Documentation of existing and potential oil/geothermal projects, mapping their likely adverse negative effects on the biodiversity conservation and community livelihoods in the Greater Virunga Landscape

Rwenshama Drill Site, Queen Elizabeth National Park. A.J.Plumptre/WCS

A.J.Plumptre, S. Prinsloo, S.Ayebare and G. Nangendo

January 2016

EXECUTIVE SUMMARY

The Greater Virunga Landscape (GVL) is one of the most species rich areas of contiguous natural habitat in the World. The GVL contains at least 1,409 terrestrial vertebrate species and 3,755 plant species of which 109 species are considered to be globally threatened and 241 species endemic to the Albertine Rift region of Africa. The Albertine Rift region has more threatened and endemic vertebrates than anywhere else on the African continent and the GVL is the richest part of the Albertine Rift making it one of the foremost sites for global biodiversity conservation.

The recent exploration for oil and gas in Virunga National Park within the GVL by the oil company SOCO, and in Queen Elizabeth Park by Dominion Oil has raised concerns and much press about their conservation and long term viability. Trial drilling has already taken place in Uganda in the Queen Elizabeth National Park by Dominion Oil although no oil was discovered at that time. This report is an interim report of a study to assess the potential impacts that oil/gas and geothermal exploration and production could bring to the GVL and to identify the most sensitive areas for the conservation of the biodiversity of this landscape. It summarises the results of the first three objectives of the study:

i) Determine the potential adverse impacts of the oil/geothermal industry

ii) Determine, map and delineate a suite of biodiversity targets that are sensitive to, or likely to be affected by adverse impacts of oil/geothermal industry

iii) Based on the suite of biodiversity targets, model scenarios of adverse negative impacts that would be used by decision makers to avoid conflicts and balance trade offs

iv) Document existing impacts that have already occurred

The first part of the report summarises the impacts that can occur with oil/gas and geothermal and what would need to be assessed and monitored if exploration or production went ahead in the landscape. These impacts are summarised by the impact types such as increased access by people, land take, pollution etc.

The second part of the report summarises the results of species distribution modeling of species endemic to the Albertine Rift and threatened species on the IUCN redlist (CR, EN,VU). We modeled threatened and endemic large and small mammals, birds, reptiles, amphibians and plants and map these for the GVL. The results show that the species most likely to be impacted by oil and gas exploration, which is likely to be near or on Lake Edward, would be the threatened large mammals and birds, many of which are species important for the tourism industry.

The third aspect of the report looks at modeling where habitat sensitive to oil and gas exploration is likely to occur and then assessing how routes to the lake shore with potentially increased traffic might affect these sensitive areas. This shows that some access roads/tracks would have more impact than others on sensitive habitat, in particular severing corridors linking the landscape, and there would be a need to get a better estimate of the impacts away from these tracks of increased traffic before deciding which ones to use.

The fourth component of the report documents existing impacts that have been observed in the GVL as a result of oil/gas and geothermal exploration. This section gathered inputs form various stakeholders about the impacts that have been observed. Of note is that many practitioners concluded that there were few impacts but it is concluded that this shows a lack of training in knowing what to expect rather than there being few impacts.

The report concludes that the Greater Virunga Landscape is exceptionally rich in diversity and in species of global conservation concern, It is one of the top five sites in the World for these conservation values. Any development within a protected area will affect at least one species of conservation concern and the more sensitive species and habitats are found around the lakes, which is where oil developments are most likely to occur. Assessment of existing impacts that have been small-scale show that the clean up after operations is not up to global standards and that even with these small scale developments residual impacts remain several years after the operation. EIA documents were unavailable for the most part and nobody appeared to be monitoring whether companies were following the recommendations of the EIA reports. Given and oil/gas production in the landscape would have significantly greater impacts we would therefore recommend that production does not go ahead in the landscape but that alternative income generating options such as greater promotion and management of tourism be explored.

Table of Contents

INTRODUCTION

The Greater Virunga Landscape has faced historical and continuing threats due to armed conflict, population pressure for land, poaching (international trade and game meat) and fluctuations in political support for conservation. As a result, protected area managers, in conjunction with conservation organisations, have initiated a number of on-going support programmes. In recent years additional threats have emerged, including artisanal and industrial extraction—primarily natural resource mining and energy production.

Exploration for oil and gas, together with potential geothermal sites, are two specific new threats that existing conservation management programmes in protected areas are ill-equipped to manage because of a lack of knowledge about, and a lack of resources to monitor the industry. These activities involve not only direct threats to the continued integrity of these landscapes through the development of infrastructure, but also indirect threats as the scale of the investments and resulting developments is predicted to change the nature of the entire region (settlement patterns, socio-economic status, industrial landscape, etc). This developing situation gives rise to an urgent need to better understand both the nature of the new threats and the ability of the landscape to absorb the developments, whilst ensuring that the overall integrity of the landscape and its ecological functions, component habitats and species can be maintained.

Background

The Greater Virunga Landscape is one of the most biodiverse landscapes in the world and is thought to contain more vertebrate species than any other landscape in Africa. Straddling the borders of Democratic Republic of Congo, Rwanda and Uganda, it encompasses a great variety of habitats and high species richness due to its altitudinal range (600-5,100 metres a.s.l.). A large part of the centre of the landscape is made up of savanna grassland and woodland in the sedimentary basins of the Rift Valley within the Virunga and Queen Elizabeth National Parks, a habitat bordered by uplands of tropical high forest. Nine protected areas are included in this landscape, including three World Heritage Sites, one Biosphere Reserve and one Ramsar Site (see figure 1). The protected areas are managed by the Institut Congolais de la Conservation de la Nature (ICCN) in DRC, Rwanda Development Board (RDB) in Rwanda and the Uganda Wildlife Authority (UWA) in Uganda. The Wildlife Conservation Society (WCS) works with each of these protected area authorities in all three countries.

These natural features of the Landscape are valuable as the basis of a thriving tourism industry which in Rwanda and Uganda form the primary source of foreign currency for the country, dependent on the scenic beauty of the spectacular and varied landscape and the wildlife it contains, including some of the most iconic or charismatic species in the world today.

Objectives

WCS has already been active in assisting the governments and protected area authorities in the Greater Virunga landscape to prepare for oil and gas exploration and production. This project, funded by the Greater Virunga Transboundary Collaboration

(GVTC), with funding from the Government of the Netherlands was developed with the following objectives:

i) Determine the potential adverse impacts of the oil/geothermal industry

ii) Determine, map and delineate a suite of biodiversity targets that are sensitive to, or likely to be affected by adverse impacts of oil/geothermal industry

iii) Based on the suite of biodiversity targets, model scenarios of adverse negative impacts that would be used by decision makers to avoid conflicts and balance trade offs

iv) Document any adverse negative impacts reported by the PAAs and other stakeholders in the area of scope.

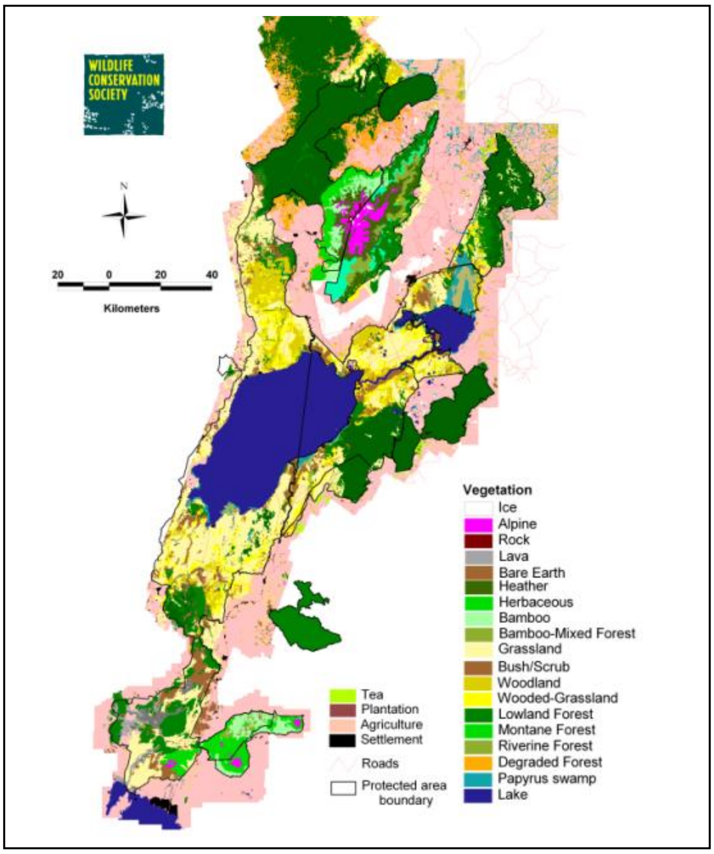

Figure 1. Map of the Greater Virunga Landscape showing the varied habitats to be found here.

This report addresses the first two objectives, giving a summary of the types of impacts that are possible, and how to plan for them if oil and gas exploration or production goes ahead. It also assesses the distribution of species of conservation concern in the GVL and identifies which areas are critical for their conservation. Whilst recognizing that energy security is essential for the countries of Rwanda, DRC and Uganda, such development can result in high costs both to communities and the environment.

OBJECTIVE 1: TYPES OF IMPACT TO CONSIDER

Whilst the social and developmental impacts of energy development projects can be large and likely to negatively affect human populations, either directly or indirectly, this review is primarily designed to consider the biophysical effects of development on the landscape and on its biodiversity. A separate specialist review of social impacts is recommended, however, this review will include the impacts of social change (in-migration, changing socio-economic environment) on the biophysical sphere.

