Project: Protected Area Watch for the Albertine (PAWAR)

Report to NASA 2010
(No Cost extension)

Nadine T. Laporte (P.I.)
Woods Hole Research Center (WHRC)
149 Woods Hole Road
Falmouth, MA 02540-1644 USA
Phone: (508) 540-9900 x114
Fax: (508) 540-9700
E-mail: nlaporte@whrc.org
www.whrc.org

WHRC team: Wayne Walker, Jared Stabach, Greg Fiske, Alessandro Baccini, Adam Bausch

We want to thank all our collaborators for their help making this project a success, especially Andy Plumptre and Grace Nagendo at the Wildlife Conservation Society, Aggrey Rweitsiba at the Uganda Wildlife Authority, Lilian Pintea at the Jane Goodall Institute in Washington, DC, the staff of the National Forest Authority in Uganda, and the Ministry of Environment, Nature Conservation and Tourism (MECNT) in the DRC.

Table of contents

1. Short overall assessment of the project

Several government agencies and NGOs are in the process of developing a strategy for the conservation of biodiversity in the Albertine Rift region. Remote sensing technology has been recognized for its value in characterizing and monitoring wildlife habitats, and as an important decision support tool.

In response to this strategic request, the **P**rotected **A**rea **W**atch for the **A**lbertine **R**ift (PAWAR) project was developed under the NASA application program. This project is a contribution to the ongoing national, regional and global efforts to better manage and conserve biodiversity by focusing on the integration of remote sensing information in decision systems for one the most diverse and endangered hotspots on earth, the Albertine Rift. Most of the region is predominantly poor, dominated by rural communities depending on agricultural production, with 35% to 86% of households living below $1 per day. Throughout the region approximately 80% of GDP is derived from agriculture. The Albertine Rift region (southwest Uganda, Rwanda, and Burundi and the adjacent areas of DRC) contains some of the highest human population densities in Africa, with up to 700 people per km^2.

In Uganda, the project has succeeded in increasing the overall use of NASA/remote sensing derived products and their integration within existing information systems such as the MIST[1]. Our main government partner in Uganda, the Uganda Wildlife Authority (UWA), has requested that we extend the PAWAR project to include all protected areas throughout the country. The National Forest Authority has requested that we assist them with the development of their national strategic plan for a Reduction of Emissions from Deforestation and Degradation (REDD), and a MOU has been signed between the WHRC and the NFA in 2009. We have also been able to show that remote sensing could be used effectively to assess the impact of conservation policies; for example, changes in the savanna/forest cover dynamics and biodiversity in Kibale National Park, Uganda (Laporte et al., 2008). Also, we tested new modeling techniques in collaboration with Wildlife Conservation Society (WCS) and UWA to assist with the conservation and management of an endangered bird species, the Grey Crowned-crane (*Balearica regulorum gibbericeps*) (Stabach et al., 2009). These results coincided at the international level with the crane's reassessment for the 2009 IUCN Red List for birds. Furthermore, those habitat-modeling approaches can now be applied to other species of concern. We also assisted in several international initiatives, such as the **G**reat **A**pes **S**urvival **P**roject (GRASP) with our NASA derived remote sensing products, and results were presented by IUCN at the 2007 UNFCC Conference of the Parties (COP 13) in Bali. In the Republic of Congo, remote sensing derived habitat maps were also used successfully to compare great ape densities, habitat composition and population dynamics (Devos et al., 2007) in two regions, the Odzala and Nouabale Ndoki national park area. These habitat

[1] MIST **M**anagement **I**nformation **S**ys**t**em

maps were subsequently used in an article released in the February 2010 issue of *National Geographic* (p136).

We also contributed to a better understanding of the use of NASA products for carbon stocks mapping in the region (Baccini et al., 2008). Increasingly, carbon projects within the region are being considered catalysts for encouraging carbon sequestration, while at the same time, rehabilitating degraded tropical forests, enhancing biodiversity, and strengthening the protection of both. One such example is the Uganda Wildlife Authority - Forest Absorbing Carbon Dioxide Emissions (UWA-FACE) project. This project is located in Kibale National Park, where approximately 10,000 ha of degraded forest are being restored. Kibale is known for its remarkable diversity of primates, including the endangered chimpanzee. As part of a 2008 PAWAR workshop, we discussed with collaborators how satellite technologies could provide detailed analyses on the state of national parks and the associated carbon stocks contained therein. This type of information is critical for conservation agencies to assimilate into the growing carbon market. A brief synopsis of the workshop and the associated presentations is posted on the WHRC website. (http://www.whrc.org/africa/PAWAR/Workshops/index.htm)

In 2009, the historical analysis of burn dynamics in the Queen Elizabeth area derived from Landsat time series was finalized. The WCS and UWA are now focusing their work on field measurements including flora and fauna observations for 200 plots along a gradient of burn frequency. These data will be used to assess the importance of fire and burn frequency in the park in influencing habitat and species abundances for birds and large mammals. The results will be conveyed to the park managers who are developing a fire management plan for the park. We expect to publish these results in 2010.

As part of the Woods Hole Research Center's efforts to advance the state of knowledge concerning the threats to the Albertine Rift ecosystems function, we developed a WebGIS tool to assist decision makers and park managers with the conservation of this hot spot of biodiversity (http://www.whrc.org/africa/PAWAR/PAWAR-data.htm). This website allows users to combine various remote sensing derived variables, such as land-cover or per cent tree cover information, with park-specific spatial datasets collected during ranger patrols. The spatial datasets, provided by the Uganda Wildlife Authority, consist of ranger patrol data collected over the past decade (1997-present) that provide valuable information about sightings of wildlife and threats to the parks. Data are currently available for the Budongo and Bugoma Forest Reserves, Kibale National Park, Murchison Falls Conservation Area, Queen Elizabeth National Park, and Semuliki National Park. The same information was made available on CDs to UWA for park managers with limited access to the Internet.

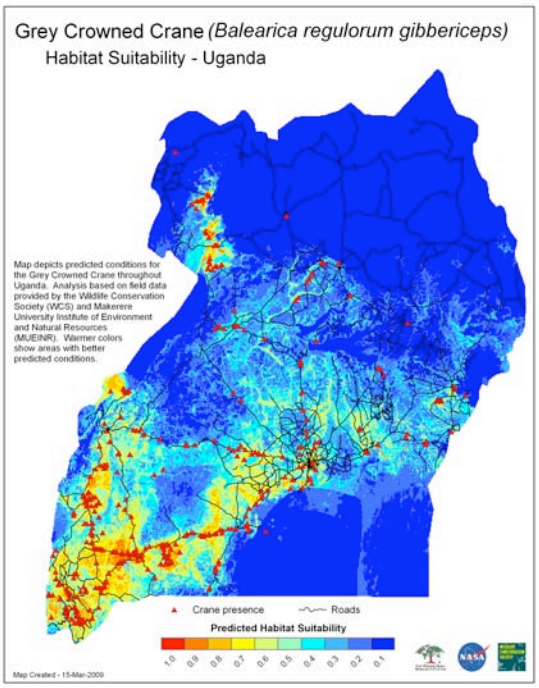
Overall, the project success can be assessed through an increasing demand and integration of remote sensing derived products by park managers. Our carbon maps, burn frequency maps and species distribution maps are being used by decision makers in the region. The participation at our technical thematic workshops has been a great success. Governmental agencies from Uganda, Tanzania, Zambia, DRC, and Sudan have

participated, as well as local and international NGOs, and more than 130 people have been trained at these workshops over the project period.

