot Bridge	7/1/2009	18.67	0.186	0.121	81.8	7.64	40.6
Site A	Mulot Bridge	7/12/2009	19.69	0.183	0.119	81.5	7.45	35.9
Site A	Mulot Bridge	8/19/2009	20.16	0.152	0.099	80.4	7.29	29.3
EFA 1.2	Silibwet Bridge	8/20/2008	17.25	0.039	0.025	81.9	7.87	28.3
EFA 1.2	Silibwet Bridge	9/6/2008	17.24	0.04	0.026	82.7	7.96	37.4
EFA 1.2	Silibwet Bridge	9/27/2008						13.5
EFA 1.2	Silibwet Bridge	10/12/2008						36.7
EFA 1.2	Silibwet Bridge	10/28/2008	18.5	0.042	0.027	83.1	7.78	51.7
EFA 1.2	Silibwet Bridge	11/6/2008	16.08	0.043	0.028	82.2	8.1	
EFA 1.2	Silibwet Bridge	11/17/2008	14.74	0.056	0.036	81.4	8.25	40.4
EFA 1.2	Silibwet Bridge	12/4/2008	19.26	0.049	0.032	87	8.03	31.7
EFA 1.2	Silibwet Bridge	12/20/2008	19.35	0.052	0.034	102.8	9.47	23.9
EFA 1.2	Silibwet Bridge	1/8/2009	17.77	0.059	0.038	85	8.09	18
EFA 1.2	Silibwet Bridge	1/28/2009	20.54	0.068	0.044	80.5	7.24	117
EFA 1.2	Silibwet Bridge	2/10/2009	20.82	0.077	0.05	85.2	7.62	15.5
EFA 1.2	Silibwet Bridge	2/22/2009	17.76	0.081	0.053	76.4	7.27	17.5
EFA 1.2	Silibwet Bridge	3/5/2009	25.59	0.074	0.048	80.4	6.57	13.7
EFA 1.2	Silibwet Bridge	3/17/2009	26.8	0.097	0.063	81.7	6.54	25.4
EFA 1.2	Silibwet Bridge	4/27/2009	19.3	0.087	0.056	86.6	7.98	51.2
EFA 1.2	Silibwet Bridge	5/14/2009	19.33	0.072	0.047	92.5	8.52	66.4
EFA 1.2	Silibwet Bridge	5/30/2009	19.16	0.06	0.039	83.5	7.73	83.7
EFA 1.2	Silibwet Bridge	6/23/2009	19.83	0.064	0.042	88	8.03	

Site Name	Location	Date	Temp (ºC)	Specific Conductivity (mS/cm)	Total Dissolved Solids (mg/L)	Dissolved Oxygen (% saturation)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
EFA 1.2	Silibwet Bridge	7/2/2009	17.21	0.06	0.039	83.3	8.02	26.3
EFA 1.2	Silibwet Bridge	7/19/2009	20.86	0.061	0.04	89.7	8.02	24.3
EFA 1.2	Silibwet Bridge	8/22/2009	18.14	0.046	0.03	87.2	8.23	
Site B	Bomet Bridge	8/20/2008	15.51	0.039	0.025	82.2	8.2	31.5
Site B	Bomet Bridge	9/6/2008	15.91	0.041	0.026	86.6	8.56	35.3
Site B	Bomet Bridge	9/27/2008						13.5
Site B	Bomet Bridge	10/12/2008						32.9
Site B	Bomet Bridge	10/28/2008	19.17	0.042	0.027	83	7.67	58.8
Site B	Bomet Bridge	11/6/2008	17.89	0.044	0.029	85.1	8.07	
Site B	Bomet Bridge	11/17/2008	15.26	0.056	0.036	81	8.12	46.7
Site B	Bomet Bridge	12/5/2008	15.49	0.05	0.033	82	8.18	28.3
Site B	Bomet Bridge	12/20/2008	18.44	0.054	0.035	103.2	9.68	25.4
Site B	Bomet Bridge	1/8/2009	18.59	0.065	0.042	76.1	7.12	18.6
Site B	Bomet Bridge	1/28/2009	19.9	0.069	0.045	73.9	6.74	163
Site B	Bomet Bridge	2/10/2009	21.21	0.081	0.052	75.2	6.68	22.1
Site B	Bomet Bridge	3/5/2009	24.42	0.091	0.059	88.9	7.43	12.6
Site B	Bomet Bridge	3/17/2009	24.71	0.103	0.067	73.9	6.14	34.1
Site B	Bomet Bridge	4/27/2009	19	0.096	0.063	80.6	7.48	189
Site B	Bomet Bridge	5/11/2009	20.33	0.085	0.055	84.5	7.64	89.3
Site B	Bomet Bridge	5/30/2009	17.1	0.064	0.042	86.1	8.3	94.7
Site B	Bomet Bridge	6/23/2009	20.91	0.069	0.045	85.7	7.65	
Site B	Bomet Bridge	7/2/2009	18.16	0.066	0.043	78.9	7.44	28
Site B	Bomet Bridge	7/19/2009	19.98	0.068	0.044	93.4	8.49	25.4
Site B	Bomet Bridge	8/22/2009	19.32	0.05	0.033	83.7	7.72	49.8
EFA 2	Ngerende	8/25/2008	19.44	0.065	0.042	81.8	7.52	79.9
EFA 2	Ngerende	9/9/2008	18.89	0.067	0.044	81.8	7.61	43.8
EFA 2	Ngerende	9/26/2008						15.3
EFA 2	Ngerende	10/10/2008						53.2
EFA 2	Ngerende	10/26/2008	20.49	0.082	0.054	89.6	8.06	91.9
EFA 2	Ngerende	11/5/2008	19.94	0.071	0.046	90	8.19	43.4
EFA 2	Ngerende	11/18/2008	21.58	0.096	0.062	75.4	6.64	73.4
EFA 2	Ngerende	12/4/2008	19.97	0.098	0.064	79.8	7.26	42.8
EFA 2	Ngerende	12/21/2008	23.82	0.146	0.095	95.2	8.03	26.1