When considering impacts of development it is normal to look at the different stages of development (at which the scale and type of impact differ considerably). Whilst it is certainly important to identify and distinguish impacts at each stage of the process, awareness of impacts from the full life cycle is critical, bearing in mind that different stages may be occurring concurrently in adjacent oil fields or geothermal locations.

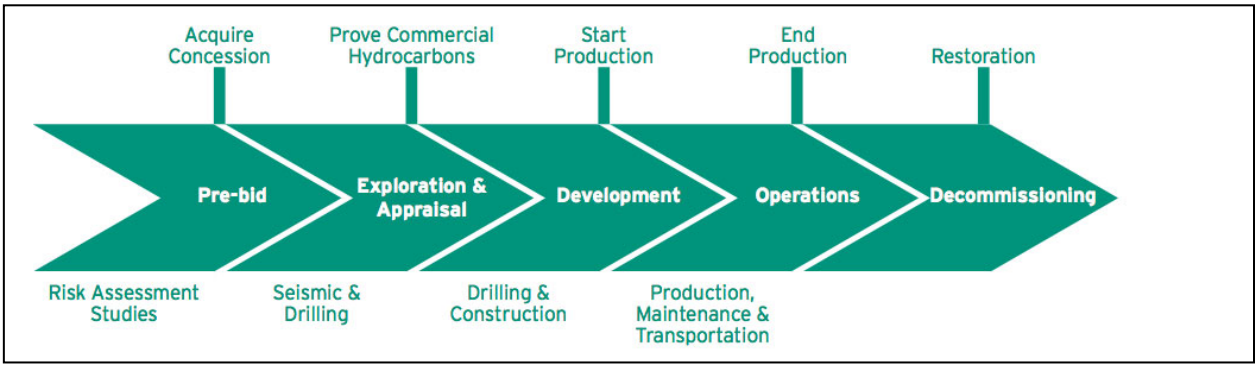

Figure 2. Typical stages of development in the oil and gas industry

It is also possible to consider development from the standpoint of activity type, i.e. development of well pads, field processing centres, accommodation centres, pipelines, roads and each of these developments will normally require an ESIA to be approved by government.

However, within this document, we will instead group the activities according to the category of impact. We will consider the effect within the landscape of the following specific and distinct impact types:

- Increased Access
- Fragmentation of habitats
- Land-take and lake clearance
- Pollution (includes noise and light as well as chemicals, spills and waste)
- Construction activities
- Human presence – avoidance and habituation
- Potential conflict

Oil and gas activities have been considered in conjunction with geo-thermal activities as many of the same impacts may occur. Geothermal developments do also require exploration, drilling (into the steam or brine reserves), production activities and power plant but will omit seismic, pipelines and refining capacity. Geothermal operations tend to differ in their scale of operation and in the need to locate a power generating plant very close to the geothermal source (ie typically less flexibility over siting of associated infrastructure than with oil and gas operations). Mention is made in the text where specific differences arise for geothermal and also for any potential offshore activities.

The following issues are considered highly important and should be borne in mind when looking at any of the impacts in a spatial context within the landscape:

- Inter-relationship of impacts - Cumulative, secondary/indirect;
- Time frame: temporary or permanent (as it relates to changes in habitats and species decline over time);
- Normal operations or accident & emergency situations;
- Boundary of scope of impacts (e.g. from site-only through to wide impacts such as climate change);
- Effect of demographic change induced by energy industries, including in-migration and population increase;
- socio-economic change, differential wealth distribution and unemployment;
- sectoral collapse in traditional resource based industries (often due to a combination of effects, including over-extraction of resources, increased access to markets, price rise due to competition for resources)
- Ecology: inter-relationships between species and habitats, food supplies, breeding areas, migration routes, predator/prey relationships and potential feedback loops;
- Vegetation and soil impacts: removal gives rise to both soil erosion and siltation and therefore can threaten ecological integrity in the whole catchment (incl. nutrient balance & microbial activity upset);

Increased Access

This is primarily through road construction or improvement, but also may include rail links or improved water transportation. This type of impact gives rise to some of the most significant effects in rural and relatively undisturbed locations and can easily be seen within forested areas where denudation and settlement occur along the line of a road and to a significant distance either side.

CAUSES

1. **Road building**

(i) Areas with no existing resident human population.

Roads allow access to natural resources in areas where previous access may have been difficult or impossible. This includes resources previously only extracted and carried out on foot, limiting the range and amount of extraction possible. A road allows access by vehicles, vastly increasing the area and quantity of resources available. Typically this will be followed by human settlement unless the road is within a Protected Area and strong safeguards prevent this.

(ii) Areas with existing resident human population.

Isolated communities may live in areas connected only by footpath, or by roads only seasonally navigable by 4WD vehicles. Road access not only opens up access to resources for extraction, but also gives the previously isolated communities access to markets to sell both raw materials and basic processed goods (e.g. firewood, charcoal, fresh and dried fish, grass, sand, bushmeat, crops and livestock)

The result of such access may be particularly noticeable within forest or inaccessible environments previously hard to access and when taken in context with a potential rise in the number of residents in an area, and increasing competition for resources.

Photo 1: Access by refrigerated trucks to the fish landing sites along Lake Albert allowed residents to catch and sell 4 times the number of fish than when they transported the fish up the escarpment by foot, according to respondents from the communities (Community respondent interview, Kaiso Village 2008)). There is further potential to sell fish to the larger resident population and oil company (photo: Tullow Oil).

2. **Railways**

Rail links tend to give a more controlled type of access and do not tend to result in the same tendency for illegal access, nor linear settlement patterns as roads, but are normally even more likely to be associated with induced development of settlements at the terminus points and with urbanisation, leading to an increased rate of resource extraction, land conversion to agriculture and a tendency for industrial development facilitated by the constant easy access provided by rail.

3. **Water transportation**

Larger, more frequent boats or ferries with higher powered engines similarly allow increased access to previously isolated settlements around lakes, many of which may be otherwise isolated and unlikely to be connected with markets.

4. **Line-cutting**

Many activities give rise to line-cutting, but the prime reason is to create temporary access for seismic activities (the lines may in fact be tracks if seismic operations use vibreosis, or thumper trucks, instead of controlled explosive charges. Line cutting is a temporary measure, but local communities may continue to use the lines long after the seismic operations have ceased.

An example of this is in Maramagambo Forest, Queen Elizabeth National Park, where despite 'dog-legging' of the line end (angling the entrance to reduce its visibility to the road), the local communities were well-aware of the entrance location and allegedly used the lines to enter deep into the forest for hunting and to set snares despite restoration attempts to scarify the ground to allow forest regeneration. This is exacerbated in vegetation types where rehabilitation may take years and be easily interrupted by the activities of illegal users.

Fragmentation

Fragmentation of habitats can be a serious cause of decline of fauna (and occasionally flora) often overlooked as the land-take involved may be minimal and the overall habitat size barely affected. However, any cause of fragmentation will tend to split and then isolate populations, and even narrow roads can cause an insurmountable barrier effect to some species and larger roads permanently separate populations formerly able to interbreed, leading to a decline in both genetic diversity (increasing vulnerability to disease) and breeding success if the resulting isolated populations are in low numbers (vulnerable to population fluctuations, climatic or weather disruptions, or other changes in the catchment)

1. **Roads and railways**

The most obvious cause of fragmentation is usually road construction, either as new roads or upgrading of an existing murram track to a hard-surfaced road with drainage and ditches. Roads may proliferate through the life of the energy project and a single habitat may end up becoming criss-crossed by many roads, starting even before exploration begins in earnest, as government and concessionaires open up an area to exploration and need to facilitate the access of large trucks carrying machinery. Outside of protected areas, induced road development is then likely to result from the increase in population and spread of settlements associated with these types of developments. With further land conversion, grazing and erosion, all giving rise to greater barrier effects.

Photo 2: New road construction in Kabwoya WR, 2008 (credit Tullow Oil)

Most mammals and some bird species view roads with extreme caution. For a simple road with no obvious physical barrier, the removal of vegetation and construction of a murram surface are enough to cause a very real barrier effect. It is clear from observing the largest mammals (e.g. elephants) how difficult and dangerous they view this whilst smaller species may not successfully cross at all. Vehicles using these improved roads will also be responsible for road kills as the grading and maintenance increases vehicle speeds.

The worst barrier effects associated with roads are in steeper terrain, such as the Rift Valley escarpments where the walls of road revetments and cuttings can constitute absolute barriers.

2. Oil and Gas Pipelines

Above ground pipelines can cause a total barrier to all species, depending on the manner of construction. Where raised from the ground surface small animals may be able to cross. In some cases pipelines may be buried, which can reduce the worst barrier impacts, although some infrastructure (e.g. power transmission lines for heating) and roads for access and maintenance will still be present and a temporary barrier during construction cannot be avoided.

Photo 3: Typical pipeline construction (source unknown)

3. Power transmission Lines

Power will be required to run operations on site for oil and gas. Whilst generator plant may be utilised in oil exploration stages, during production a constant and uninterrupted power source requires transmission lines. For geothermal and oil fired power stations, power transmission will be required. Such high voltage transmission cables have a considerable impact and will affect birds to a considerable height (dependent on the height of the lines) and interrupt forest canopy for primates.

Photo 4: power line passing through a forest with trees cleared on either side to prevent wires from touching (BPA transmission Line, Olympic Peninsula, Oregon, USA. 2008)

4. Industry infrastructure and induced development

A further source of fragmentation is the continued expansion of human influence, settlements and company sites, particularly if these have not been well planned.

Whether following a road, or scattered (roads still likely to follow later) these can give rise to a significant barrier effect.