2. Major activities and accomplishments for 2009 - Synopsis

2.1 Data collection and analysis

2.1.1 Species Modeling



"Modeling Habitat Suitability for Grey Crowned-Cranes (*Balearica regulorum gibbericeps*) throughout Uganda" published in the *International Journal of Biodiversity and Conservation*. This study combines regional species occurrence data that has been collected over the last few decades with gridded datasets collated and organized in a geodatabase by the WHRC to provide a continuous surface of habitat suitability throughout the country for the species. *See Appendix I.*

2.1.2 Burn Scar Analysis

Analysis of the areal extent and frequency of burns through Queen Elizabeth National Park (Uganda) for the time period 1973-2009. *Figures provided in Appendix II.* The results of the remote sensing analysis are also shared with the Wildlife Conservation Society (WCS) and the UWA in collaboration with their long-term vegetation plots throughout the area to assess the relationship between burn frequency and vegetation type. The project goal is to determine if seasonal fires are affecting Ungulate distributions.

2.1.3 MODIS analysis

Using observations from MODIS in combination with large forest inventory datasets, we mapped woody aboveground biomass (AGB) across tropical Africa. Results, based on a cross-validation approach, show that the model explained 82% of the variance in AGB, with a root mean square error of 50.5 Mg ha-1 (25 Mg C ha-1) (Baccini et al., 2008).

These data are the first estimates of AGB throughout tropical Africa based on satellite observations, and thus provide important and reliable information on carbon stocks for 2000. The maps have been used in the Albertine Rift by several conservation organizations and national governments to explore a financing system based on conserving carbon or restoring degraded lands via payments for ecosystem services. Our maps have also been used by international bodies including the World Conservation Monitoring Center (WCMC) and the UNEP-UNESCO Great Apes Survival Project (GRASP), among others. We hope to continue to expand these collaborations. National level maps are available for download: http://www.whrc.org/Africa/carbonmap2000.htm

In addition to the 1-km map of above ground biomass that was finalized and published for tropical Africa (Baccini et al., 2008), in the last year of the project we produced a preliminary map at 500-meter resolution. The input data used to create the 500-meter biomass map (MODIS NBAR V5) is a best quality reflectance (QA) cloud free composite for the time period 2004-2006. This new MODIS mosaic based on 2004-2006 imagery is now available as a base-layer for the entire Albertine Rift; an illustration of the mosaic for the Albertine is provided in Appendix III. The final biomass map will be made available at the next Conference of the Parties (COP16) as part of the WHRC REDD+ activities.

2.2 Outreach and education

2.2.1 Data Distribution

PAWAR data for five protected areas of the Albertine Rift can now be viewed online via our interactive WebGIS. http://www.whrc.org/africa/PAWAR/PAWAR-data.htm
A front-page illustration is provided in Appendix IV.

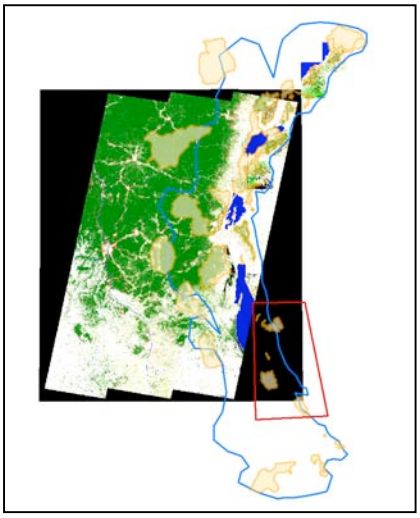
The WebGIS displays Uganda Wildlife Authority patrol data in relation to various remote sensing and GIS-derived data products. The interactive atlas allows users to visualize their datasets in relation to these layers, and also allows for additional spatial information to be loaded directly into the application.

3. Major activities and accomplishments – Project Synopsis

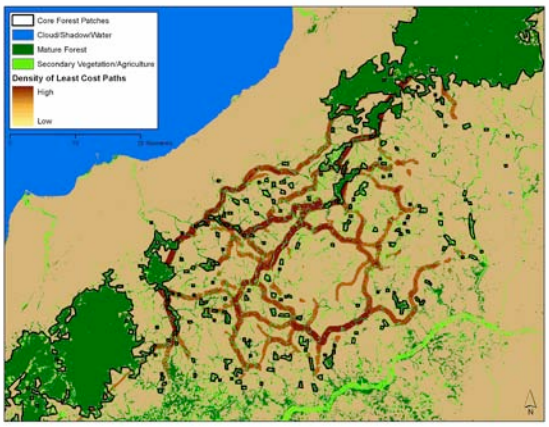
A summary of all major activities and accomplishments is also synthesized in a matrix in Appendix V.

3.1 Data collection and Analysis

3.1.1 Land-Cover Change Analysis



One of the main analysis activities of the project was to generate and compile existing land-cover change information throughout the entire Albertine Rift. While a complete map of the all Albertine could not be completed due to a lack of available cloud-free imagery, most protected areas (PA) are now covered by land-cover change information at various dates. Land-cover changes analyses were completed for a series of specific protected areas throughout the study area. Land-cover change results include (1) an analysis of land-cover change throughout Kibale National Park, which was published (Laporte et al., 2008) as part of a book on long-term research throughout the area, and (2) an analysis of land-cover change throughout the Primewest study area (stretching from Murchison Falls National Park to Semuliki National Park along the eastern shore of Lake Albert (Uganda) using Landsat SLC-off gap filled imagery (Report to USAID, lead by the WCS and in collaboration with WHRC), (3) Bwindi, Budongo, Bugoma and several other PA that were shared with official authorities and WCS (various reports to WCS, UWA).
We also investigated existing land cover maps such as the Hansen South Dakota State University map produced for CARPE (http://carpe.umd.edu/) (*figure above*) , but large areas of the Albertine are still not covered by any analysis. We are in discussion with Boston University and South Dakota State University to develop a proposal to NASA of a wall-to-wall land-cover change analysis for the entire Albertine.



Overall, we found that all non-protected forests are under major threat and are vanishing at high rates. The main sources of stress include unregulated human population migration, influx of refugees, and illegal charcoal trade, especially in eastern DRC. In Uganda, significant losses of forests are associated with the conversion of forests to settlements, as well as the expansion of industrial and traditional agriculture. In the Budongo-Bugoma Reserves, the land-cover change analysis from 1986-2000 was used as a layer of information to predict the best corridors for conservation of chimpanzee populations between the two reserves (Budongo and Bugoma). The figure above illustrates the least-cost paths identified as the best potential corridors for chimpanzee movement (Laporte et al., 2010).

3.1.2 Burn Scar Analysis

In 2008, the Uganda Wildlife Authority was able to report to its Board of Trustees, for the first time, on the dynamics and distribution of burn scars in Uganda parks based on the new information provided by PAWAR. The UWA is now in the process of implementing the monitoring system in other parks, a capability it did not have before the beginning of the project. In addition, the Monitoring and Research Coordinator at the UWA was invited to the Southern African Fire Network (SAFNet) workshop in Namibia in September 2008. He presented results of the PAWAR WHRC/UWA burn scar monitoring project for the national parks and the historical dynamics of fires throughout Queen Elizabeth NP. SAFNeT is a regional network that fosters collaborative efforts in fire monitoring and management in southern Africa (http://afis.meraka.org.za/safnet/index.php).