Site Name	Location	Date	Temp (ºC)	Specific Conductivity (mS/cm)	Total Dissolved Solids (mg/L)	Dissolved Oxygen (% saturation)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
EFA 2	Ngerende	1/12/2009	22.55	0.232	0.151	73.5	6.36	24.6
EFA 2	Ngerende	1/29/2009	25.13	0.246	0.16	68.6	5.65	266
EFA 2	Ngerende	2/11/2009	22.8	0.323	0.21	66.4	5.72	198
EFA 2	Ngerende	2/23/2009	24.47	0.431	0.28	28.6	2.38	72.1
EFA 2	Ngerende	3/7/2009	22.65	0.49	0.318	16.8	1.45	118
EFA 2	Ngerende	3/16/2009	24.2	0.593	0.385	27.4	2.29	102.4
EFA 2	Ngerende	5/2/2009	23.05	0.168	0.109	91.5	7.84	133
EFA 2	Ngerende	5/19/2009	21.56	0.107	0.07	76.9	6.78	818
EFA 2	Ngerende	6/3/2009	20.99	0.149	0.097	49.7	4.43	627
EFA 2	Ngerende	6/25/2009	21.9	0.222	0.144	77.6	6.8	42.3
EFA 2	Ngerende	7/5/2009	21.23	0.251	0.163	77	6.83	
EFA 2	Ngerende	7/20/2009	22.47	0.289	0.188	77.2	6.69	25.4
EFA 2	Ngerende	8/8/2009	22.68	0.239	0.156	70.7	6.1	31.6
Site C	Old Mara Bridge	8/23/2008	20.85	0.07	0.046	90.2	8.06	83.7
Site C	Old Mara Bridge	9/10/2008	21.2	0.076	0.05	84.4	7.49	193
Site C	Old Mara Bridge	10/10/2008						83
Site C	Old Mara Bridge	10/27/2008	20.66	0.085	0.055	82.9	7.44	118
Site C	Old Mara Bridge	11/4/2008	21.23	0.074	0.048	87.4	7.75	60.3
Site C	Old Mara Bridge	11/17/2008	21.96	0.088	0.057	84	7.35	85.9
Site C	Old Mara Bridge	12/3/2008	24.76	0.107	0.069	88.1	7.31	53.7
Site C	Old Mara Bridge	12/22/2008	24.08	0.16	0.104	93.8	7.88	31.5
Site C	Old Mara Bridge	1/11/2009	26.21	0.254	0.165	91.4	7.39	22.8
Site C	Old Mara Bridge	1/30/2009	23.21	0.228	0.148	75.3	6.43	236
Site C	Old Mara Bridge	2/11/2009	27.31	0.283	0.184	82.1	6.51	225
Site C	Old Mara Bridge	3/7/2009	27.88	0.588	0.382	104.5	8.19	80.8
Site C	Old Mara Bridge	3/15/2009	29.41	0.553	0.359	103.1	7.86	68.6
Site C	Old Mara Bridge	5/3/2009	24.85	0.213	0.138	83.8	6.94	189
Site C	Old Mara Bridge	5/18/2009	22.99	0.164	0.107	84.9	7.28	270
Site C	Old Mara Bridge	6/3/2009	22.08	0.113	0.073	85.1	7.43	221
Site C	Old Mara Bridge	6/25/2009	25.54	0.226	0.147	82.6	6.75	40.8
Site C	Old Mara Bridge	7/5/2009	19.37	0.261	0.169	79.3	7.3	
Site C	Old Mara Bridge	7/23/2009	24.63	0.281	0.182	82.6	6.87	31.8
Site C	Old Mara Bridge	8/7/2009	25.55	0.327	0.212	84.2	6.88	21.8

Site Name	Location	Date	Temp (ºC)	Specific Conductivity (mS/cm)	Total Dissolved Solids (mg/L)	Dissolved Oxygen (% saturation)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
Site D	Governor's Oxbow	8/23/2008	21.49	0.072	0.047	84.4	7.45	89.1
Site D	Governor's Oxbow	9/10/2008	20.55	0.073	0.047	83.2	7.48	134
Site D	Governor's Oxbow	10/11/2008						89
Site D	Governor's Oxbow	10/27/2008	20.71	0.102	0.066	76.4	6.85	162
Site D	Governor's Oxbow	11/4/2008	23.42	0.076	0.05	79.1	6.73	73.7
Site D	Governor's Oxbow	11/17/2008	21.78	0.093	0.061	83.5	7.33	93.1
Site D	Governor's Oxbow	12/3/2008	25.02	0.111	0.072	77.6	6.41	57.4
Site D	Governor's Oxbow	12/22/2008	24.41	0.168	0.109	80.6	6.73	35.2
Site D	Governor's Oxbow	1/11/2009	29.6	0.31	0.202	77	5.86	77.7
Site D	Governor's Oxbow	1/29/2009	27.73	0.258	0.167	48.1	3.78	208
Site D	Governor's Oxbow	2/11/2009	32.05	0.139	0.09	125	9.12	1598
Site D	Governor's Oxbow	3/7/2009	28.48	0.503	0.327	129.1	10.01	134
Site D	Governor's Oxbow	3/15/2009	31.95	0.588	0.382	103.1	7.53	80.4
Site D	Governor's Oxbow	5/3/2009	23.36	0.228	0.148	74.8	6.37	207
Site D	Governor's Oxbow	5/19/2009	21.55	0.145	0.094	65	5.74	1262
Site D	Governor's Oxbow	6/25/2009	34.27	0.32	0.208	87.5	6.15	38.6
Site D	Governor's Oxbow	7/21/2009	23	0.6	0.39	68	5.83	40.7
Site D	Governor's Oxbow	8/8/2009	19.25	0.61	0.397	61.2	5.64	205
Site E	Mara at the Talek Confluence	8/22/2008	22.18	0.078	0.051	88.9	7.75	129
Site E	Mara at the Talek Confluence	9/12/2008	20.63	0.082	0.053	74.3	6.67	1230
Site E	Mara at the Talek Confluence	9/25/2008						109.3
Site E	Mara at the Talek Confluence	10/8/2008						162
Site E	Mara at the Talek Confluence	10/27/2008	24.69	0.116	0.075	76.9	6.39	290
Site E	Mara at the Talek Confluence	11/3/2008	24.05	0.082	0.053	82.3	6.92	109.8
Site E	Mara at the Talek Confluence	11/18/2008	23.9	0.107	0.069	86.2	7.27	
Site E	Mara at the Talek Confluence	12/2/2008	26.34	0.123	0.08	76.5	6.17	121
Site E	Mara at the Talek Confluence	12/23/2008	26.24	0.199	0.129	90.3	7.29	58.3
Site E	Mara at the Talek Confluence	1/10/2009	27.08	0.331	0.215	96.4	7.66	34.6
Site E	Mara at the Talek Confluence	1/31/2009	22.66	0.158	0.103	76.1	6.57	1213
Site E	Mara at the Talek Confluence	2/12/2009	26.65	0.319	0.208	64.9	5.2	309
Site E	Mara at the Talek Confluence	3/8/2009	21.28	0.506	0.329	40.2	3.56	167
Site E	Mara at the Talek Confluence	3/14/2009	30.37	0.735	0.478	83	6.22	122
Site E	Mara at the Talek Confluence	5/4/2009	24.84	0.255	0.166	74.9	6.2	249

Site Name	Location	Date	Temp (ºC)	Specific Conductivity (mS/cm)	Total Dissolved Solids (mg/L)	Dissolved Oxygen (% saturation)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
Site E	Mara at the Talek Confluence	5/17/2009	24.22	0.241	0.156	76.9	6.45	774
Site E	Mara at the Talek Confluence	6/1/2009	24.75	0.109	0.071	72.8	6.04	770
Site E	Mara at the Talek Confluence	6/26/2009	26.56	0.285	0.185	89.4	7.18	61.1
Site E	Mara at the Talek Confluence	7/4/2009	20.85	0.4	0.26	71.1	6.35	59.7
Site E	Mara at the Talek Confluence	7/24/2009	26.24	0.449	0.292	106.4	8.58	
EFA 3	New Mara Bridge	8/23/2008	21.21	0.08	0.052	75.5	6.7	80.9
EFA 3	New Mara Bridge	9/11/2008	23.04	0.086	0.056	76.1	6.52	171
EFA 3	New Mara Bridge	9/25/2008						123
EFA 3	New Mara Bridge	10/8/2008						182
EFA 3	New Mara Bridge	10/27/2008	24.22	0.122	0.079	72.8	6.11	330
EFA 3	New Mara Bridge	11/3/2008	24.65	0.086	0.056	71.2	5.92	109.9
EFA 3	New Mara Bridge	11/12/2008	20.53	0.098	0.064	80.9	7.28	151
EFA 3	New Mara Bridge	12/3/2008	23.66	0.123	0.08	65.3	5.53	86.6
EFA 3	New Mara Bridge	12/23/2008	22.39	0.197	0.128	62.7	5.44	53.7
EFA 3	New Mara Bridge	1/11/2009	22.59	0.294	0.191	51.2	4.42	43.2
EFA 3	New Mara Bridge	1/30/2009	28.22	0.256	0.166	48.4	3.78	271
EFA 3	New Mara Bridge	2/12/2009	23.51	0.273	0.177	41.3	3.51	243
EFA 3	New Mara Bridge	2/24/2009	25.41	0.567	0.368	33.6	2.75	74.5
EFA 3	New Mara Bridge	3/7/2009	27.79	0.538	0.35	48.2	3.78	105.9
EFA 3	New Mara Bridge	3/15/2009	27.01	0.673	0.437	64.2	5.11	95.3
EFA 3	New Mara Bridge	5/4/2009	22.07	0.231	0.15	59	5.15	198
EFA 3	New Mara Bridge	5/17/2009	26.52	0.216	0.14	64.4	5.17	679
EFA 3	New Mara Bridge	6/2/2009	22.65	0.097	0.063	89.5	7.72	1329
EFA 3	New Mara Bridge	6/26/2009	22.16	0.244	0.158	55.7	4.85	56.4
EFA 3	New Mara Bridge	7/4/2009	23.04	0.333	0.216	79	6.76	54.7
EFA 3	New Mara Bridge	8/7/2009	23.41	0.377	0.245	33.5	2.85	34.9
Site F	Talek at Mara Simba	10/28/2008	24.03	0.228	0.148	53.3	4.48	423
Site F	Talek at Mara Simba	11/18/2008	25.67	0.314	0.204	65.7	5.36	
Site F	Talek at Mara Simba	12/23/2008	27.8	0.223	0.145	121.9	9.57	55.3
Site F	Talek at Mara Simba	1/10/2009	26.18	0.225	0.146	112.2	9.07	47.3
Site F	Talek at Mara Simba	2/12/2009	27.29	0.252	0.164	68.7	5.44	264
Site F	Talek at Mara Simba	3/8/2009	24.8	0.242	0.158	94.8	7.86	40.6
Site F	Talek at Mara Simba	3/14/2009	27.21	0.242	0.157	87	6.91	39.5