Photo 5: Fragmentation due to growth of settlement and oil company infrastructure, separating the Kabwoya WR from Lake Albert, the only water source during dry season for some large mammals (credit S. Prinsloo)

Land Take

Many activities throughout the life of an energy scheme will result in land take. Land take becomes more significant when there is high population pressure and a lack of good agricultural land, particularly in the vicinity of Protected Areas. In the Greater Virunga Landscape there is the additional pressure of the need to conserve the diversity of habitats and in large enough areas to allow the associated rich biodiversity and Landscape species to thrive. Land take by industry and the associated population increases obviously concentrates the pressures into a decreasing area of natural habitat, exacerbating degradation and conversion.

Typical impacts of land take beyond the significance of pressure for land are the impacts of land clearance on increasing erosion, hydrology (increased surface run-off and sediment loads), soil and soil biota changes.

Land take at Exploration Stages

The first noticeable landtake will occur with the initial exploration activities, including seismic and 'wildcat' drilling (usually the first 1 or 2 drill sites before the presence of oil is well-established), followed by a scaling up of activities with a multi-drill site field exploration programme once the presence of oil is indicated. This may involve

Photo 6: suspected diesel leak remaining from geo-thermal survey work at Katwe-Kikorongo site (photo: Louise Johnson)

only temporary use of land for drill pads, site offices and other infrastructure, camps and access roads, with restoration and return to the habitual users, or to the Protected Area Managers, after activities cease. However, often sites may end up being contaminated and unable to be used, where companies violate the terms of their ESIA license and government inspections are not vigilant. This was experienced during early exploration in the Semliki Valley, with sites abandoned without clean up, (pictures 6 and 7) and effectively the 'land-take' either becomes semi-permanent, or the community and/or wildlife continues to use the site but suffer from the effects of the contamination.

In some cases, where a site contains recoverable resources and production is expected to proceed following completion of the exploration stage, the infrastructure and perimeter may remain secured and the site 'mothballed' for later use (access roads remain and security will be left in place).

Photo 7: abandoned camp equipment at Turaco-3 (Photo: I. Owiunji

Production

The footprint will now be considerable causing problems in places where natural habitats are under pressure and human population pressure for land is also high. The amount of landtake required needs to be quantified and should include an estimation of the likely level of additional landtake from induced development (or preferably include measures to be taken to limit induced development to acceptable levels – this will need government buy-in and land-use and zoning plans). It should be noted that some of the aspects of development might be quite flexible in terms of location (e.g. accommodation), whilst other elements have limited potential for alternative siting (e.g. oil wells, geothermal plant).

The production phase is typified for both oil and gas and geothermal by two activity types: construction and operation. During construction the landtake directly by the energy industry is expected to be larger as the construction workforce must be accommodated and locations found for the construction plant and equipment, borrow pits, sand, lime and other raw materials (which may involve additional temporary road building). The land take is usually also larger than the final site size as room is needed for manoeuvring large vehicles around the site boundaries and vegetation clearance and soil compaction may be carried out over a much larger area than the size of the site itself. The construction phase itself can take several years.

During operation and with good management the associated effects of the industry (pollution, human disturbance, etc.) may be reduced to acceptable levels and the land take fairly stable throughout the life of the project. Where care has been taken to control erosion, pollution and other off-site effects, the operations may be efficiently managed to minimise disturbance from landtake. However, this is when the induced impacts will become noticeable (may exceed the industry effects by a factor of 10) and if precautionary or mitigation measures have not been put in place, the effects can be disastrous. It will be difficult for companies to accept responsibility for such induced or secondary impacts and with government departments usually underfunded and unaware of the potential outcomes, the lack of responsibility for action can leave a very large gap between the desired, or planned, and the actual conservation outcomes.

The footprint is likely to include all of the following aspects:

(i) Roads
- Permanent access roads into area sufficient for large machinery and oil tankers,;
- distribution roads between sites, camps and other infrastructure locations and nearby towns or trading centres (some may be temporary, but tend to proliferate);
- pipeline and transmission maintenance roads;
- access lines for seismic (temporary)

(ii) Plant
- Well pads,
- mud pits and water storage pits
- central processing plant and topping facilities,
- pipelines,
- water offtake or well locations,
- power plant,
- refinery,
- oil storage and transport centres (at site and also at pipeline bulkhead),
- vehicle yards and plant maintenance sites,
- communications infrastructure (e.g. mobile company mast locations),
- Offices

(iii) Waste facilities
- Solid unhazardous waste and recycling facilities,
- waste mud and cuttings pits,
- produced and contaminated water storage pits,
- hazardous waste containment and disposal facilities (including for crude oil wastes from well site, processing plant, power generation facilities and refineries, typically 70% of oil quantity in total)

(iv) Support facilities
- Accommodation camps for shift workers and visitors
- Medical facilities
- Permanent housing for staff
- Kitchens and other camp logistics, storage areas (refrigerated)
- Airstrip & port facilities

- Storage & safe areas
- Oil/gas/water separation equipment
- Export & storage facilities

Important aspects to include in the siting of all of these facilities will need to be considered for the choice of location: eg. potential loss of habitat, visual intrusion, disturbance to local population, wildlife and habitats, transport and access, topographical and hydrological considerations, including erosion and wetland or groundwater contamination risks, physical interruption of catchment or other hydrological processes, likely size and siting of induced development.

Consequences of land take on animal populations

Increases in local populations and the development of sites for the industry bring people and industry into contact with formerly undisturbed animal populations. Most species will tend to move away from the disturbed area, provided there is sufficient remaining habitat to maintain healthy populations and the land take is not too large, however some species have proved to be attracted to development sites and sites of human habitation. This clearly leads to a number of consequences detrimental to both people and wildlife.

- Antelope species tend to move only to a point where they are still able to observe the 'danger' in common with normal prey behaviour.
- Many species, including elephant will be attracted to disturbed ground as this can be rich in minerals (soil stockpiles, murram piles and murram pads for drillsites).
- All species may be attracted to mud and water pits especially in the dry season.
- Many species are quickly adaptable to human presence and learn to scavenge for food from human waste pits.
- Some species are attracted to lights at a site where operations can continue both day and night under floodlights

In all well sites in Uganda, reptiles, amphibians, small mammals and birds have been found within well pads and waste water and mud and cuttings pits (all potentially contaminated) and the oil companies have failed to find a solution to date. Within MFNP elephants have broken through fences to reach water pits and crocodiles have had to be relocated from mud pits on numerous occasions. Antelope have been found with their horns stuck in chain-link fencing and some birds have been found poisoned around pits.

In the case of local communities, juxtaposition of animal and human communities generally leads to an increase in human-wildlife conflict, and potentially disease transfer (both ways). Animals are exposed to the effects of human, domestic and medical wastes, with consequences to their health (including reproductive health) and again will become habituated causing increasing problems as they lose their fear of humans.

Decommissioning

Decommissioning of a site following production is on a very different scale to the simple restoration activities following temporary use of a site at exploration stage and may take many years. It will include the removal not only of the large plant, including factories, power plant, refineries, etc, but will also involve retrenching of a work force, the redeployment of company technical personnel and significant business and job losses for industry and service that has grown up reliant on the presence of the energy production industry. This is normally associated with a significant slump in the local economy and where funds have not been wisely invested in the development of other sectors in the area, will result in hardship and poverty for many of the resident population – once again potentially increasing reliance on the non-monetised natural resource base. Decommissioning if poorly carried out and underfunded often results in significant residual impacts and contamination, especially where disposal of hazardous wastes have not been clearly stipulated.

Restoration plans and decommissioning plans must be included in the ESIA and EMP on application for licenses, and these sections should be carefully checked to ensure that the plans are through and detailed. Simple statements that the site will be restored to pre-operation status is absolutely unacceptable without detailed plans as to how that will be achieved. A preferred approach is to insist that companies put aside sufficient funds for decommissioning and restoration prior to commencing development (this can run to many millions of dollars for a large project).

Pollution

There are many potential causes of pollution. In every case the resultant impact will depend on the sensitivity of the receiving environment and the specific aspect (habitat, species, physical receptor) under consideration. In practise it is helpful to have a matrix of potential impact types and then list all the potential receptors and consider the impacts on an individual basis. Given here is a list of the potential causes of pollution and examples given for the likely effects.

Noise

Both people and wildlife are strongly susceptible to noise which can have a number of different impacts. For people noise can be a nuisance, a cause of sleep deprivation and in extreme cases can result in damage to hearing. Most energy operations continue on a 24 hour basis, particularly during drilling and construction operations, where hire of plant and personnel is costly and companies want to limit the hire period. Noise is also an issue in aquatic environments (see separate section on offshore impacts) but little is known about the effects in a lacustrine environment as most studies have been in marine environments.

Sources of noise include

- low aircraft during initial aerial surveys
- vehicle traffic including large trucks and generally increased traffic due to potential population increase
- Construction equipment
- Generators and other power plant

- Fabrication and maintenance equipment and plant including welding and steelworking
- Seismic operations including either detonations of explosives or vibreosis
- Drilling rigs and hydraulic impact drivers
- Flaring and burners
- Central processing plant and oil refinery
- Human voice levels, music, films, etc.

The effect on animals can be similar to humans, however most species will move away from the source of noise if able to. This can disrupt normal patterns of behaviour and spatial distribution of animal species. Many species are reluctant or unable to move, either because they are territorial or restricted range species, because the habitat available to them is limited, or noise impacts occur during the breeding season and nest/den sites cannot be abandoned. Any cause of animals moving out of the area of operations may also increase human-wildlife conflict in surrounding areas, depending on distances and areas of suitable habitat involved.