The analysis of the extent and frequency of burns throughout the Greater Virunga Landscape, including Virunga National Park (DRC) and Queen Elizabeth National Park (Uganda), for the entire Landsat archive has been completed and shared with the Wildlife Conservation Society (WCS) for further analysis and integration with recent and ongoing field surveys. Vegetation structure for more than 100 plots throughout the area have been assessed to study the relationship between burn frequency and vegetation type, with the ultimate goal of assessing whether ungulate distributions and densities are affected by seasonal fires.

A technical manual on "Monitoring Burn Scars Using Historical Landsat Quick-Look" was also introduced to the park manager community at the Uganda, Kasunga Remote Sensing Workshop, June 2007 (Stabach et al., 2007). Analyses are ongoing as part of a Makerere University training class.

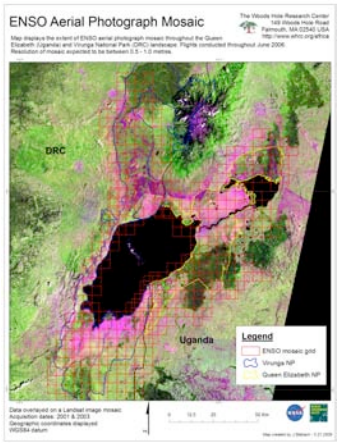
3.1.3 Species Modeling

Literature review and web research to determine the type of model (GIS-based binary or stand alone species distribution) most suitable for the development of species distribution analyses were performed. Several GIS-based and stand-alone models were identified and examined (including MaxEnt, BIOCLIM, GARP, Generalized Additive Models (GAM), and Generalized Linear Models (GLM)). From this review, GARP (Genetic Algorithm for Rule set Prediction) and MaxEnt (Maximum Entropy) emerged as the preferred options.
Finally, MaxEnt (Maximum Entropy) was used for modeling the habitat suitability for Grey Crowned-Cranes (*Balearica regulorum gibbericeps*) throughout Uganda (Stabach et al., 2008).

A series of gridded datasets (soil, elevation, precipitation, temperature, land-cover, percent of wetlands) were compiled and compared with available regional species occurrence datasets to provide an estimate of habitat suitability for Grey Crowned-Cranes

throughout Uganda. Analysis was compared against GARP (Genetic Algorithm for Rule-Set Prediction).

3.1.4 Aerial Photograph Mosaic



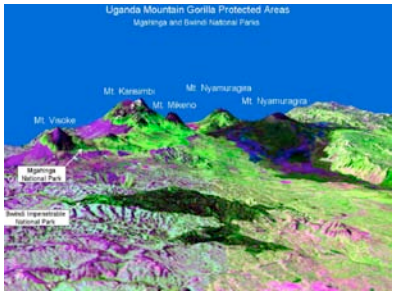
An aerial photograph mosaic was completed for the Greater Virunga Landscape, including Queen Elizabeth NP (Uganda), Virunga NP (DRC), Mt. Kabobo (DRC), and the eastern border of Lake Albert (Uganda). The mosaic covers roughly 35,000 km^2. From the aerial photograph mosaics, WCS performed a vegetation classification in 18-classes at 250m resolution for the Queen Elizabeth NP. The map has been used as an input for biodiversity modeling analysis. The classification was performed using standard visual photo interpretation methods. Generation of a similar classification for Virunga NP is also available (Nagendo, *personal communication*).

3.1.5 MODIS

A map of above ground biomass was finalized for Central Africa. The work used MODIS NBAR V4 reflectance data in combination with field observations in a regression tree (randomForest) statistical model to predict biomass in each 1 km x 1 km MODIS pixel (Baccini et al., 2008).

A cloud-free basemap using MODIS NBAR V5 data at 500-meter resolution for the period 2004-2006 was also generated for the entire study area, selecting only the best quality pixels at each location.

3.1.6 ASTER mosaics



We have compiled an extensive catalogue of ASTER imagery throughout the study area and assembled these data in CD data products and online to be used in combination with collaborator datasets. We also generated a wall-to-wall mosaic of ASTER imagery covering the central part of the western protected areas. A 3-D illustration for park managers was produced (*left*).

3.2 Institutional Capacity Building

3.2.1 Workshops

Over the course of the project, four successful workshops were held in Uganda for protected area managers and conservation practitioners. These workshops helped to build GIS and remote sensing capacity among our collaborators, as measured by (a) participants continuing to utilize the tools demonstrated in the class in their respective protected areas, (b) publishing results, and (c) presenting results at internationally recognized conferences. In addition, we provided material and personnel for other workshops in the region.

List of the workshops run by WHRC:

- **Introduction to Remote Sensing Workshop** – June 2006. Eight participants were introduced to the theory and practice of remote sensing.

- **Burn-scar Mapping Workshop** – June 2007. Fourteen participants from the Uganda Wildlife Authority were instructed in how to rebuild and track past and present fire regimes in protected area savannas.

- **MIST (Management Information System) Monitoring and Research training workshop**
  Sponsored by the Wildlife Conservation Society and the WHRC (June 2007). Attendees included 20+ protected area managers and NGO personnel from throughout Uganda, as well as the eastern Democratic Republic of Congo.

- **Biomass mapping workshop 2008:**
  The latest workshop was held at the Budongo Forest Reserve and focused on estimating carbon stocks in protected areas. There were more than 40 participants from 7 different African countries (Uganda, Democratic Republic of Congo, Rwanda, Tanzania, Sudan, Kenya, and Mozambique), and 17 institutions were represented. A complete workshop agenda including presentations has been incorporated at the following web address:
  http://www.whrc.org/africa/PAWAR/Workshops/index.htm.

3.2.2 Students and decision makers presentations

Several students and decision makers have also benefited directly from PAWAR activities.

Hillary Agaba, a former burn scar mapping workshop attendee (2007), recently completed his undergraduate degree (at Makerere University) entitled, "Assessing the Effect of Fire in the Lake Mburo National Park Ecosystem using Remote Sensing Techniques." Hillary provided a synopsis of fires for the period 1987 to 2007 in the Lake Mburo National Park area and used the burn scar mapping methodology designed by WHRC as his guide.

Publication: "Agaba, K. H., 2007. Assessing the Effect of Fire in the Lake Mburo National Park Ecosystem using Remote Sensing Techniques. B.Sc. (WHM) Special Project. Makerere University."

Dennis Babaasa, a student of the first PAWAR workshop (2006), is now a graduate student at the University of Massachusetts. Dennis is working on a remote sensing project focusing on Bwindi Impenetrable National Park.

Aggrey Rwetsiba, Senior Monitoring and Research Coordinator at the Uganda Wildlife Authority, was invited to the Southern African Fire Network (SAFNet) workshop in Namibia in September 2008. Aggrey presented results of the PAWAR WHRC/UWA collaboration regarding burn scar monitoring throughout national parks and the historical dynamic of fires throughout Queen Elizabeth NP. SAFNET is a regional network that fosters collaborative efforts in fire monitoring and management in southern Africa (http://afis.meraka.org.za/safnet/index.php).

Dr. Grace Nangendo visited the WHRC for six weeks in the fall of 2006. Dr. Nangendo is a remote sensing specialist and native Ugandan working at the Wildlife Conservation Society in Kampala with project support from NASA via WHRC. Dr. Nangendo has been our main remote sensing contact within the WCS in Uganda, facilitating all communications with different governmental conservation organizations in the region.