Site Name	Location	Date	Temp (ºC)	Specific Conductivity (mS/cm)	Total Dissolved Solids (mg/L)	Dissolved Oxygen (% saturation)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
Site F	Talek at Mara Simba	5/4/2009	23.77	0.171	0.111	59.8	5.06	586
Site F	Talek at Mara Simba	5/16/2009	25.47	0.162	0.105	73.2	5.99	830
Site F	Talek at Mara Simba	6/1/2009	24.82	0.163	0.106	65	5.38	674
Site F	Talek at Mara Simba	6/22/2009	22.71	0.219	0.142	54.1	4.66	106.9
Site F	Talek at Mara Simba	7/3/2009	23.08	0.19	0.124	61.8	5.29	298
Site F	Talek at Mara Simba	7/24/2009	25.24	0.241	0.156	86.1	7.08	
Site G	Talek U/S of Naibor Camp	9/12/2008	23.7	0.54	0.351	72.8	6.16	64.2
Site G	Talek U/S of Naibor Camp	9/25/2008						139
Site G	Talek U/S of Naibor Camp	10/8/2008						215
Site G	Talek U/S of Naibor Camp	10/27/2008	26.83	0.247	0.16	63.9	5.11	2511
Site G	Talek U/S of Naibor Camp	11/3/2008	27.43	0.48	0.312	43.5	3.44	275
Site G	Talek U/S of Naibor Camp	11/18/2008	28.35	0.356	0.231	63.3	4.92	
Site G	Talek U/S of Naibor Camp	12/2/2008	27.79	0.18	0.117	63.5	4.99	207
Site G	Talek U/S of Naibor Camp	12/23/2008	28.96	0.826	0.537	121.2	9.31	66
Site G	Talek U/S of Naibor Camp	1/10/2009	26.85	1.252	0.814	53.4	4.25	60.1
Site G	Talek U/S of Naibor Camp	1/31/2009	23.64	0.169	0.11	78.9	6.68	1093
Site G	Talek U/S of Naibor Camp	2/12/2009	25.8	0.352	0.229	64.9	5.28	310
Site G	Talek U/S of Naibor Camp	3/8/2009	22.15	1.105	0.718	49	4.26	50
Site G	Talek U/S of Naibor Camp	3/14/2009	28.39	1.162	0.755	51	3.95	71.3
Site G	Talek U/S of Naibor Camp	5/4/2009	24.48	0.304	0.197	70.9	5.91	269
Site G	Talek U/S of Naibor Camp	5/17/2009	22.77	0.252	0.164	75.9	6.54	983
Site G	Talek U/S of Naibor Camp	6/1/2009	24.25	0.105	0.068	85.3	7.14	882
Site G	Talek U/S of Naibor Camp	6/26/2009	27.9	0.799	0.519	83.7	6.55	32.5
Site G	Talek U/S of Naibor Camp	7/4/2009	20.08	0.83	0.539	5.8	0.53	59.2
Site G	Talek U/S of Naibor Camp	7/24/2009	26.43	0.888	0.577	32.9	2.64	
Site G	Talek U/S of Naibor Camp	8/6/2009	28.56	1.194	0.776	53.3	4.12	45.5

Laboratory Analyses

Site Name	Location	Date	Dissolved Organic Carbon (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Total Phosphorous (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Total Nitrogen (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (mg/L)
EFA 1	Kapkimolwa Bridge	8/20/2008	1.688	0.56	2.15	0.56	2.53	<0.05	0.03	< 0.05	1.0	2.0	0.5	2.5	5.6	4.3
EFA 1	Kapkimolwa Bridge	9/5/2008	2.526	0.49	1.98	0.67	1.46	<0.05	0.03	0.09	1.0	0.6	0.2	0.8	2.1	3.1
EFA 1	Kapkimolwa Bridge	9/28/2008	2.833	0.14	2.17	0.63	0.94		< 0.1	0.077		1.416	0.614	3.495	8.42	
EFA 1	Kapkimolwa Bridge	10/12/2008	1.112	0.45	2.08	1.03	1.78	<0.05	0.02	< 0.05	1.3	2.0	0.5	1.8	4.3	2.8
EFA 1	Kapkimolwa Bridge	10/28/2008	2.989	0.18	2.10	0.71	1.05		< 0.1	0.145		2.005	0.489	3.593	5.71	
EFA 1	Kapkimolwa Bridge	11/5/2008	1.831	0.39	2.01	0.76	1.57	<0.05	0.03	< 0.05	1.0	2.6	0.7	2.7	6.2	2.3
EFA 1	Kapkimolwa Bridge	11/16/2008	1.796	0.19	2.55	1.33	1.56		< 0.1	0.162		1.361	0.415	2.103	2.30	
EFA 1	Kapkimolwa Bridge	12/5/2008	1.344	0.55	4.51	0.96	3.33	<0.05	0.02	< 0.05	1.3	1.1	0.5	1.7	5	2.3
EFA 1	Kapkimolwa Bridge	12/20/2008	2.237	0.26	3.10	0.77	2.03		< 0.1	0.148		1.476	0.987	4.639	7.29	
EFA 1	Kapkimolwa Bridge	1/8/2009	3.215	0.62	4.44	0.85	3.89	<0.05	0.02	0.06	1.2	5.7	1.6	5.2	13.7	1.3
EFA 1	Kapkimolwa Bridge	1/28/2009	2.412	0.51	5.16	0.53	3.58		< 0.1	0.143		6.7	1.837	6.599	8.31	
EFA 1	Kapkimolwa Bridge	2/10/2009	5.639	1.40	5.47	1.24	5.45		< 0.1	0.149		8.353	1.631	11.57	12.93	
EFA 1	Kapkimolwa Bridge	2/21/2009	3.499	0.68	6.48	0.53	7.59		< 0.1	0.103		9.571	3.577	15.76	26.70	
EFA 1	Kapkimolwa Bridge	3/5/2009	4.073	0.93	8.90	0.54	10.33		< 0.1	0.116		10.428	4.106	16.264	35.09	
EFA 1	Kapkimolwa Bridge	3/17/2009	4.061	1.02	6.89	0.69	5.46		< 0.1	0.127		7.861	2.423	16.52	18.25	
EFA 1	Kapkimolwa Bridge	4/28/2009	2.226	0.71	7.03	2.30	6.87		< 0.1	0.485		2.087	0.48	2.111	10.53	
EFA 1	Kapkimolwa Bridge	5/11/2009	5.944	0.66	7.32	1.64	7.87		< 0.1	0.121		8.958	3.188	14.106	24.45	
EFA 1	Kapkimolwa Bridge	5/29/2009	4.4	0.42	3.35	1.49	2.71		< 0.1	0.197		3.974	0.98	5.883	8.85	
EFA 1	Kapkimolwa Bridge	6/23/2009	2.55	0.37	3.13	1.26	2.45		< 0.1	0.226		5.754	1.573	7.724	12.60	
EFA 1	Kapkimolwa Bridge	7/1/2009	3.95	0.56	4.84	1.67	4.43		< 0.1	0.101		4.763	1.521	8.475	10.76	
EFA 1	Kapkimolwa Bridge	7/12/2009	2.945	0.46	4.26	1.08	3.99		< 0.1	0.09		5.705	2.065	10.45	12.76	
EFA 1	Kapkimolwa Bridge	8/21/2009	3.859	0.40	3.79	0.63	2.88		< 0.1	0.191		5.066	1.84	9.683	9.35	
Site A	Mulot Bridge	8/28/2008	2.406	0.22	2.42	0.67	1.34		< 0.1	0.15		1.343	0.505	3.917	6.20	