Noise can effect animal and bird species by preventing them from hearing vocalisations which can interfere with feeding, breeding and even alarm calls and gives rise to significant amounts of stress which can impact health further. Differential sensitivity to noise frequencies hampers our understanding of the impacts, although it is known that elephants are sensitive to lower frequencies which resonate to a greater distance (potentially to 32km).

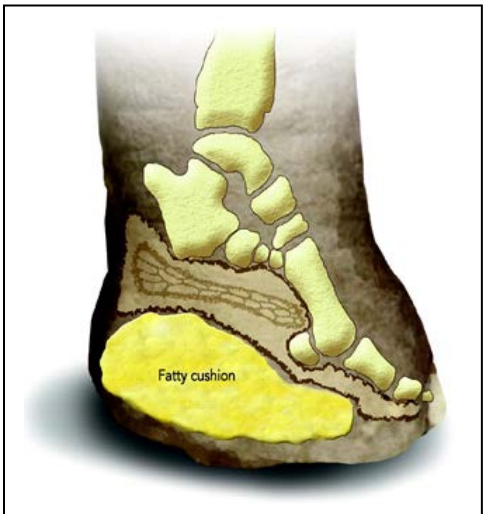

Figure 3. The cartilaginous fat pad that is located in the heel of the elephant foot has similar properties to acoustic fat found in marine mammals, which may facilitate impedance matching of signals between the ground and the elephant's body (O'Connel-Rodwell, 2007)

Allied to noise is the effect of vibration, caused mainly by large machinery, vibreosis trucks and hydraulic ramming (to insert the first pipe for drilling). The effects of vibration have been studied in elephants and shows that they do move away from seismic operations up to 4-5 km away in Murchison Falls National Park. Whether this is due to the vibrations, noise or the presence of people undertaking the work is unclear and responses may be greater where elephants are more nervous of people.

1. **Light**

Studies have shown that light during night hours can interrupt sleep patterns and give rise to fatigue in humans. The same effects have been observed in tests on animals.

In addition light can disrupt patterns of behaviour. Oil and gas and geothermal sites tend to have permanent bright light at all sites, and even a single drill rig can power lights the equivalent of a village. Some relief can be gained by insisting that the company involved installs shielded lights, which only light the site within the perimeter and which avoid raising background light levels, and preserve dark night skies.

Insects are attracted to light sources, which in turn attracts nocturnal species towards the source of light, increasing their exposure to other potential sources of harm. Nocturnal species are often particularly sensitive to light and the intense light usual on such sites can interrupt their navigation ability and cause temporary blinding.

Chemicals and toxic waste

Whilst the oil and gas industry is most notoriously associated with major spills or accidental flaring, the effect of a chemical spill on site can be more harmful in terms of toxicity, longevity of impacts and as a cause of mortality, and is certainly more common. Whilst the major components of the muds used for drilling (lubrication, cooling and lining the well) are generally inert, chemicals used in the operations (particularly during drilling but also for maintaining wells, pipelines and plant during production) include some particularly toxic substances.

Main sources of contamination:

- Overflow during rains from mud, cuttings, wastewater pits or chemical or fuel containment bays (photo 8),
- Leakage from a breach in the containment material of mud, cuttings or wastewater pits (concrete may deteriorate or crack, flexible liners or membranes may be physically damaged or cut, sometimes containment of lower toxicity substances may be just within a soil pit, although this should not be allowed).
- Accidental spillages during activities, of chemicals or fuel on site
- Liquid discharges - sanitary waste disposal, sewage, camp waste water, muds & cuttings, wash-water
- Solid waste disposal, either stable waste, contaminated industrial waste, medical or domestic waste. This will include the cuttings from the well normally separated from the water and stabilised prior to disposal (typically 100-5000m2 per well) and potentially radioactive and contaminated with heavy metals.

Photo 8: US Geological Service study, Oklahoma:

- Produced water stored in ‘brine pit’
- Pits overflow in heavy rain
- Salt scars caused down slope
- Vegetation & trees died
- Water runs into lake

(http://pubs.usgs.gov/wri/wri03-4260/)

Particular mention should be made of two common sources of contamination:

(i) process water (fresh or brine) resulting from processing or refining activities or from power generation which is often contaminated but also at a high temperature. and should not be returned directly into an open water body without first cooling and testing to ensure that there is no contamination requiring separation or treatment (see also water abstraction);

(i) produced water which is separated from oil following extraction and prior to processing and which may be heavily contaminated with heavy metals, radioactive isotopes and is usually very strongly saline. Disposal of produced water is a common problem worldwide and particularly within aquatic environments where it will need to be returned to shore unless immediately used in injection wells. Production water may be used in processing or refining to reduce additional abstraction, but will still require disposal afterwards. By the end of the life of a well, the produced water-cut approaches 80% as the oil cut declines. Typically 2,500 - 40,000m^3 per day in UK North Sea fields

Geothermal operations also result in produced water (cooled steam or brine), and process water, both of which require cooling and safe disposal following power generation through heat transfer.

Effects of a chemical spill include:

- Soil and groundwater contamination (this can also occur in deeper aquifers if the well pipes do not effectively seal subterranean aquifers).
- Contamination of open water bodies (lakes and rivers) from overground run-off and direct discharge (accidental and planned) into water bodies.
- Ill heath, possible reduced reproductive success, or even death of people, livestock or wildlife from ingesting contaminated water, crops or from the direct effects of exposure to a spill (NB animal ingress into mud and wastewater pits is almost impossible to prevent).

Effects depend on the toxicity, the time taken for the toxicity to reduce to safe levels, and the sensitivity of the receptor.

Oil spills

This is a potentially serious threat to habitats and species (no geothermal equivalent). There is no clear cut correlation between size of spill and extent of damage (affected by oil type, location character & sensitivities, etc). An oil spill can occur as a result of a 'blow-out", ie loss of containment of the pressure in a well (on or off-shore depending on well location), from leakage from stored oil within tanks (central processing facility, refinery or distribution bulkhead), or through transportation by truck or pipeline. Amounts may be small but continuous as well as single major events.

Photo 9: Water pumping station on Lake Albert with stored diesel for generators (credit Louise Johnson)

Containment on land is easier than water.

- Terrestrial containment: clean up of soil & proper disposal
- On/near water: initial impact from minimal to extensive
- Transboundary: a spill from a Ugandan rig could impact DRC shore.

The chance of a major well blow-out scenario in the Greater Virunga Landscape appears to be low, as the oil is held in small quantities in shallow deposits and is consequently at a relatively low pressure. However mistakes can still lead to accidental flowing and possibly flaring of oil and gas. Highly likely is the potential for accidents during transportation, with accidents on the escarpment in the case of oil tankers (or rail containers), or damage to pipes either through earth tremor or earthquake (crossing of fault lines) or through hostile damage to the pipe, as has occurred in the Nigeria Delta area.

(i) Potential impacts from oil spills:

Additional pressure on sensitive areas:

- Lake environment with lower energy to weather the oil
- Seasonality risks: breeding times, presence of migratory species, seed germination, etc

Heavy oil, or oil with a high wax content (as found in the Murchison-Semliki Landscape) will lead to organisms killed through smothering rather than toxicity. An oil spill can decimate wetlands, marsh or swamp forest. These are areas with high biological productivity and able to absorb pollution from the water environment, but they make the worst oil traps (burrows & stems).

Oil soaks into sediments leading to longer recovery times

- Toxicity is still a problem: ingestion by wildlife (including water and migrating birds) dependant on wetlands
- Contamination of fish & shellfish
    - Concern regarding tainting of flesh, carcinogenic compounds
    - Community food & export implications

See IPIECA Guidelines on biological impacts of oil pollution - species specific sensitivities

(ii) Potential oil movement on lake:

Oil spill modelling scenarios should be completed for lakes prior to any offshore drilling programme. Oil movement and behaviour would depend on prevailing conditions (wind, water temperature and pH).

At risk are:

- Numerous lakeside communities - water supply, livelihood & food
- Ancient lake: unique biological communities
- Spread and concentration of oil towards lakeshore wetlands and river deltas used by birds/wildlife.

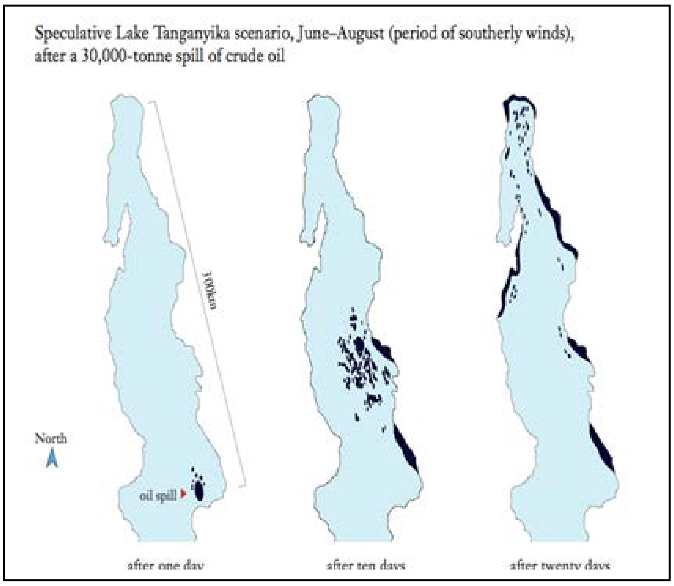

Figure 4. Scenario uses 30,000 tonnes (220,000 barrels or 34 million litres approx.). Credit: IPIECA

(iii) Potential Oil spill on land

The characteristics of a pipeline rupture spill or the spread from a well 'blow out' will depend on prevailing terrestrial conditions, soil type, steepness, depth to watertable, location within the catchment, which will affect how quickly the oil can spread and soak into the ground. The characteristics of the oil, its flow potential and any contaminating factors should also be factored in.