Some of our NASA results were reported to high-level policy makers in Africa in the context of forest conservation and carbon monitoring during the COP12 meetings in Nairobi Kenya, and the COP13 in Bali in December 2007. Several pamphlets and posters were distributed at both events. In Bali, a report on the D.R. Congo has been also distributed to present how the Congo can avoid deforestation and identify critical areas for conservation (Laporte et al., 2007).

3.3 Outreach/education

3.3.1 WebGIS

To facilitate the exchange of information, WHRC collaborated with the Institute for the Application of Geospatial Technology (IAGT), the WCS and UWA to develop a WebGIS platform. This platform allows park managers and the larger community to visualize specific spatial data sets combining remote sensing products, GIS datasets, and field wildlife surveys from the MIST database (1985-2006). Users can also upload their own GIS layers and visualize those in combination with the PAWAR database.

The application is now available online (http://atlas.whrc.org/pawar/), and it provides datasets for six protected areas throughout Uganda (Budongo and Bugoma Forest Reserves, Kibale National Park, Murchison Falls Conservation Area, Queen Elizabeth National Park, and Semuliki National Park).

3.3.2 Data Samplers

Data samplers CDs were distributed to the Uganda Wildlife Authority (UWA). These CDs integrated MIST data (1985-2006) with Landsat and Aster Imagery, along with GIS data analysis for protected areas throughout the region (such as Murchison Falls, Kibale, Bwindi, and Queen Elizabeth National Park). Data has been normalized for survey effort and displays ranger patrol data, including animal sightings and illegal activities (poaching sign, encroachment) with underlying raster layers. CDs for two other protected areas (Budongo/Bugoma Forests and Semuliki NP) are also available for distribution (*see Appendix IV*).

Internationally, we worked on the development of a geodatabase for the protection of great apes (GRASP - Great Apes Survival Project), in collaboration with the Harvard Peabody Museum, the Paris Museum of Natural History, and the Max Plank Institute. The products generated to support the UNEP Great Apes Survival Project (GRASP) are routinely used by policy makers and scientists to develop conservation strategies in the Albertine Rift and elsewhere across the African continent[2]. This database was also used to derive great apes conservation educational material for the Kampala Natural History Museum for an exhibit currently on the road in the Albertine Rift region of Uganda targeting schools and communities.

[2] http://www.whrc.org/africa/prioritypops/index.htm

3.3.3 Education/Training material & Field Research product outreach

Various training material and data products generated by this project were distributed directly to the Wildlife Conservation Society (WCS) and other researchers throughout the region to allow flow of information among various research and policy networks. These data included electronic and hard copy maps of specific study areas, manuals, etc. Maps were used to guide field crews through their scientific data collection and logistics, as well as, providing information towards the establishment of new protected areas throughout the region for decision makers. A manual on burn scar mapping using Landsat imagery (Stabach et al., 2007) was also distributed to UWA technicians and to conservation practitioners in 4 other countries, and was used by students at the Makarere universities for their Master's programs.

Further, we developed outreach-education conservation posters using NASA satellite imagery for the GRASP UNESCO/UNEP exhibit on Great Apes at the Uganda National Museum (Principal POC Sabrina Krief from the Paris Natural History Museum). More than 8,000 people visited our exhibit during July 2006. The exhibit will eventually travel throughout Uganda. Additionally, plans are underway to develop materials for exhibition in other great ape range states. For more information on the Uganda Great Apes exhibit, please visit our website (http://www.whrc.org/africa/GRASP/index.htm)

4. Publications and presentations

Project results were published in a number of different outlets. These include international recognized journals, book chapters, Wildlife Conservation Society internal reports, and via our website. The full list is provided in the publication and presentation section.

4.1 Peer Reviewed Journals

Laporte, N., Jantz P., Plumptre, A. M., McLennan, M., Bausch, A., 2010. Remote sensing and modeling of chimpanzee habitat corridors connecting the forest reserves of Western Uganda, *In preparation*.

Baccini, A., N. Laporte, S.J. Goetz, M. Sun, and H. Dong. 2008. A first map of tropical Africa's above-ground biomass derived from satellite imagery. *Environmental Research Letters* (3)045011 doi: 10.1088/1748-9326/3/4/045011

Devos C., C. Sanz, D. Morgan, J.R. Onononga, N. Laporte**,** M.C. Huynen. 2007. Comparing Ape Densities and their Habitats in Northern Congo: Marked-Nest Surveys of Sympatric Gorillas and Chimpanzees in the Ndoki and Odzala Regions, *American Journal of Primatology* 70:1–13.

Goetz, S.J., A. Baccini, N.T. Laporte, T. Johns, W. Walker, J. Kellndorfer, R.A. Houghton, and M. Sun. 2009. Mapping and monitoring carbon stocks with satellite observations: a comparison of methods. *Carbon Balance and Management* 4:2.

Laporte, N.T, J.A. Stabach, R. Grosch, T.S. Lin, S.J. Goetz. 2007. Expansion of Industrial Logging in Central Africa. *Science.* 316. 1451.

Stabach, J., Laporte, N., Olupot, W. 2009. Modeling Habitat Suitability for Grey Crowned Cranes (*Balearica regulorum gibbericeps*) throughout Uganda. *Biodiversity and Conservation. pp. 177-186. Online Journal: http://www.academicjournals.org/IJBC/contents/2009cont/Sept.htm*

4.2 Book Chapters

Laporte, N., J. Stabach, G. Fiske, and G. Bush. 2010. Threats to the Protected Areas in the Albertine Rift – Contribution to Land Cover Change Analysis, WCS in prep.

Laporte N.T, Walker W., J. A. Stabach, Landsberg F., 2008. Monitoring Forest-Savanna Dynamics in Kibale National Park with Satellite Imagery (1989-2003): Implications for the Management of Wildlife Habitat, in "Science and conservation in African forests: how long-term research promotes habitat protection." Edited by Richard Wrangham & Elizabeth Ross.

4.3 Technical Reports

Plumptre, A.J., and Nangendo, G., December 2008. Integrating Earth Science Enterprise Results into Protected Area Decision Support for the African Albertine Region. Wildlife Conservation Society internal report.

Five years of biodiversity investment in Uganda, Wildlife Conservation Society (WCS) and Makerere University Institute of Environment and Natural Resources (MUIENR) Final Report. Productive Resources Investment for Managing the Environment, September 2008.

Debroux, L., Hart, T., Kaimowitz, D., Karsenty, A., Topa, G., Abdon, A., Amsini, F., Aveling, C., Bertrand, A., Bekhechi, M., Bravi, C., Chezeaux, E.,

Chomitz, K., Dewachter, P., d'Huart, J., Diaw, C., Dieterle, G., Dijire, A., Dupain, J., Erdlenbruch, K., Fauvet, N., Forni, E., Hall, J., Kakinda, J., Kalambay, G., Diwa, K., Laporte, N., Lumbuenamo, R., Makana, J., Malkombo, J., Megevand, C., Mehlman, P., Montagne, P., Mpoyi, A., Mukadi, K., Mwinyihali, R., Ndoye, O., Ngomba, C., Ngoy, B., Pagiola, S., Roda, J., Rossignol, I., Russel, D., Schenkman, N., Schinkel, R., Schmidt-Soltau, K., Staver, C., Tshamba, M., Tshombe, R. and Yambayamba, N. (Ed.). 2007. Forests in post-conflict Democratic Republic of Congo: Analysis of a priority agenda. Jakarta: World Bank, Center for International Forestry Research (CIFOR), Centre International de Recherche Agronomique pour le Développement (CIRAD), African Wildlife Foundation (AWF), Conseil National des ONG de Développement du Congo (CNONGD), Conservation.