Site Name	Location	Date	Dissolved Organic Carbon (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Total Phosphorous (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Total Nitrogen (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (mg/L)
Site A	Mulot Bridge	9/5/2008	1.248	0.55	2.79	0.49	1.94	<0.05	0.02	< 0.05	0.8	1.7	0.5	1.7	4.6	2.7
Site A	Mulot Bridge	9/27/2008	1.456	0.19	2.01	0.60	0.93		< 0.1	0.093		1.998	0.862	5.431	4.67	
Site A	Mulot Bridge	10/12/2008	1.497	0.42	2.08	0.97	1.60	<0.05	0.02	< 0.05	1.1	2.4	0.6	2.3	5.8	2.4
Site A	Mulot Bridge	10/28/2008	2.91	0.14	1.98	0.74	1.18		< 0.1	0.044		1.697	0.522	4.136	5.69	
Site A	Mulot Bridge	11/6/2008	1.826	0.47	2.63	0.74	1.81	<0.05	0.02	< 0.05	0.9	3.0	0.8	3.0	7.9	3.3
Site A	Mulot Bridge	11/16/2008	2.829	0.29	2.47	1.25	1.44		< 0.1	0.184		2.035	0.699	4.635	7.22	
Site A	Mulot Bridge	12/5/2008	1.234	0.59	2.78	1.07	2.14	<0.05	0.02	< 0.05	0.9	3.1	0.9	3.1	8.5	2.2
Site A	Mulot Bridge	12/20/2008	2.091	0.34	3.30	0.85	2.39		< 0.1	0.1		3.109	0.705	4.101	6.20	
Site A	Mulot Bridge	1/8/2009	3.985	0.63	6.84	0.77	5.35	<0.05	0.02	< 0.05	0.9	7.2	1.9	6.4	22	1.2
Site A	Mulot Bridge	1/28/2009	2.03	0.62	9.73	0.72	5.00		< 0.1	0.31		6.998	1.411	6.669	8.06	
Site A	Mulot Bridge	2/10/2009	4.556	1.19	11.79	0.93	7.42		< 0.1	0.607		10.94	2.435	12.9	25.10	
Site A	Mulot Bridge	3/5/2009	4.033	1.17	11.23	0.61	9.56		< 0.1	0.025		14.046	4.212	15.4	30.43	
Site A	Mulot Bridge	3/16/2009	3.524	1.63	8.53	0.28	7.67		< 0.1	0.243		13.628	3.508	16.568	22.66	
Site A	Mulot Bridge	4/28/2009	5.919	1.05	9.31	2.18	8.25		< 0.1	0.18		7.782	1.794	11.76	14.29	
Site A	Mulot Bridge	5/11/2009	5.654	0.75	7.82	1.38	7.09		< 0.1	0.142		10.486	2.806	10.87	19.64	
Site A	Mulot Bridge	5/29/2009	5.306	0.71	2.98	0.74	1.94		< 0.1	0.282		4.178	1.004	9.809	10.57	
Site A	Mulot Bridge	6/23/2009	3.387	0.60	5.90	2.20	4.69		< 0.1	0.087		6.926	1.927	9.858	15.13	
Site A	Mulot Bridge	7/1/2009	3.364	0.72	6.55	1.61	5.11		< 0.1	0.24		8.082	1.962	9.124	20.99	
Site A	Mulot Bridge	7/12/2009	2.944	0.61	6.57	1.38	5.23		< 0.1			8.376	2.549	10.48	20.56	
Site A	Mulot Bridge	8/19/2009	4.751	0.54	5.69	0.57	4.05		< 0.1	0.01		5.933	2.07	12.24	16.79	
EFA 1.2	Silibwet Bridge	8/20/2008	1.602	0.09	1.90	0.44	0.90		< 0.1	0.036		1.025	0.298	2.058	3.29	
EFA 1.2	Silibwet Bridge	9/6/2008	0.610	0.36	1.76	0.57	1.31	<0.05	< 0.02	< 0.05	0.6	0.5	0.2	0.7	1.8	2.5
EFA 1.2	Silibwet Bridge	9/27/2008	1.858	0.10	1.61	0.57	0.78		< 0.1	0.119		1.153	0.367	3.135	4.04	
EFA 1.2	Silibwet Bridge	10/12/2008	1.060	0.43	2.12	0.82	1.59	<0.05	< 0.02	< 0.05	0.9	1.4	0.4	1.7	4.2	2.0
EFA 1.2	Silibwet Bridge	10/28/2008	1.933	0.10	2.09	0.55	0.99		< 0.1	0.203		1.737	0.467	2.702	4.02	