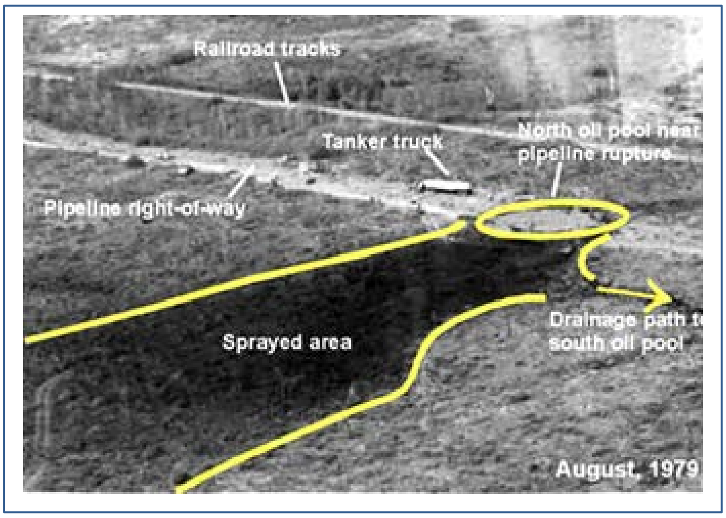

Figure 5. 1979 pipeline rupture Bemidji, Minnesota, US (10,700 bbls released, spray towards wetland). After clean-up 2,500 bbls crude oil remained in sub-soil.

Air emissions

Produced gas is <u>the</u> most significant source of air emissions from E&P operations, Gases are sold, re-injected, flared, or vented [preference in that order]. Release of these gases is not good from a climate change perspective, but dangers also include potential combustion, asphyxiation and long term health effects. Main gases include:

- Carbon dioxide from flaring combustion is the primary emission (& power generators, heaters, etc)

- Fugitive emissions from valves & process contain primarily methane (21xGWP than CO2)
- Emissions also include carbon monoxide, volatile organic compounds and nitrogen oxides
- Emissions of sulphur dioxides and hydrogen sulphides depend on sulphur content of the HC and diesel fuel.

Flaring causes_additional noise, light, emissions (combustion of HC's) and non-combusted oil dropout & soot.

Photo 10: Waraga oil had a lower gas:oil ratio than anticipated. Following initial burning, the oil was stored in a pit for later disposal (Tullow Oil)

Water Abstraction

There is a large requirement for water in oil and gas production processes. Significant quantities of water are used during drilling and construction, and this increases during production, particularly with an oil refinery. Refineries are normally constructed near to coastlines due to the efficiencies of transport and also the plentiful supply of water. Requirements for water include:

- Domestic use in camps and for cleaning and medical, vehicle washing etc.
- Drilling phase - typically water abstraction from lake or can be from groundwater and is used to cool and lubricate the drill bits
- Oil refining
  - water abstraction for washing out salt water from oil
  - At its peak = 5000 bbl per day (1 bbl = 42 gallons)

The most obvious and reliable water sources will be from lakes, although groundwater aquifers can be used if available with a sufficient reliable quantity of water. Both sources will have potentially serious consequences.

- Water abstraction sites close to the lake edge increase the footprint on the lake environment and increase the pollution risk. A large off-flow may cause death to fish and other aquatic species in the area.
- The quantities of water required may exceed the recharge rates, lowering lake levels over time (and current calculations may not be valid if there are changes in recharge rates caused by climate change or catchment water flow)

- Without a clear understanding of the subterranean water resource, use of aquifers can cause problems with local wells relied on by communities, and with general ground water levels (potentially including lake levels)

Social Impacts Through Life Cycle

These are usually classed as 'secondary' or 'indirect' impacts, as they are not actions carried out by the oil industry, but are a response to them. The effect of social impacts on the environment tend to be unpredictable with any reliability and also more complex as impacts may be beneficial in the short term but through increased pressure on the environment become negative in the longer term. A good example of this is the fishing industry in Lake Albert. Improved roads, access to markets, healthcare and schools resulting from the oil industry were hailed as beneficial impacts, however the result has been a significant increase in fishing effort and subsequent crash of the fishery, with most former fishermen stating they are now unable to catch enough fish to survive, but that there are no alternative employment prospects and less natural resources to rely on due to the increased population. An increase in poaching and firewood extraction from the Bugungu WR has been one consequence. The following list illustrates just some of the potential consequences and interactions.

- Contact with new diseases, cultural differences, prostitution, conflicting pressures, etc ;
- Rise in local prices due to competition and increase spending power of incoming and often wealthier populations (especially the industry personnel), local people not well-placed to compete and poverty levels increase;
- Increased burden on local resources e.g. logging, hunting, water abstraction, etc
- Growth of unplanned settlement, with increased pollution and waste
- Potential conflict

An incoming population are likely to be of a different ethnic, cultural and educational background to the resident population, potentially leading to conflicts. Conflict in an area (and increase in security personnel) is a prime cause of environmental degradation in its own right. The most common source of conflict is real or perceived access to resources (including land), services, employment and wealth.

Offshore Impacts

Many of the offshore impacts will be similar to onshore impacts and have been included in previous sections. But the lacustrine environments do pose considerable extra challenges as an operating environment which are worth highlighting.

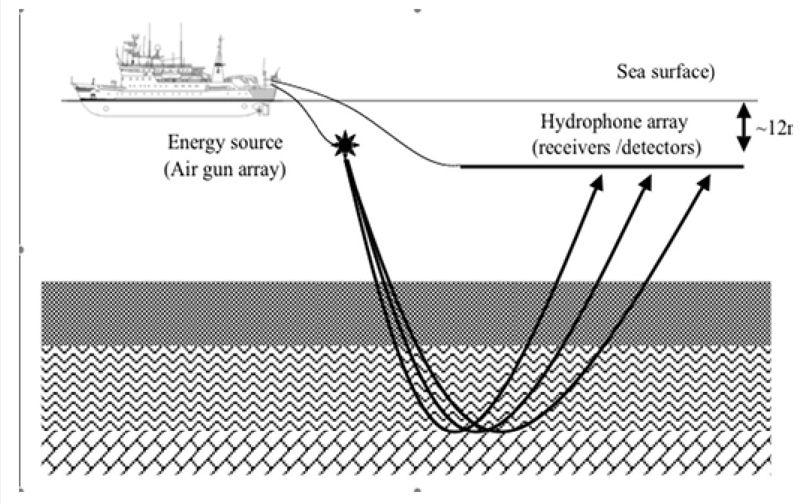

Figure 6. Typical offshore seismic operations

Potential impacts from boats and oil platforms are listed here – however it should be borne in mind that all examples and figures are reproduced from marine environments. Lacustrine environments have a much less dynamic mixing effect (almost no tides or waves), are shallower and clearly have relatively small total volume, thus increasing the impact from similar events. Few examples exist of extraction from lacustrine environments:

- disturbance, noise, light;
- other lake users (no-go zones, fish kill from seismic or discharges, etc);
- wildlife avoidance/mortality;
- offtake of water
  - Reduced lake water (depending on lake recharge: lake offtake levels)
  - Shallow aquifer - reduces water available at boreholes for others;
- offshore discharges- bilge water and accidental chemical or fuel spillage, produced water, muds, cuttings and also domestic ‘grey’ water and sewage dumped over the side;
  - Ocean Oil-based Drilling Muds effect benthic biota 800m from discharge (Some organisms show increased hydrocarbon effects at 150ppm)
  - Ocean Water-based Drilling Muds effect benthos out to 25m (smothering);
- Damage from anchoring or securing platform on lake bed: Unknown lake bed qualities.
- Sensitive lacustrine wetland environments
- High groundwater levels
- Community reliance on groundwater abstraction

Figure 7. Offshore drilling platform: May be modular floating or ‘jacked-up’ secured from lakebed.

OBJECTIVE 2: MAPPING SPECIES OF CONSERVATION CONCERN THAT MAY BE SENSITIVE TO OIL/GAS OR GEOTHERMAL IMPACTS

Species Distribution Modeling

WCS has been modelling the distribution of species that are classed as globally threatened by the IUCN Redlist criteria (CR, EN, VU and DD) and species that are endemic to the Albertine Rift region to better identify the critical sites for their conservation in the region.

The process used to model the distribution of the species is as follows:

We estimated the current and future distributions areas for 191 endemic and threatened species using field data observations and species range maps. Species occurrence records for 147 species across 5 taxa: Birds(33), Large Mammals(12), small mammals (26), Plants(43), Reptiles(11) and Amphibians (17) were obtained from Wildlife Conservation Society surveys, Tanzania mammal data atlas , Global Biodiversity Information Facility (GBIF 2012: http://www.gbif.org/), and from personal records held by Michele Menegon, Eli Greenbaum and Julian Kerbis Peterhans. A total of 31,120 presence records were used in the modeling process, Birds (8,035), Large mammals (16,334), Small mammals (1,448), Plants (4,473), reptiles(436) and amphibians (394). Species occurrence data for each species used for model parameterization varied between 10 to 4000 records.

For species with fewer than 10 records we used a different method: Species range maps represent extent of occurrence of a species and are used for mapping species richness (Graham & Hijmans, 2006). We used the altitudinal ranges to estimate area of occupancy within the extent of occurrence by randomly selecting "pseudo presence records" for species that had few or no presence occurrence records. The distribution areas for 44 endemic species; birds (14), amphibians (15) and small mammals (15) were estimated using the randomly generated pseudo presence records.

Potential predictor variables that are likely to influence the distribution of the birds, mammals, plants, reptiles and amphibians in the Albertine rift were selected from literature. The final predictor variables used in the model consisted of 9 climatic, 4 topographical, 2 hydrological, 1 geological and 1 quantifying the influence of human activity (Table 2).