Plumptre, A.J., G. Picton Phillips, J. Stabach, N. Laporte, E. Ourum, S. Ayebare, R. Grosch, R. Knox, and T. Akuguzibwe. 2008. Modeling Factors that Predict the Distribution and Density of Ungulate Species in the Queen Elizabeth National Park: Preliminary Findings. Wildlife Conservation Society Preliminary Report.

Laporte, N., F. Merry, A. Baccini, S. Goetz, J. Stabach, and M. Bowman. 2007. Reducing CO2 Emissions from Deforestation and Degradation in the Democratic Republic of Congo: A First Look. United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP), Thirteenth session.

Stabach, J., Laporte, N., Walker, W. 2007. Monitoring Burn Scars Using Historical Landsat Quick-Look Data Case Study: Queen Elizabeth National Park, Uganda Presented and distributed at the Kasunga Remote Sensing Workshop, June 2007

4.4 Other Publications

Stabach, J.A., D. Deneau, G. Fiske, A. Rwetsiba, W. Walker, and N. Laporte. 2010. Enhanced WebGIS Functionality for Protected Area Monitoring in the Albertine Rift, Africa. ESRI, ArcNews.

Agaba, K. H. 2007. Assessing the Effect of Fire in the Lake Mburo National Park Ecosystem using Remote Sensing Techniques. B.Sc. (WHM) Special Project. Makerere University.

4.5 Posters

Laporte, N., G. Fiske, W. Walker (2006), Uganda Great Apes Posters series. Uganda National Museum, Kampala. The posters were designed by Sabrina Krief and Erica Nichols from the Paris Museum of Natural History as part of the UNEP Great Apes Survival Project. Great Ape maps distribution and satellite imagery products were prepared by the WHRC team. http://www.whrc.org/africa/GRASP/index.htm

Laporte, N., A. Baccini, J. Stabach, S. Goetz, W. Walker, R. Houghton, J. Ipalaka, and V. Kasulu. A Carbon Monitoring System for Tropical Countries - Democratic Republic of Congo Case Study. Center for International Forestry Research, COP-13, Bali, Indonesia, December 2007.

Laporte, N., W. Walker, J. Stabach, G. Fiske, G. Nangendo, A. Plumptre, and A. Rwetsiba. Integrated Forest Monitoring System for Central Africa (INFORMS) and the Protected Area Watch in the Albertine Rift (PAWAR): Remote Sensing Tools for Conservation Policy – Albertine Rift Region Case Study. The George Wright Society Biennial Conference. St. Paul, Minnesota, April 2007.

4.6 Presentations

Laporte, N., W. Walker, G. Fiske, J. Stabach (2006), Monitoring Great Apes habitats with satellite imagery", The Great Apes Scientific Workshop on Great Ape Priority Populations and Sites. UNESCO-Paris GRASP Meeting April 18th, 2006. In addition several posters illustrating relevant analyses based on satellite imagery where provided to the primatologists

Laporte, N., 2006 International Primatological Society, Entebbe, Uganda (June 25-30, 2006) as part of a symposium titled, "Remote Sensing Tools for Great Ape Research and Conservation: Current Applications and Future Needs."

Laporte N., A.J. Plumptre, W. Walker (2006), Land use & Land cover change in Great Ape Habitat of the Ugandan Albertine, International Primatological Society, Entebbe, 25-30 June, www.asp.org/ips/ips2006/

Pintea L., N. Laporte, A. Plumptre, M. Leighton (2006), Prioritizing and monitoring Great Ape populations with satellite imagery and GIS: The case of Tanzania, International Primatological Society, Entebbe, Uganda from the 25-30 June 2006, http://www.asp.org

Walker, W., N. Laporte, L. Pintea, (2006), Remote sensing and geographic information systems: an introduction to tools and techniques for Great Apes research and conservation, International Primatological Society, Entebbe, 25-30 June, http://www.asp.org

Laporte, Walker and Stabach gave several presentations, 2007, at the Makerere University Biological Field Station, Kibale National Park, commemorating the 20th Anniversary of the Kibale Chimpanzee Project. Results of the NASA PAWAR project were presented and a short workshop was held during which the Kibale National Park data sampler was presented and distributed to attendees (*see Appendix IV for DVD data samplers*).

Stabach, J., G. Reinartz, N. Laporte, and W. Walker. Utilizing Remote Sensing Information to Identify Bonobo (Pan Paniscus) Habitat in Salonga National Park, Democratic Republic of Congo. Society for Conservation Biology Conference. Port Elizabeth, South Africa, July 2007.

Laporte, N., P. Jantz, J. Stabach, M. McLennan, and A. Plumptre. Habitat Modeling Utilizing Remote Sensing Tools for Chimpanzee Conservation in Western Uganda. Society for Conservation Biology Conference. Port Elizabeth, South Africa, July 2007.

Laporte N., NASA annual 2006, 2007, 2008, 2009 meetings.

APPENDIX I- Modeling habitat suitability for Grey Crowned-cranes

Modeling habitat suitability for Grey Crowned-cranes (*Balearica regulorum gibbericeps*) throughout Uganda

Jared A. Stabach[1*], Nadine Laporte[1], and William Olupot[2]

[1]The Woods Hole Research Center, 149 Woods Hole Road, Falmouth, MA 02540 USA
[2]Wildlife Conservation Society, Plot 802, Mitala, Kiwafu Road, Kansanga, P.O. Box 7487, Kampala, Uganda
*Corresponding author: jstabach@whrc.org

Accepted 12 August 2009
***International Journal of Biodiversity and Conservation*, Vol. 1(5), September 2009, 177-186.**