Site Name	Location	Date	Dissolved Organic Carbon (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Total Phosphorous (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Total Nitrogen (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (mg/L)
EFA 1.2	Silibwet Bridge	11/6/2008	1.357	0.45	1.78	0.71	1.18	<0.05	< 0.02	< 0.05	0.8	1.8	0.5	2.1	4.6	2.9
EFA 1.2	Silibwet Bridge	11/17/2008	1.401	0.12	1.78	0.86	0.60		< 0.1	0.004		0.993	0.273	1.447	2.00	
EFA 1.2	Silibwet Bridge	12/4/2008	1.788	0.41	1.72	0.75	1.25	<0.05	< 0.02	0.05	0.9	1.8	0.5	2.3	5	1.7
EFA 1.2	Silibwet Bridge	12/20/2008	1.58	0.23	1.64	0.51	0.60		< 0.1	0.011		1.539	0.439	2.651	3.78	
EFA 1.2	Silibwet Bridge	1/8/2009	2.223	0.47	1.99	0.61	1.28	<0.05	< 0.02	0.05	0.6	2.4	0.7	2.9	6.4	1.0
EFA 1.2	Silibwet Bridge	1/28/2009	2.932	0.26	3.29	0.57	1.38		< 0.1	0.161		2.103	0.805	6.397	5.06	
EFA 1.2	Silibwet Bridge	2/10/2009	2.366	0.26	2.72	0.39	0.97		< 0.1	0.073		2.785	1.008	5.925	7.37	
EFA 1.2	Silibwet Bridge	2/22/2009	2.709	0.32	2.60	0.18	0.81		< 0.1	0.051		2.494	0.858	6.736	8.23	
EFA 1.2	Silibwet Bridge	3/5/2009	2.904	0.33	2.67	0.21	0.84		< 0.1	0.201		2.727	0.859	6.608	8.82	
EFA 1.2	Silibwet Bridge	3/17/2009	3.265	0.24	2.62	0.27	0.79		< 0.1	0.1		3.427	1.186	8.081	8.59	
EFA 1.2	Silibwet Bridge	4/27/2009	3.391	0.30	2.75	2.23	1.37		< 0.1	0.23		4.068	1.245	6.65	7.60	
EFA 1.2	Silibwet Bridge	5/14/2009	3.308	0.27	2.75	2.26	1.42		< 0.1	0.192		2.938	0.824	4.664	6.62	
EFA 1.2	Silibwet Bridge	5/30/2009	2.082	0.22	2.45	1.83	1.71		< 0.1	0.165		1.733	0.532	4.738	5.59	
EFA 1.2	Silibwet Bridge	6/23/2009	1.461	0.21	2.13	1.16	0.98		< 0.1	0.113		1.833	0.442	2.961	4.91	
EFA 1.2	Silibwet Bridge	7/2/2009	3.29	0.22	2.01	0.58	0.99		< 0.1	0.223		2.569	0.727	3.94	6.32	
EFA 1.2	Silibwet Bridge	7/19/2009	2.363	0.21	2.15	0.52	0.94		< 0.1	0.162		1.977	0.34	3.168	6.12	
EFA 1.2	Silibwet Bridge	8/22/2009	5.029	0.13	1.68	0.24	0.90		< 0.1	0.261		1.883	0.468	3.349	4.32	
Site B	Bomet Bridge	8/20/2008	1.857	0.13	1.95	0.51	1.01		< 0.1	0.139		1.216	0.254	1.993	3.37	
Site B	Bomet Bridge	9/6/2008	1.459	0.09	1.64	0.45	0.87		< 0.1	0.077		1.895	0.32	1.476	1.82	
Site B	Bomet Bridge	9/27/2008	1.365	0.09	1.77	0.55	0.77		< 0.1	0.093		1.49	0.257	1.923	2.44	
Site B	Bomet Bridge	10/12/2008	0.900	0.46	2.05	0.82	1.72	<0.05	0.03	< 0.05	1.7	0.7	0.6	2.2	4.7	3.1
Site B	Bomet Bridge	10/28/2008	0.893	0.11	1.70	0.54	0.95		< 0.1	0.062		0.118	-0.099	0.458	-0.34	
Site B	Bomet Bridge	11/6/2008	1.422	0.35	1.46	0.63	1.04	<0.05	0.03	0.09	1.5	1.7	0.5	2.4	4.4	3.0
Site B	Bomet Bridge	11/17/2008	2.178	0.16	2.45	1.46	1.27		< 0.1	0.255		2.101	0.634	3.162	6.82	
Site B	Bomet Bridge	12/5/2008	1.242	0.50	2.65	0.82	2.53	<0.05	0.03	< 0.05	1.6	1.6	0.3	1.4	3.1	2.9

Site Name	Location	Date	Dissolved Organic Carbon (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Total Phosphorous (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Total Nitrogen (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (mg/L)
Site B	Bomet Bridge	12/20/2008		0.18	3.22	0.59	0.94		< 0.1	0.082		0.411	0.024	1.033	0.87	
Site B	Bomet Bridge	1/8/2009	2.291	0.49	2.06	0.61	1.18	<0.05	0.06	< 0.05	1.6	2.7	0.8	3.7	6.8	1.4
Site B	Bomet Bridge	1/28/2009	3.276	0.23	3.81	0.54	1.36		< 0.1	0.478		2.914	0.818	5.27	6.14	
Site B	Bomet Bridge	2/10/2009		0.27	3.61	0.44	1.12		< 0.1	0.077		3.615	1.136	5.462	6.98	
Site B	Bomet Bridge	3/5/2009		0.33	2.82	0.20	1.09		< 0.1	0.145		3.539	1.053	6.626	8.20	
Site B	Bomet Bridge	3/17/2009	3.483	0.38	3.42	0.35	1.36		< 0.1	0.131		4.238	0.941	6.74	9.36	
Site B	Bomet Bridge	4/27/2009	5.22	0.39	3.47	2.96	2.28		< 0.1	0.274		3.419	0.872	5.578	14.29	
Site B	Bomet Bridge	5/11/2009	2.43	0.30	3.09	2.64	1.46		< 0.1	0.105		2.809	0.79	4.912	8.14	
Site B	Bomet Bridge	5/30/2009	2.388	0.24	2.48	2.03	1.94		< 0.1	0.193		1.79	0.58	4.908	6.95	
Site B	Bomet Bridge	6/23/2009	2.083	0.20	2.03	0.92	1.04		< 0.1	0.092		2.119	0.406	3.107	4.88	
Site B	Bomet Bridge	7/2/2009	2.826	0.22	2.14	0.92	1.36		< 0.1	0.098		2.625	0.861	5.22	6.76	
Site B	Bomet Bridge	7/19/2009	2.154	0.23	2.51	0.68	1.29		< 0.1	0.17		2.612	0.764	5.16	6.87	
Site B	Bomet Bridge	8/22/2009	3.079	0.15	1.95	0.40	1.05		< 0.1	0.164		1.811	0.538	4.471	5.39	
EFA 2	Ngerende	8/25/2008	1.898	0.55	2.96	0.59	2.85	<0.05	0.02	< 0.05	1.1	2.1	0.4	2.2	6.2	5.0
EFA 2	Ngerende	9/9/2008	1.517	0.61	3.64	0.62	3.87	<0.05	0.02	< 0.05	0.9	3.0	0.6	2.6	7.5	6.6
EFA 2	Ngerende	9/27/2008	1.575	0.16	2.97	0.64	2.47		< 0.1	0.148		2.644	0.585	2.963	5.33	
EFA 2	Ngerende	10/10/2008	0.871	0.76	4.29	0.95	3.73	<0.05	0.02	< 0.05	1.3	0.8	0.4	1.7	4.7	4.8
EFA 2	Ngerende	10/26/2008	2.598	0.33	3.97	0.55	3.26		< 0.1	0.152		3.217	0.593	4.516	8.70	
EFA 2	Ngerende	11/5/2008	1.519	0.53	3.80	0.70	3.41	<0.05	0.03	< 0.05	0.9	3.1	0.7	2.8	8.4	3.0
EFA 2	Ngerende	11/18/2008	2.733	0.26	3.57	1.35	2.85		< 0.1	0.143		3.019	0.413	3.651	8.63	
EFA 2	Ngerende	12/4/2008	1.329	0.81	11.3	0.83	8.24	<0.05	0.04	< 0.05	1.2	1.9	0.3	1.3	4.8	3.9
EFA 2	Ngerende	12/21/2008	1.653	0.31	4.28	0.29	4.12		< 0.1	0.096		3.678	0.556	1.949	5.54	
EFA 2	Ngerende	1/12/2009	2.780	0.66	16.4	0.63	16.8	<0.05	0.02	< 0.05	1.0	8.8	1.9	5.8	28	1.6
EFA 2	Ngerende	1/29/2009	3.907	1.07	14.41	0.51	15.91		< 0.1	0.174		9.964	2.144	8.558	30.09	
EFA 2	Ngerende	2/11/2009	4.042	1.19	14.12	0.59	15.21		< 0.1	0.081		11.03	2.52	11.85	33.29	