Climate layers at a spatial resolution of $\sim 1\ km^2$ were obtained from the WorldClim database (Hijmans et al. 2005; http:\\www.worldclim.org). Additional variables used in model prediction included: cloud mean, cloud max, digital elevation model, aspect, slope, eastness, northness, distance to rivers, drainage basin, lithology and distance to roads, . Cloud mean and cloud max were computed from MOD09GA Surface Reflectance data which is provided in Hierarchical Data Format (HDF) at daily temporal resolution and was calculated by G. Picton-Phillipps. A 90m digital elevation model was obtained from the USGS (http://srtm.usgs.gov/) and the slope, aspect, eastness and northness were derived as well. Drainage basins were obtained from USGS Global data set of 2003.The distance to roads and rivers were derived by computing the euclidean distance from each point in the study area to the nearest road or river. Rivers and roads data layers were obtained from the African data sampler dataset (WRI 2010). Lithology reflects key geological parent materials which are determinants in the distribution of vegetation (Source; U.S. Geological Survey/ The Nature Conservancy). All the predictor variables were clipped to the area of interest (Albertine Rift) and a pairwise pearson correlations between predictor variables were obtained using ENMTOOLs (Warren et al. 2010; a toolbox for comparative studies of environmental niche model; http://purl.oclc.org/enmtools) to minimize the effect of multicolinearity and overfitting, only variables with less than (+/-0.75) correlation were retained. Predictor variable were resampled to a 1km^2 resolution using Arcgis 9.3 for model input.

Table 2. Covariates used for modeling the distribution of endemic and threatened species in the Albertine Rift

Covariate	Description of Variable
Bio2	Mean daily temperature range
Bio7	Temperature annual range
Bio6	Minimum temperature of coldest month
Bio5	Maximum temperature of warmest month
Bio12	Annual precipitation
Bio17	Precipitation of driest quarter
Bio16	Precipitation of wettest quarter
Cloud mean	Annual normal percent cloud cover
Cloud max	Maximum cloud cover for each pixel
DEM	Digital elevation model
Aspect	Direction a slope is facing
Slope	Rate of maximum change in elevation
Eastness	Orientation East - West
Northness	Orientation North- South
Drainage basins	Topographically delineated area drained by a stream system
Roads	Distance to nearest road
Lithology	Geologic parent material
Rivers	Distance to nearest river

We used Maximum Entropy Species Distribution Modeling approach (hereafter 'Maxent', Maxent version 3.3.3e; Phillips., et al, 2006), to estimate the current and future distribution areas for endemic and threatened species in the Albertine rift. We selected Maxent, a machine learning approach because it requires only species' presence data and environmental variables(continuous or categorical), and has been shown to perform as well or better than other species distribution modeling techniques (Phillips et al. 2006, Elith., et al 2006). Maxent makes inferences from incomplete information and estimates species' distributions by generating a probability distribution of maximum entropy (ie:closest to uniform), subject to constraints imposed by the information regarding presence records and the background information across the study area (Phillips et al. 2006; Elith et al. 2011). Maxent default parameters (Auto features, convergence threshold of 0.00001, maximum number of background points

=10,000, regularization multiplier=1) were used to fit the models. However, about a third of the species were fitted using hinge features, which are functions for piecewise linear splines and fit models closely related to Generalized Additive Models (Elith et al. 2011).

Model accuracy was assessed by testing how well the model prediction differentiates between suitable and unsuitable habitat at varying thresholds using the area under the receiver operating characteristic curve (AUC) test statistic (Fielding & Bell, 1997; Freeman & Moisen, 2008). AUC is a threshold independent metric that represents how likely a random selection from a presence site is ranked compared to a random selection from an absence/pseudo absence site (Fielding and Bell 1997; Phillips & Dudík, 2008). An AUC value of 0.5 indicates a model that performs no better than random while a model with perfect discrimination has a value of 1. Model outputs with AUC values ≥ 0.8, were selected for the final analysis (Manel et al. 2001). 75% of the occurrence records were used for training and 25% for testing . After assessing model accuracy, the final models for all the species were fitted using all occurrence records. To convert the predicted habitat suitability from a continuous logistic output format into a binary (presence/absence) output , the "maximum training sensitivity plus specificity" threshold rule was used(Freeman and Moisen, 2008).This threshold rule minimizes the mean error rate for positive observations and the error rate for negative observations (Freeman and Moisen, 2008).

Mapping Species Distribution in the GVL

We then developed maps of species distributions for each taxon for the Greater Virunga Landscape by selecting the region of the GVL within the Albertine Rift region and then checking the distribution maps for each species that was found to occur in the GVL. Some maps needed to be edited to ensure they were accurate at this finer scale. We then developed maps of endemic and threatened species richness for the GVL for each taxon (figures 8-12). These results show that different parts of the GVL are important for different taxa. The endemic species tend to be found in the mountains and highland areas such as the Virunga Volcanoes, Rwenzori Mountains and Bwindi Impenetrable National Park. The threatened species are more widely distributed depending on the taxon. Threatened large mammals are more abundant in the base of the rift valley in the savanas and include species such as elephants, lions, hippos, as well as species found in forests such as the chimpanzees and gorillas. Threatened plants tend to be species that are being harvested by man and particularly timber species and so most of these are found in the forests on the escarpment above the rift valley. Threatened birds are common in the savannas because most threatened species are vultures in this landscape.

The composite map for all threatened and endemic species (figure 14) identifies the areas of higher altitude and the forested areas as the important areas for species conservation primarily. However, this hides the fact that certain taxa such as the threatened large mammals and threatened birds (many of the species that attract tourism to the landscape) are more abundant in the open savannah grasslands and woodlands as well as the wetlands around the lakes. If we are to conserve all species therefore we need to focus on all f the major habitats within the landscape.

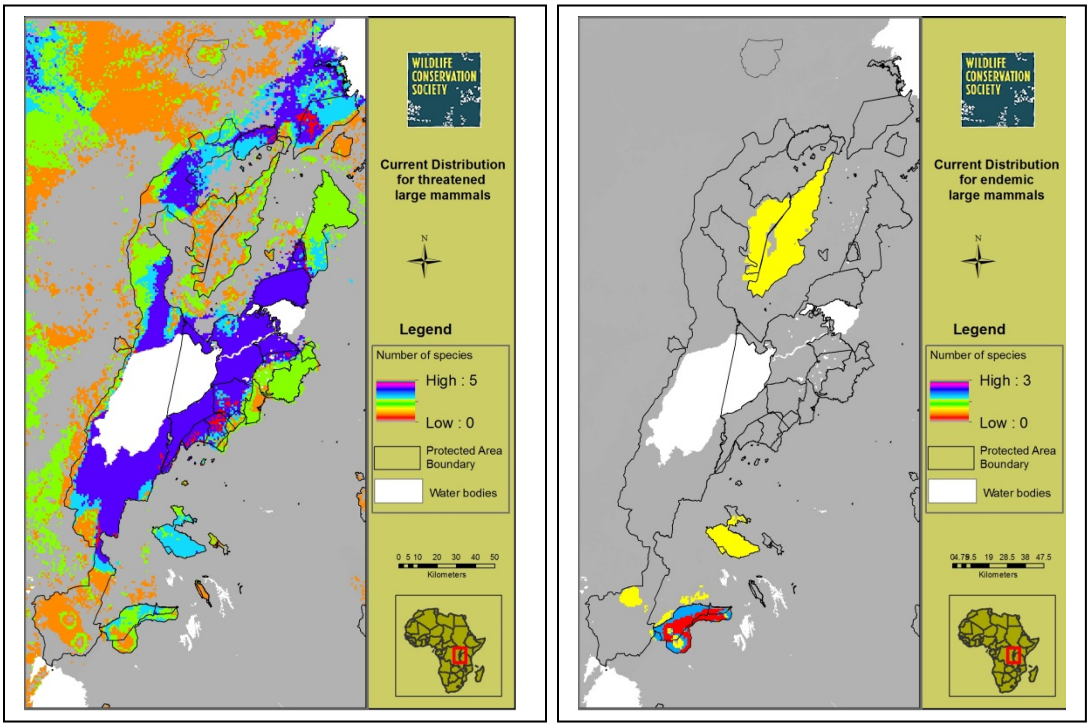

Figure 8. Map of the species richness of threatened large mammals (left) and endemic large mammals (right).