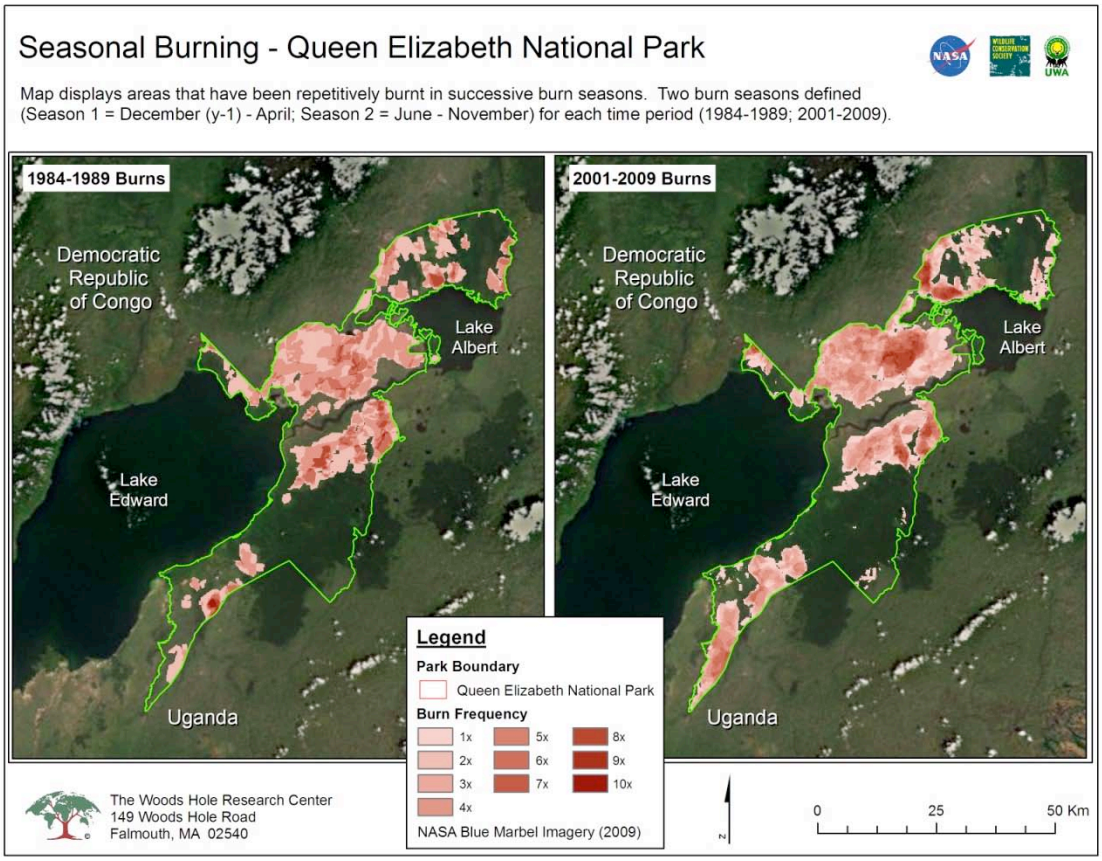
Abstract. Grey Crowned-cranes occur throughout the mixed wetland-grassland habitats of Eastern and Southern Africa. Due primarily to loss of habitat, however, the species is in swift decline over much of its historic range. We present a prediction of habitat suitability throughout Uganda using a Maxent modeling approach, combining presence-only field data collected over the last few decades (1970 - 2006) with remote sensing and climate derived variables. We ran six feature type models, with the Auto feature type model having the best fit to the data (AUC = 0.912). Our results provide detailed information regarding the characteristics of habitats used and highlight specific areas of high habitat suitability for the species. While wetlands were certainly important in the prediction (9.2% contribution), other variables (namely temperature seasonality) were more important within the model (19.5%). Areas of high habitat suitability (defined as > 0.6 probability of presence) accounted for only a small amount of the total area throughout the country (5.8 - 6.9%), and were mainly found in the Southwestern corner of the country and along the Albert Nile River. These data provide a statistical basis for extrapolating into areas that have not been surveyed and provide valuable information for the future conservation of the species.

Key words: *Balearica regulorum gibbericeps*, East Africa, Grey Crowned-crane, habitat suitability, Maxent, modeling, Uganda.

APPENDIX II- Burn scars

Queen Elizabeth National Park, Uganda (2109.70 km^2)

Burn Scar Extent and Frequency Comparison



Burn Extent:

1980s (1984-1989) – Averaged Results

	n	Average # of Burns	Average Min. Burn Area (km^2)	Average Max. Burn Area (km^2)	Average Avg. Burn Area (km^2)	Average Total Area Burnt (km^2)
All Delineated Seasons	8	21	0.74	65.32	11.18	201.68
Good Data*	4	34	0.02	65.46	8.89	275.57
Burn Season 1**	1	18	0.00	49.47	13.71	246.76
Burn Season 2**	3	40	0.02	70.79	7.29	285.16

2000s (2001-2009) – Averaged Results

	n	Average # of Burns	Average Min. Burn Area (km^2)	Average Max. Burn Area (km^2)	Average Avg. Burn Area (km^2)	Average Total Area Burnt (km^2)
All Delineated Seasons	17	42	0.22	48.54	8.80	231.52
Good Data*	15	46	0.23	52.93	8.99	258.82
Burn Season 1**	9	44	0.14	69.48	10.56	316.82
Burn Season 2**	6	49	0.37	28.10	6.65	171.83

* "Good Data" refers to a burn season that was calculated based on, at least, two images.
** Average results based only on burn seasons with at least two images.

Burn Frequency:

1980s

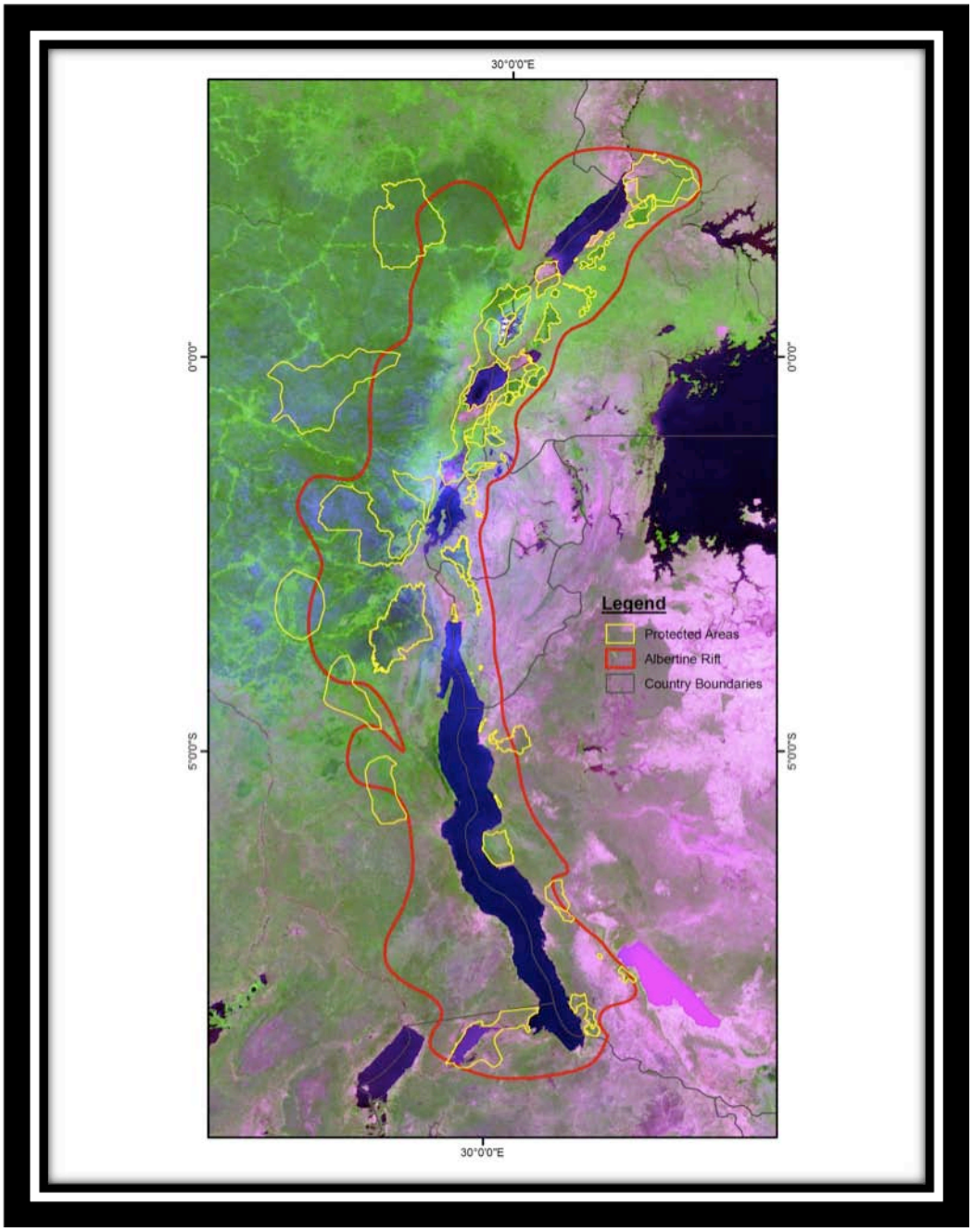
Number of Times Area Burnt (8 Seasons maximum)	Total Area Burnt (km^2)
1	395.98
2	351.54
3	110.83
4	28.45
5	2.60