Site Name	Location	Date	Dissolved Organic Carbon (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Total Phosphorous (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Total Nitrogen (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (mg/L)
EFA 2	Ngerende	2/23/2009	4.479	1.02	30.22	0.33	32.67		< 0.1	0.076		14.46	3.85	16.702	55.74	
EFA 2	Ngerende	3/7/2009	3.824	1.42	36.39	0.26	38.76		< 0.1	0.158		15.96	4.418	19.812	63.24	
EFA 2	Ngerende	3/16/2009		1.37	47.03	0.22	n.d.		< 0.1							
EFA 2	Ngerende	5/2/2009	4.718	0.63	8.94	2.43	8.91		< 0.1	0.111		6.733	1.303	8.903	19.06	
EFA 2	Ngerende	5/19/2009	7.194	0.84	4.35	1.24	3.67		< 0.1	0.21		3.934	0.518	6.625	10.38	
EFA 2	Ngerende	6/3/2009	4.824	0.61	4.51	0.95	4.72		< 0.1	0.208		4.907	0.936	8.633	11.97	
EFA 2	Ngerende	6/25/2009	3.671	0.62	13.48	1.14	14.91		< 0.1	1.491		2.752	0.276	1.096	28.57	
EFA 2	Ngerende	7/5/2009	4.036	0.69	15.49	1.01	17.19		< 0.1	0.125		8.371	2.049	10.8	25.96	
EFA 2	Ngerende	7/20/2009	3.107	0.78	17.93	0.49	20.50		< 0.1	0.101		11.022	2.604	8.874	33.40	
EFA 2	Ngerende	8/8/2009	5.251	0.61	14.59	0.37	15.76		< 0.1	0.243		10.11	2.115	9.323	27.44	
Site C	Old Mara Bridge	8/23/2008	1.934	0.62	2.88	0.54	2.70	<0.05	0.02	< 0.05	0.5	3.1	0.6	3.3	8.1	7.0
Site C	Old Mara Bridge	9/10/2008	5.074	0.56	3.78	0.58	3.69	<0.05	0.03	0.25	1.2	3.6	0.7	3.1	8.9	15.9
Site C	Old Mara Bridge	10/10/2008	0.888	0.58	3.37	1.08	2.83	<0.05	< 0.02	< 0.05	1.4	1.2	0.2	1.3	3.4	5.9
Site C	Old Mara Bridge	10/27/2008	1.609	0.40	4.22	0.54	3.59		< 0.1	0.063		0.786	0.191	1.646	2.40	
Site C	Old Mara Bridge	11/4/2008	1.064	0.60	2.81	0.58	2.69	<0.05	< 0.02	< 0.05	0.9	1.2	0.3	1.1	3.8	3.9
Site C	Old Mara Bridge	11/17/2008	2.32	0.38	3.72	1.45	3.04		< 0.1	0.187		1.58	0.539	4.533	7.43	
Site C	Old Mara Bridge	12/3/2008	2.029	0.81	5.86	1.03	8.35	<0.05	0.03	0.05	1.3	4.4	0.8	3.6	12.4	4.5
Site C	Old Mara Bridge	12/22/2008	3.335	0.46	8.35	0.65	8.44		< 0.1	0.18		3.374	1.359	7.948	17.39	
Site C	Old Mara Bridge	1/11/2009	4.449	0.61	15.8	0.40	16.3	<0.05	0.03	< 0.05	1.1	11.2	2.3	7.2	33	1.6
Site C	Old Mara Bridge	1/30/2009	2.724	1.07	13.16	0.48	14.65		< 0.1	0.567		6.458	1.084	6.777	9.10	
Site C	Old Mara Bridge	2/11/2009	5.227	1.28	17.88	0.79	18.00		< 0.1	0.112		11.772	2.196	9.96	30.12	
Site C	Old Mara Bridge	3/7/2009	5.851	1.58	40.33	0.38	36.31		< 0.1	0.15		20.952	4.38	32.804	62.84	
Site C	Old Mara Bridge	3/15/2009	6.446	1.64	41.14	0.43	36.94		< 0.1	0.15		19.96	5.04	23.552	67.98	
Site C	Old Mara Bridge	5/3/2009		0.89	12.41	2.46	13.35		< 0.1			7.158	0.922	6.616		
Site C	Old Mara Bridge	5/17/2009	2.448	0.61	4.33	1.27	3.46		< 0.1	0.168		4.241	0.571	5.793	9.58	

Site Name	Location	Date	Dissolved Organic Carbon (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Total Phosphorous (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Total Nitrogen (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (mg/L)
Site C	Old Mara Bridge	5/18/2009	4.67	0.82	6.36	1.09	6.61		< 0.1	0.216		3.771	0.643	6.24	10.11	
Site C	Old Mara Bridge	6/3/2009	4.305	0.77	5.34	1.38	5.10		< 0.1	0.209		4.309	0.48	4.629	9.43	
Site C	Old Mara Bridge	6/25/2009	4.061	0.68	13.34	1.28	14.63		< 0.1	0.322		8.606	1.576	8.653	24.89	
Site C	Old Mara Bridge	7/5/2009	2.291	0.81	16.37	1.05	16.95		< 0.1	0.243		9.187	1.368	6.173	13.27	
Site C	Old Mara Bridge	7/23/2009	4.616	0.89	18.11	0.27	18.68		< 0.1	0.288		10.54	2.316	9.922	32.08	
Site C	Old Mara Bridge	8/7/2009	5.96	0.85	22.44	0.22	23.25		< 0.1	0.486		10.336	2.878	15.438	37.96	
Site D	Governor's Oxbow	8/23/2008	1.350	0.66	3.11	0.63	3.08	<0.05	0.03	< 0.05	1.5	1.9	0.3	1.5	4.3	8.3
Site D	Governor's Oxbow	9/10/2008	1.588	0.67	3.43	0.66	3.16	<0.05	0.04	< 0.05	1.5	2.5	0.4	2.3	6.1	12.6
Site D	Governor's Oxbow	9/26/2008	1.848	0.23	2.95	0.61	2.55		< 0.1	0.161		1.783	0.349	2.458	3.81	
Site D	Governor's Oxbow	10/11/2008		0.50	2.91	1.05	2.88	<0.05	0.04	< 0.05	1.6	1.5	0.3	1.7	4.2	7.8
Site D	Governor's Oxbow	10/27/2008	2.918	0.43	5.03	0.59	4.22		< 0.1	0.116		3.082	0.63	5.349	9.55	
Site D	Governor's Oxbow	11/4/2008	2.401	0.58	3.32	0.84	3.49	<0.05	0.04	0.10	1.4	1.1	0.2	1.1	3.4	5.5
Site D	Governor's Oxbow	11/11/2008	5.092	0.79	6.10	0.73	3.88		< 0.1	0.147		3.532	0.678	7.924	9.28	
Site D	Governor's Oxbow	11/17/2008	3.383	0.36	5.27	1.24	2.69		< 0.1	0.093		3.006	0.466	4.173	6.53	
Site D	Governor's Oxbow	12/3/2008	1.967	0.71	5.48	1.06	6.24	<0.05	0.06	< 0.05	1.9	3.4	0.6	2.7	8.8	19.2
Site D	Governor's Oxbow	12/22/2008	3.126	0.39	5.17	0.25	4.99		< 0.1	0.15		5.466	1.371	7.671	15.36	
Site D	Governor's Oxbow	1/11/2009	6.331	0.73	16.3	0.07	2.09	0.19	0.02	< 0.05	3.0	21	3.0	5.9	24	7.8
Site D	Governor's Oxbow	1/29/2009	3.395	1.02	13.75	0.29	15.52		< 0.1	0.257		8.393	1.857	12.11	27.79	
Site D	Governor's Oxbow	2/11/2009	5.594	1.37	5.40	-0.03	5.35		< 0.1	0.197		7.302	1.389	8.66	11.93	
Site D	Governor's Oxbow	3/7/2009	10.7	1.70	30.97	n.d.	15.00		< 0.1	0.21		24.84	5.32	18.64	53.61	
Site D	Governor's Oxbow	3/15/2009	9.307	1.93	50.21	n.d.	n.d.		< 0.1	0.463		22.384	4.968	24.864	76.45	
Site D	Governor's Oxbow	5/3/2009	5.539	1.03	11.31	1.77	11.41		< 0.1	0.198		8.534	1.738	14.15	18.64	
Site D	Governor's Oxbow	5/19/2009	4.416	1.05	6.77	1.65	6.72		< 0.1	0.283		5.166	0.849	8.456	17.61	
Site D	Governor's Oxbow	6/25/2009	6.936	1.01	12.76	n.d.	9.55		< 0.1	0.094		17.756	3.326	13.244	32.52	
Site D	Governor's Oxbow	7/5/2009	3.066	0.91	15.85	n.d.	6.42		< 0.1	0.405		18.364	2.076	6.3	12.21	