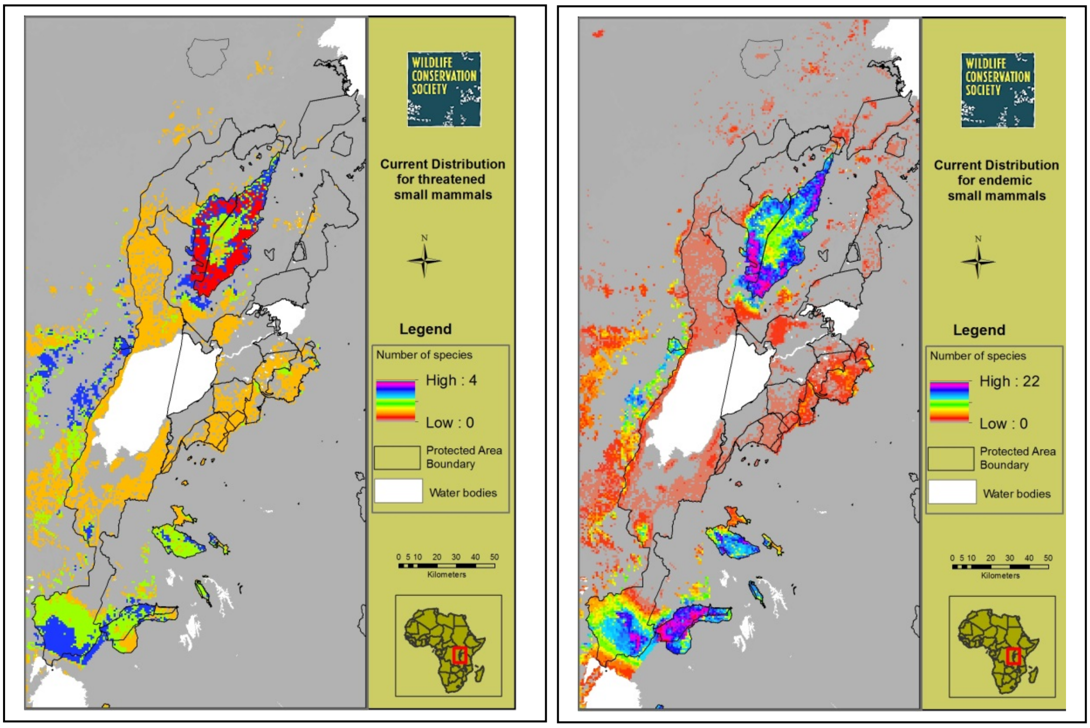

Figure 9. Map of the species richness of threatened small mammals (left) and endemic small mammals (right).

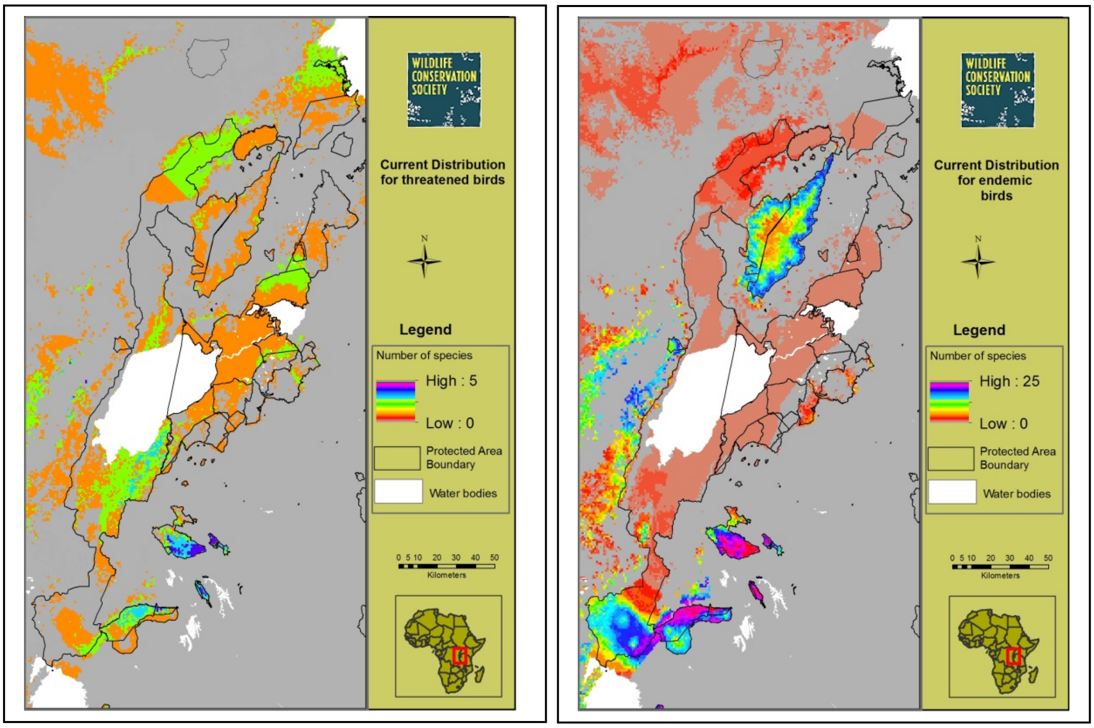

Figure 10. Map of the species richness of threatened birds (left) and endemic birds (right).

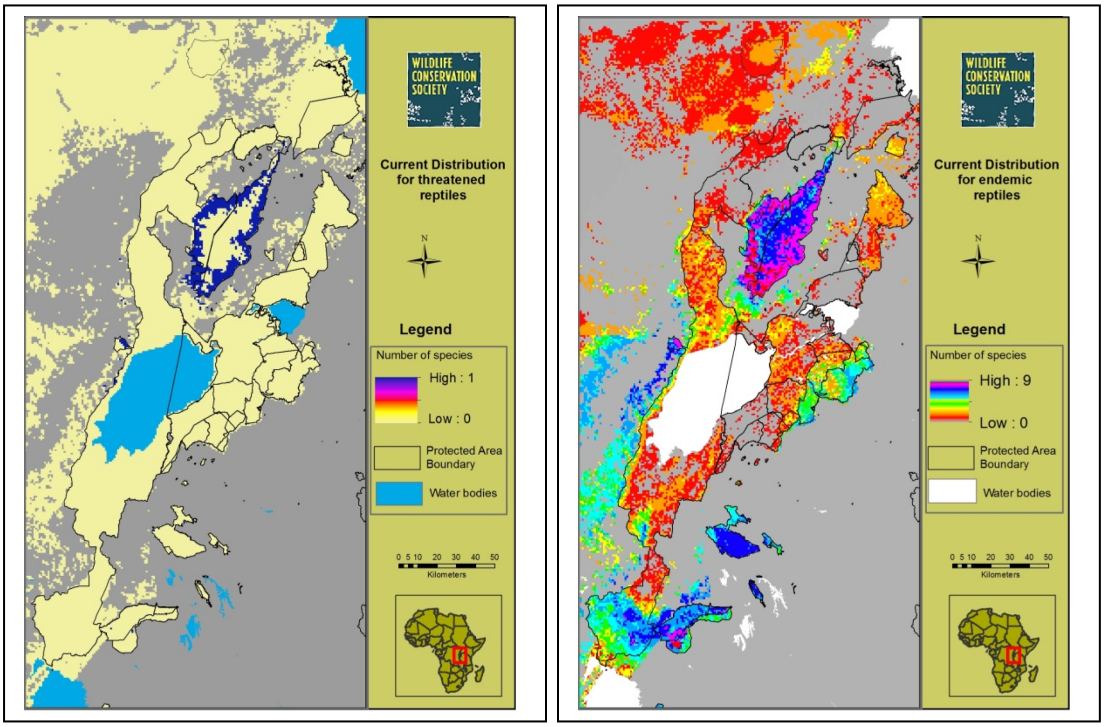

Figure 11. Map of the species richness of Near-threatened reptiles (left) and endemic reptiles (right).

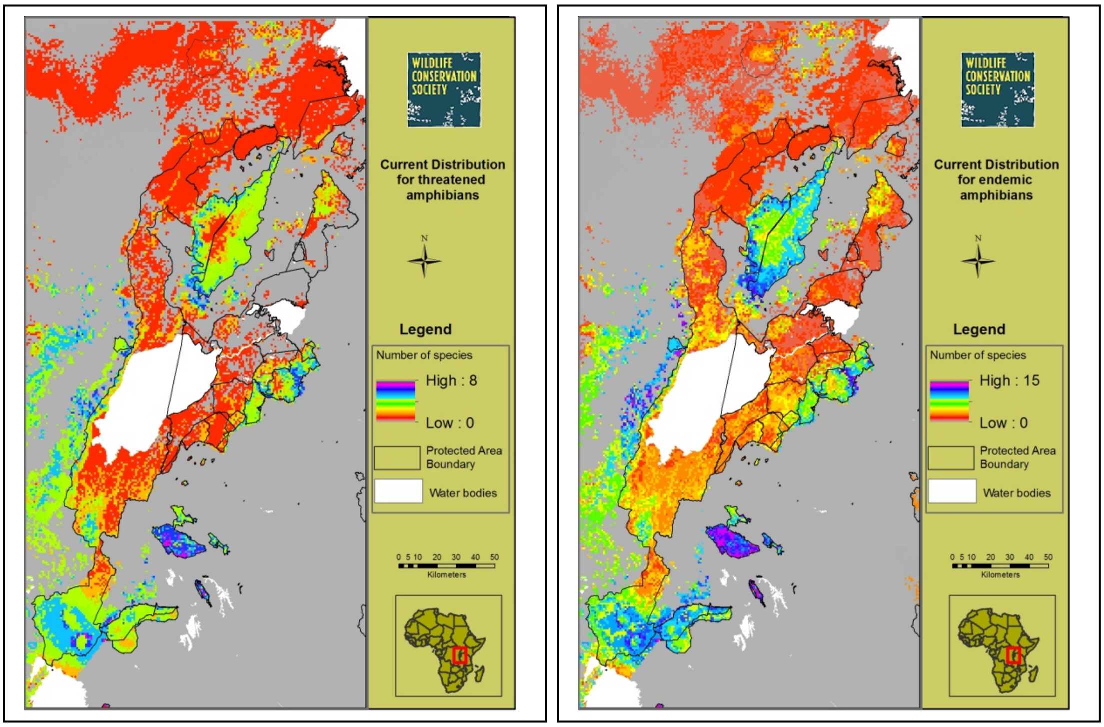

Figure 12. Map of the species richness of threatened amphibians (left) and endemic amphbians (right).