2000s

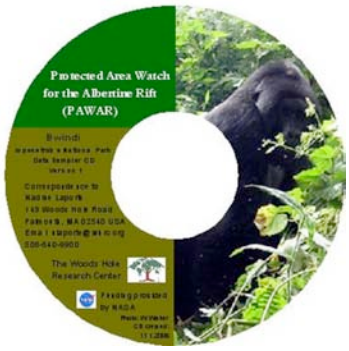
Number of Times Area Burnt (17 Seasons maximum)	Total Area Burnt (km^2)
1	253.61
2	199.55
3	182.95
4	161.85
5	87.53
6	48.79
7	31.15
8	30.23
9	9.34
10	0.21

APPENDIX III-MODIS MOSAIC 2004-2006

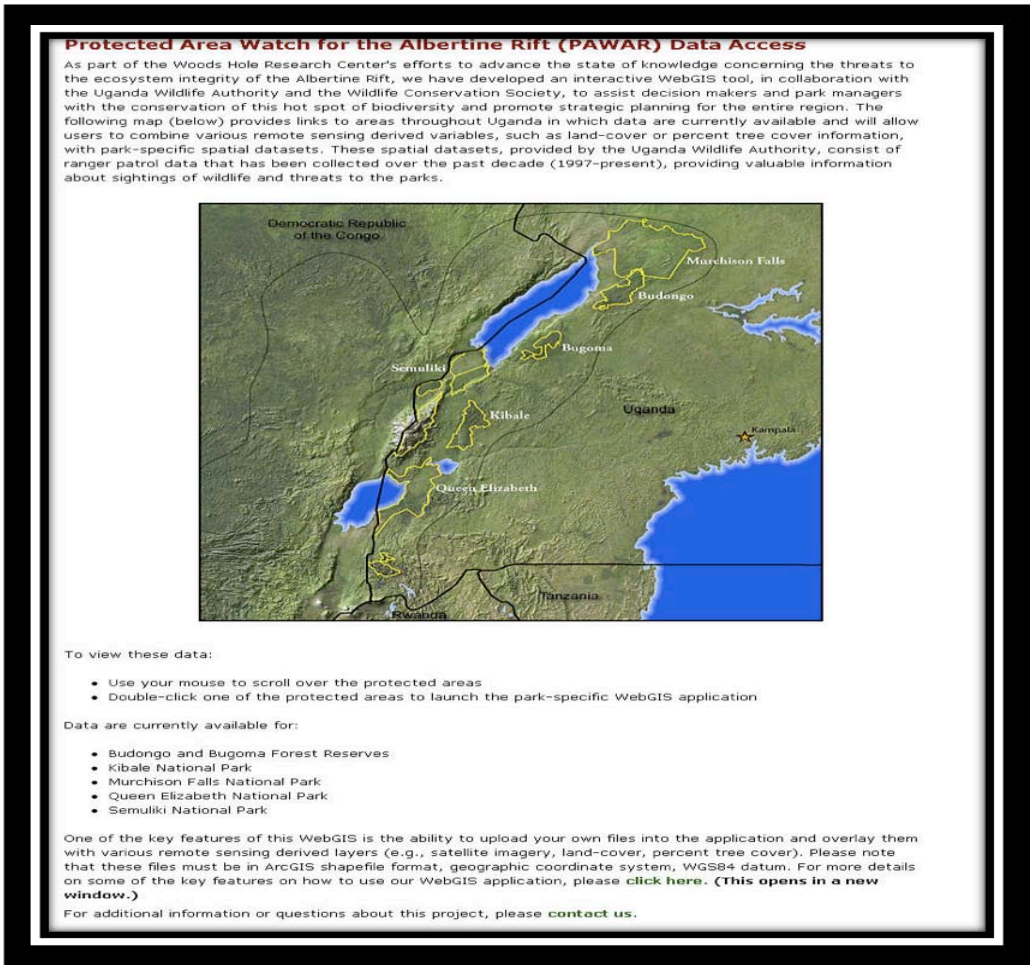
MODIS NBAR V5 Image Mosaic
500-meter resolution
(2004-2006)



APPENDIX IV - PAWAR WebGIS- & DVD series

 Budongo – Bugoma DVD	 Bwindi DVD	 Kibale DVD

http://www.whrc.org/africa/PAWAR/PAWAR-data.htm



Protected Area Watch for the Albertine Rift (PAWAR) Data Access

As part of the Woods Hole Research Center's efforts to advance the state of knowledge concerning the threats to the ecosystem integrity of the Albertine Rift, we have developed an interactive WebGIS tool, in collaboration with the Uganda Wildlife Authority and the Wildlife Conservation Society, to assist decision makers and park managers with the conservation of this hot spot of biodiversity and promote strategic planning for the entire region. The following map (below) provides links to areas throughout Uganda in which data are currently available and will allow users to combine various remote sensing derived variables, such as land-cover or percent tree cover information, with park-specific spatial datasets. These spatial datasets, provided by the Uganda Wildlife Authority, consist of ranger patrol data that has been collected over the past decade (1997-present), providing valuable information about sightings of wildlife and threats to the parks.

To view these data:

- Use your mouse to scroll over the protected areas
- Double-click one of the protected areas to launch the park-specific WebGIS application

Data are currently available for:

- Budongo and Bugoma Forest Reserves
- Kibale National Park
- Murchison Falls National Park
- Queen Elizabeth National Park
- Semuliki National Park

One of the key features of this WebGIS is the ability to upload your own files into the application and overlay them with various remote sensing derived layers (e.g., satellite imagery, land-cover, percent tree cover). Please note that these files must be in ArcGIS shapefile format, geographic coordinate system, WGS84 datum. For more details on some of the key features on how to use our WebGIS application, please **click here. (This opens in a new window.)**

For additional information or questions about this project, please **contact us**.