Site Name	Location	Date	Dissolved Organic Carbon (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Total Phosphorous (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Total Nitrogen (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (mg/L)
Site D	Governor's Oxbow	7/22/2009	10.92	1.17	17.21	n.d.	5.14		< 0.1	0.163		36.82	8.96	19.06	57.96	
Site D	Governor's Oxbow	8/8/2009	10.06	2.15	12.39	n.d.	19.12		< 0.1	1.851		20.196	6.532	20.58	74.31	
Site E	Mara at the Talek Confluence	8/22/2008		0.74	3.72	0.77	3.96	<0.05	0.03	< 0.05	1.6	3.4	0.5	3.3	6	11.5
Site E	Mara at the Talek Confluence	9/12/2008	2.253	0.88	3.47	0.66	4.00	<0.05	< 0.02	0.06	3.1	3.1	0.5	3.1	9.3	55
Site E	Mara at the Talek Confluence	9/25/2008	2.464	0.28	3.26	0.75	3.06		< 0.1	0.185		2.985	0.543	4.684	7.86	
Site E	Mara at the Talek Confluence	10/8/2008	2.381	0.79	3.48	0.90	3.53	<0.05	0.03	< 0.05	2.0	3.3	0.5	2.8	7.3	17.7
Site E	Mara at the Talek Confluence	10/27/2008	2.657	0.64	4.77	0.64	6.78		< 0.1	-0.004		3.891	0.395	2.967	6.01	
Site E	Mara at the Talek Confluence	11/3/2008	1.344	0.60	2.94	0.67	45.2	<0.05	0.04	< 0.05	1.5	1.5	0.3	1.5	4.2	10.6
Site E	Mara at the Talek Confluence	11/18/2008	2.487	0.44	4.30	1.35	4.57		< 0.1	0.171		2.537	0.409	3.25	5.70	
Site E	Mara at the Talek Confluence	12/2/2008	0.843	0.64	7.58	0.96	7.58	<0.05	0.04	< 0.05	2.2	2.6	0.1	0.9	2.2	9.4
Site E	Mara at the Talek Confluence	12/23/2008	3.192							0.076		7.704	1.229	5.256	12.32	
Site E	Mara at the Talek Confluence	1/10/2009	5.213	0.81	23.2	0.34	27.9	<0.05	< 0.02	< 0.05	2.1	16.1	2.9	9.7	40	3.3
Site E	Mara at the Talek Confluence	1/31/2009	3.131	0.98	9.19	0.23	14.40		< 0.1			5.157	0.741	6.401	8.80	
Site E	Mara at the Talek Confluence	2/12/2009	6.021	1.42	15.90	0.77	29.85		< 0.1	2.51		14.23	2.758	14.728	42.26	
Site E	Mara at the Talek Confluence	3/8/2009	9.258	1.60	30.07	0.13	29.77		< 0.1	1.989		19.232	5.48	30.264	50.43	
Site E	Mara at the Talek Confluence	3/14/2009	10.22	1.90	52.16	0.23	42.63		< 0.1	0.405		24.208	5.96	32.048	78.33	
Site E	Mara at the Talek Confluence	5/4/2009	7.882	1.00	10.57	1.48	16.35		< 0.1	0.312		9.748	1.775	15.53	20.69	
Site E	Mara at the Talek Confluence	5/17/2009	5.269	1.30	11.45	0.96	20.96		< 0.1	-0.081		8.693	1.537	14.45	27.87	
Site E	Mara at the Talek Confluence	6/1/2009	7.601	0.89	4.12	0.19	7.91		< 0.1	0.318		5.77	0.771	7.032	10.19	
Site E	Mara at the Talek Confluence	6/26/2009	2.891	0.80	17.51	1.09	18.93		< 0.1	0.131		11.808	1.234	6.04	9.85	
Site E	Mara at the Talek Confluence	7/4/2009	5.9	0.97	24.15	0.84	n.d.		< 0.1	0.353		18.772	3.968	13.984	44.53	
Site E	Mara at the Talek Confluence	7/24/2009		1.13	29.26	0.05	n.d.		< 0.1			20.064	4.54	14.928		
EFA 3	New Mara Bridge	8/23/2008	1.507	0.77	4.28	0.78	4.20	<0.05	0.03	< 0.05	1.3	2.9	0.4	2.2	6	9.2
EFA 3	New Mara Bridge	9/11/2008	1.443	1.01	4.23	0.82	4.52	<0.05	0.04	< 0.05	1.5	4.2	0.4	1.8	5.2	12.8
EFA 3	New Mara Bridge	9/25/2008	2.705	0.35	3.05	0.65	2.97		< 0.1	0.25		1.788	0.308	2.87	3.99	

Site Name	Location	Date	Dissolved Organic Carbon (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Total Phosphorous (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Total Nitrogen (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (mg/L)
EFA 3	New Mara Bridge	10/8/2008	2.039	0.65	3.39	0.88	3.40	<0.05	0.02	< 0.05	1.7	3.0	0.5	2.5	6.2	15.0
EFA 3	New Mara Bridge	10/27/2008	2.84	0.70	5.22	0.68	6.30		< 0.1	0.291		2.23	0.32	4.353	6.79	
EFA 3	New Mara Bridge	11/3/2008	1.385	3.14	7.88	0.97	10.5	<0.05	0.03	< 0.05	1.6	2.0	0.3	1.6	4.4	7.3
EFA 3	New Mara Bridge	11/11/2008	6.267	0.99	4.66	0.74	4.79		< 0.1	0.022		3.983	0.809	8.119	9.76	
EFA 3	New Mara Bridge	11/18/2008	3.192	0.53	4.80	1.63	4.44		< 0.1	0.143		3.223	0.595	4.505	7.46	
EFA 3	New Mara Bridge	12/3/2008	2.429						0.05	< 0.05		5.3	0.6	2.8	7.7	
EFA 3	New Mara Bridge	12/23/2008	3.136	0.59	9.26	0.58	8.99		< 0.1	0.15		7.196	1.783	10.53	14.34	
EFA 3	New Mara Bridge	1/11/2009	4.619	0.73	18.7	0.17	16.1	0.08	0.02	< 0.05	1.7	11.1	1.2	4.1	13.6	2.9
EFA 3	New Mara Bridge	1/30/2009	4.976	0.98	13.12	0.33	15.13		< 0.1	0.562		9.77	1.804	12.14	24.86	
EFA 3	New Mara Bridge	2/12/2009	5.912	1.28	13.41	0.97	20.94		< 0.1	0.559		14.786	2.62	11.702	26.39	
EFA 3	New Mara Bridge	2/24/2009	10.86	1.51	35.99	-0.04	31.94		< 0.1	0.135		24.912	5.976	28.368	55.65	
EFA 3	New Mara Bridge	3/7/2009	10.15							0.152		20.756	5.592	30.572	56.73	
EFA 3	New Mara Bridge	3/15/2009	5.068	0.67	10.52	0.21	9.24		< 0.1	0.36		5.617	0.966	9.145	17.37	
EFA 3	New Mara Bridge	5/4/2009	5.557	0.98	11.04	2.21	12.68		< 0.1	0.27		10.164	1.8	11.256	23.09	
EFA 3	New Mara Bridge	5/17/2009	5.616	1.19	8.90	0.94	12.64		< 0.1	0.257		7.672	1.361	13.73	23.37	
EFA 3	New Mara Bridge	6/2/2009	2.749	0.71	3.66	0.63	5.31		< 0.1	0.324		2.169	0.184	2.978	8.96	
EFA 3	New Mara Bridge	6/26/2009	5.798	0.74	15.23	1.17	470.31		0.307	0.069		7.988	2.314	13.93	28.12	
EFA 3	New Mara Bridge	7/4/2009	5.428	0.98	20.12	0.76	23.46		< 0.1	0.111		12.566	2.766	16.38	31.77	
EFA 3	New Mara Bridge	7/24/2009	7.586	0.90	19.68	n.d.	20.18		< 0.1	0.278		20.308	4.42	15.232	48.21	
EFA 3	New Mara Bridge	8/7/2009	8.586	1.07	22.18	-0.04	16.99		< 0.1	0.114		15.974	3.7	18.324	45.92	
Site F	Talek at Mara Simba	10/28/2008	4.964	1.34	7.80	0.36	8.64		< 0.1	0.377		12.12	1.524	8.412	17.40	
Site F	Talek at Mara Simba	11/18/2008	5.652							0.063		15.318	2.112	12.754	30.78	
Site F	Talek at Mara Simba	11/18/2008		1.65	16.6	0.45	25.7	<0.05	0.05		1.2					14.9
Site F	Talek at Mara Simba	12/23/2008	3.097	0.80	13.0	0.12	14.0	<0.05	0.02	0.05	0.5	13.2	2.0	4.2	14.2	3.0
Site F	Talek at Mara Simba	1/10/2009	3.869	0.66	12.0	0.16	5.27	<0.05	< 0.02	< 0.05	0.9	11.1	2.4	5.2	16.1	3.2