APPENDIX V- Matrix of Project results

Activities	
1. Phase 1: EVALUATION of existing and new Earth Science Results (ESR)	
• **WHRC:** Assess the application of existing NASA products from INFORMS, Landsat Pathfinder, Monitoring Land Use / Cover Dynamics (MOLAND) o Evaluate product with users, Provide standardized land cover, etc. o Evaluate product with users, for selected Landscape (regional - cross border)	Completed
• **WHRC:** Select and acquire new spatial data sets, (MODIS, Landsat, ASTER, IKONOS imagery etc) to develop new products based on user recommendations	Completed
• **WCS/WHRC:** Acquire digital aerial imagery for validation of NASA products	Completed
2. Phase 2: INTEGRATING Earth Science Results with existing DSSs	
• **WHRC/WCS:** Provide new standardized products to DSSs o Landsat Geocover Mosaic (basemaps) o Land cover maps, forest maps, etc. o Disturbance data sets (deforestation, fires, logging, etc.)	Completed
• **WCS/WHRC:** Contract specific changes in MIST to allow easier linkages to remote sensing, data export, and trend analysis by managers	Completed
• **WCS:** Assemble regional species occurrence data sets	Completed
• **WCS:** Assemble field illegal activity data sets and other socio-economic data sets	Completed
• **WCS/WHRC:** Assemble gridded climatic data sets, soils, etc..	Completed
• **WHRC/WCS:** Combine remote sensing and socio-economic layers (parks, logging limits, roads, population, etc.) into GIS system to derive layers for threat analysis	Completed
• **WHRC:** Produce regional vegetation map for GARP and HIS	Completed
• **WCS/WHRC:** Predict regional species distribution with GARP MAXENT	Completed
• **WCS/WHRC:** Evaluate distribution species maps from different models	Completed
• **WCS/WHRC:** Apply WCS landscape modeling approach to identify threats and priorities for conservation action	Ongoing
Benchmarking	
• **WCS/WHRC:** Send surveys to Park Manger to evaluate the use of NASA products and derived product (habitat suitability and threats) into their DSS	
• **WCS/WHRC:** Send surveys to NGOs to evaluate the use of NASA products into conservation planning	Survey 2007 Survey 2008
Coordination	
• **WHRC** with OSFAC/CARPE in Kinshasa -	Ongoing
• **WHRC** with NASA-GSFC/CARPE for data acquisition -	Ongoing
• **WHRC** with the UMD- Global Land Cover Facility-	Ongoing
• **WHRC** with JPL PA ASTER archive - Gary Geller	Ongoing
• **WCS** with other conservation NGOs and governments to synthesis user needs	Ongoing
Networking/ workshops	
• **WHRC:** Expand the Global Observation of Forest Cover (GOFC) to the Albertine Rift for conservation applications.	Ongoing
• **WHRC/WCS:** Co-organize training workshops in 2006, 2007, 2008 on the use of NASA products. Park managers and policy makers to present existing NASA products and discuss the needs for new products and standards.	Completed
• **WHRC:** Train WCS Uganda analyst in remote sensing / GIS	Completed
Distribution	
• **WHRC/WCS:** Distribute already existing NASA products on CDs, reports, etc.	Ongoing
• **WHRC:** Develop an interactive WEBGIS system to distribute NASA products	Completed
Outreach	
• Published general public reports, scientific publication, animations, etc…	Completed

APPENDIX VI Surveys- Project performance assessment

Survey 1: 2006

Summary of Questionnaire administered to Park Wardens in the Albertine rift

Grace Nangendo conducted a baseline survey for the project and visited seven (7) national parks and two (2) forest reserves and administered a questionnaire to national park wardens. Twenty-eight individuals completed the questionnaire. Twenty-four of them were UWA employees, two were from ICCN, one was from WCS Congo, and one was from the Institute of Tropical Forest Conservation, Mbarara University.

Remote Sensing/GIS use

Of all the respondents, only six (21.4%) used satellite imagery in their work, nineteen (67.9%) had access to Remote sensing/GIS facilities, and ten (35.7%) had licenses for the software (mainly ArcView).

Remote sensing data was mainly used as basic layer information (50%). 21.4% of the respondents used aerial photos and 7.1% used Landsat imagery. The specific reasons given for the low use of satellite data were that it was difficult to access (60.7%) because it is expensive (10.7%) and there was general lack of knowledge of how to access and process the data (32.1%). 35.7% of the respondents suggested that the best way to improve satellite imagery use was through training the wardens in the use of RS/GIS and how to apply it in their work.

The remote sensing products most needed by national park workers are forest encroachment maps (42.9%), base maps (32.1%), land cover/use maps (28.6%), and fire maps (17.9%).

Management Information System (MIST)

92.9% knew about MIST and 82.1% were users of MIST. The oldest user of MIST had started using it in 1999. 96.4% of the respondents indicated that they would want to know more about MIST.

The problems associated with MIST included:

- Limited knowledge of the software. More training was suggested.
- Technical problems could not be sorted out locally. Users had to contact a consultant who would then, after some time, come up with a new version. In the mean time, data entry stalled and when the new version was released, one needed to take time to learn it.
- Entries in the software are standardized so that any additional observations, e.g., a new species, cannot be entered. The software also has no provision for adjusting outputs in order for one to extract only the outputs of interest.

- Due the recurrent bug problems, the resultant software updates, which placed demand on workers to relearn the software, and the accumulation of unrecorded data, software user interest has declined.

Suggestions given on how to make MIST better software included the following:
- Make the software user-friendly
- Develop a data exchange link between MIST and other spatial data software packages, e.g., ArcView.
- Make the software fully functional, i.e., with no technical problems that disable it completely, and so that one can update to a new version when needed.

Survey 1 conclusions

57.1% of respondents had species distribution data and 14.3% had vegetation distribution data.

21 different types of spatial information were suggested as being of use for improving management of natural resources. The ones most often requested were illegal activities information, vegetation cover change and fire maps with each at 14.3%, current land use/cover maps, animal species distribution and resource availability information at 10.7% each.

25 different aspects were indicated as a threat to ecosystem management. Of these, illegal resource use, which included fishing, poaching and logging, was indicated as the greatest threat (67.3%). Others with high percentage are illegal fires (46.4%), encroachment (28.6%), population pressure (17.9%) and illegal grazing (14.3%).

The most frequent suggestions on how to improve the next survey were:
- To either simplify or reduce the technical terms.
- To first provide training before sending out a questionnaire that is highly technical.
- To limit the questionnaire to only the individuals who have training in RS/GIS use.

In addition to administering the questionnaire, GPS coordinates for image rectification were taken all along the routes used.

Survey 2: 2008

Summary of the results of the second survey to evaluate the integration of remote sensing and field measurements

Individuals (n=16) from 7 countries surveyed

Of the respondents, nearly all (87.5%) use satellite imagery in their work, with the same number (14/16) having access to a remote sensing facility. The software being used is predominantly ArcView or ArcGIS (71.4%), with 50% of individuals having access to ERDAS Imagine.

Remote sensing data was mainly used as a basic information layer (80%), with Landsat being the most commonly used (75%). Spot was also used frequently (37.5%), with aerial photos (25%) and QuickBird imagery (25%) used less frequently. Access to remote sensing datasets was viewed as moderate to very difficult, with specific reasons cited as (1) poor network, (2) too costly (no licenses), and (3) inability to access data for the right time period and resolution to meet study objectives.

The remote sensing products most valuable to all respondents were land-cover (100%), deforestation (64.3%), satellite image basemaps (57.1%), and biomass (42.9%). The most common suggestions on how to improve the use of satellite imagery were (1) to provide more training, (2) to reduce the cost, and (3) to provide access to more applicable imagery to reach study objectives.

Three years earlier, in a previous survey (Survey 1) done by Grace Nangendo, only (21.4%) of the interviewed individuals said they used satellite imagery in their work, 19 (67.9%) had access to remote sensing/GIS facilities, and ten (35.7%) had licenses for the software (mainly ArcView).

In conclusion, we can say that the Albertine project has been successful in increasing the involvement of park managers and conservationists, as measured through the increasing demand for NASA products in research and monitoring programs throughout the region. The integration of remote sensing products and associated models into decisions support systems of the Albertine Rift region has been growing since the beginning of the project. The information produced by the project has been integrated into the Management Information System (MIST) in Uganda and the DR Congo.