Site Name	Location	Date	Dissolved Organic Carbon (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Total Phosphorous (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Total Nitrogen (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (mg/L)
Site F	Talek at Mara Simba	2/12/2009	5.412	1.27	8.62	0.20	11.49		< 0.1	0.283		13.9	2.304	10.252	26.24	
Site F	Talek at Mara Simba	3/8/2009	3.848	0.76	12.55	0.02	5.87		< 0.1	0.137		12.906	2.88	10.236	20.50	
Site F	Talek at Mara Simba	3/14/2009	4.374	0.75	14.53	0.02	5.28		< 0.1	0.283		12.468	3.352	12.112	33.06	
Site F	Talek at Mara Simba	5/4/2009	6.392	0.87	7.87	0.47	5.38		< 0.1	0.283		10.52	2.218	11.87	9.27	
Site F	Talek at Mara Simba	5/16/2009	3.441	1.28	5.74	0.36	5.78		< 0.1	0.24		10.608	1.238	5.756	3.91	
Site F	Talek at Mara Simba	6/1/2009	5.629	0.85	5.75	0.35	5.97		< 0.1	0.394		7.573	1.512	11.84	14.49	
Site F	Talek at Mara Simba	6/22/2009	4.586	0.87	11.87	0.24	6.30		< 0.1	0.36		12.588	3.048	8.96	18.11	
Site F	Talek at Mara Simba	6/26/2009	3.954	0.78	9.52	0.17	4.58		< 0.1	0.364		11.492	3	11.172	17.13	
Site F	Talek at Mara Simba	7/3/2009	3.672	0.71	8.52	0.39	5.45		< 0.1	0.415		8.154	1.603	10.34	7.60	
Site F	Talek at Mara Simba	7/24/2009	4.52	0.78	11.49	0.44	7.09		< 0.1	0.377		14.112	2.822	9.37	17.69	
Site F	Talek at Mara Simba	8/6/2009	3.899	0.74	10.48	0.34	5.32		< 0.1	0.275		10.85	2.952	12.528	10.55	
Site G	Talek U/S of Naibor Camp	9/12/2008		0.84	34.9	0.19	36.0	0.12	< 0.02	1.56	4.7	29	2.2	5.5	27	3.6
Site G	Talek U/S of Naibor Camp	9/25/2008	10.02	1.30	33.28	0.01	78.57		< 0.1	0.283		37.815	6.73	20.355	73.71	
Site G	Talek U/S of Naibor Camp	10/8/2008		4.01	21.7	0.39	30.8	<0.05	< 0.02	0.25	2.2	24	3.6	10.2	43	14.9
Site G	Talek U/S of Naibor Camp	10/27/2008	5.768	1.99	7.89	0.42	20.35		< 0.1	3.239		10.15	1.332	8.96	24.13	
Site G	Talek U/S of Naibor Camp	11/3/2008		1.10	21.0	0.21	45.6	0.14	< 0.02	1.25	4.2	29	3.9	12.2	41	15.9
Site G	Talek U/S of Naibor Camp	11/18/2008	4.569	1.39	14.03	0.39	27.75		< 0.1	0.729		18.2	1.824	5.148	13.04	
Site G	Talek U/S of Naibor Camp	12/2/2008	4.795	0.75	7.16	0.42	13.1	<0.05	0.03	0.05	1.4	13.1	1.4	5.2	11	14.4
Site G	Talek U/S of Naibor Camp	12/23/2008	13.64	1.38	49.78	0.03	61.89		< 0.1	0.899		40.58	8.76	32.38	74.23	
Site G	Talek U/S of Naibor Camp	1/10/2009		2.26	96.9	0.28	0.59	0.94	0.37	0.57	6.4	18.2	3.1	9.9	54	4.0
Site G	Talek U/S of Naibor Camp	1/31/2009	4.656	0.99	7.51	0.23	14.41		< 0.1	0.567		7.495	1.62	14.28	15.67	
Site G	Talek U/S of Naibor Camp	2/12/2009	6.314	1.35	16.00	0.36	38.19		< 0.1	0.868		18.52	2.664	12.844	37.05	
Site G	Talek U/S of Naibor Camp	3/8/2009	16.37	1.82	67.78	n.d.	79.32		< 0.1	0.972		52.22	11.84	38.82	111.83	
Site G	Talek U/S of Naibor Camp	3/14/2009	18.07	2.04	78.40	n.d.	79.26		0.264	0.81		45.18	12.7	60.23	115.27	
Site G	Talek U/S of Naibor Camp	5/4/2009		1.38	11.54	0.30	26.73		< 0.1							

Site Name	Location	Date	Dissolved Organic Carbon (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Total Phosphorous (mg/L)	Phosphate (mg/L)	Ammonium (mg/L)	Total Nitrogen (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Iron (mg/L)
Site G	Talek U/S of Naibor Camp	5/17/2009	5.781	1.39	8.36	0.34	39.47		< 0.1	0.302		9.71	1.411	12.3	22.76	
Site G	Talek U/S of Naibor Camp	6/1/2009	7.559	0.99	4.28	0.10	5.60		< 0.1	0.334		4.701	0.64	9.136	8.52	
Site G	Talek U/S of Naibor Camp	6/26/2009	15.25	1.03	34.30	n.d.	47.12		< 0.1	3.635		44.64	10.04	34.66	80.14	
Site G	Talek U/S of Naibor Camp	7/4/2009	16.58	1.28	41.54	n.d.	49.69		< 0.1	1.134		39.144	8.844	40.92	80.63	
Site G	Talek U/S of Naibor Camp	7/24/2009	15.62	1.44	57.94	-0.03	62.87		< 0.1	0.567		50.82	9.9	26.28	87.41	
Site G	Talek U/S of Naibor Camp	8/6/2009	19.89	1.73	81.26	n.d.	84.07		< 0.1			57.03	13.24	42.2	135.40	