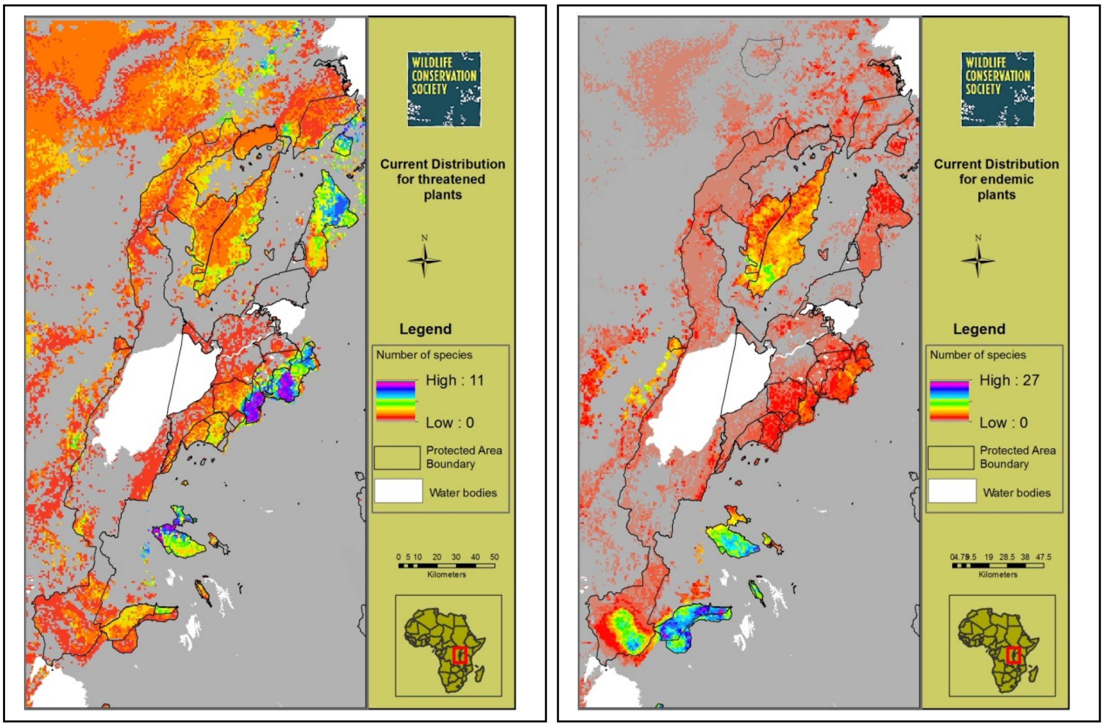

Figure 13. Map of the species richness of threatened plants (left) and endemic plants (right).

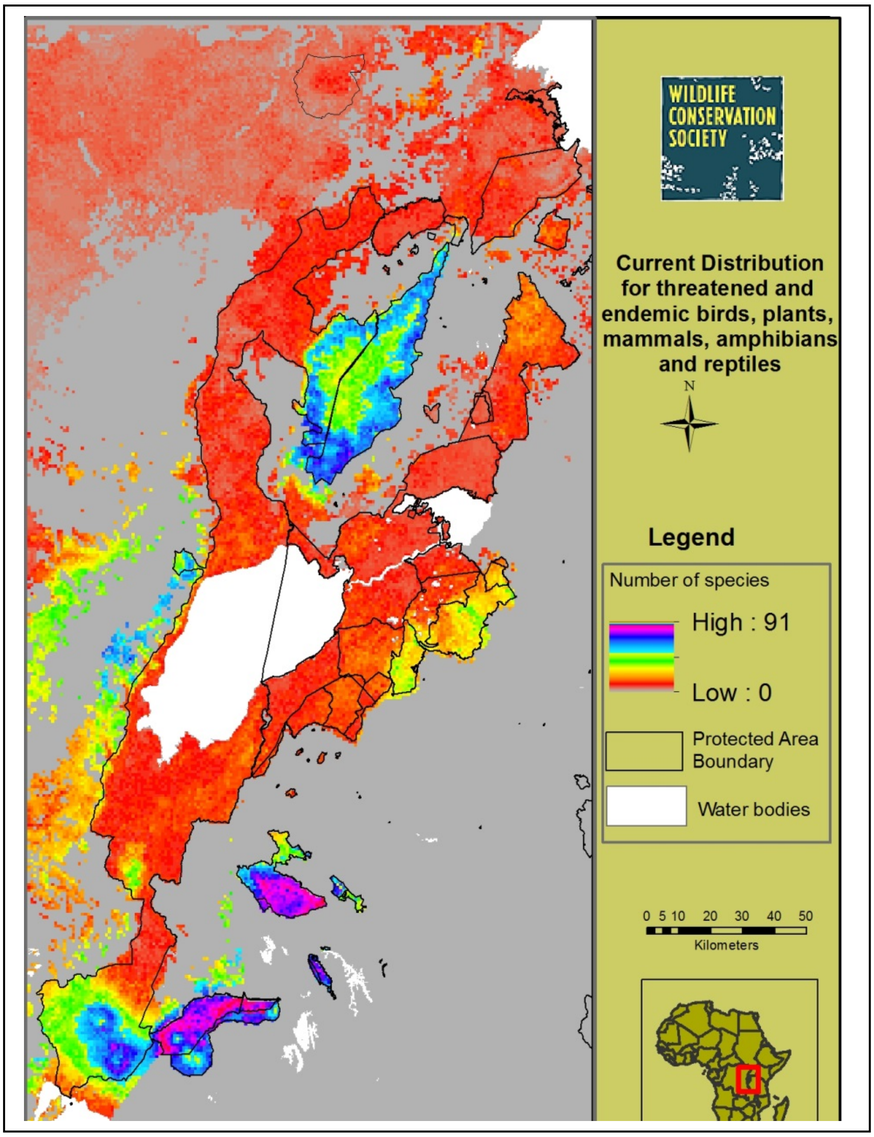

Figure 14. A composite map of the species richness of endemic and threatened terrestrial vertebrates and plants.

Species Likely to be Most Affected by Oil/Gas and Geothermal Activities

Using these maps we can assess how different activities may affect different species groups. Given that oil/gas and geothermal will take place most likely in different areas of the landscape we assess these separately here:

Oil and Gas Exploration and Production

From our discussions with the oil companies it appears that the area they believe to be most likely to hold oil or gas is under Lake Edward itself. Therefore any developments linked to oil and gas are likely to be in the savannah and woodland areas around the lake as well as the wetlands on the shores of the lake and the lake itself. These are areas where the threatened large mammals and to a lesser extent the threatened birds are relatively abundant. Threatened large mammals include species such as elephant, hippopotamus, lion, and chimpanzee all of which are species tourists most want to see when visiting the parks. Threatened large birds include both savannah and wetland species such as the vulture species, crowned crane and the shoebill stork. These again are popular with tourists visiting the area.

The lake shores are also important areas for migratory birds which feed in the wetlands and on the beaches. We mapped the wetland areas around the lakes to also highlight which areas may be important for these species in addition and also flag areas that will be sensitive to any oil spill on the lakes (figure 15).

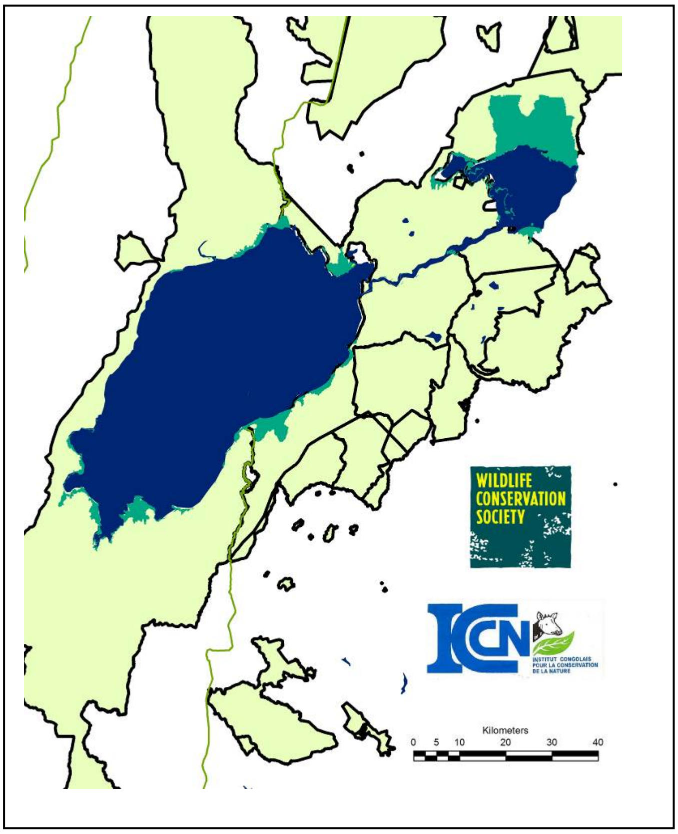

Figure 15. Map of wetland areas (Turquoise) around Lakes George and Edward which are potentially at risk of oil exploration and production.

Geothermal sites

The likely geothermal sites would be in the crater areas of Queen Elizabeth National Park (QENP) or near the active volcanoes in Virunga Park and around the Volcanoes National park. The crater areas in QENP are important for threatened large mammals and birds while the active volcano areas and Volcanoes Park are important for many of the endemic species and rank highly for all endemic and threatened species (figure 14).

What is clear from this analysis is that there is nowhere in the GVL that is not important for an endemic or threatened species. In the maps of the individual taxa (figs 8-13) anywhere where no threatened or endemic species occurs is given a grey colour. If we had only looked at the more well known taxa such as birds or large mammals we might have concluded that some parts of the GVL were not so important. However including smaller species shows that there is no part of the GVL that is a grey colour when all taxa are combined (figure 14).

OBJECTIVE 3: SCENARIOS OF NEGATIVE IMPACTS

The likely site for oil production is on and around Lakes Edward and George. Most of the oil in the Murchison-Semliki region has been found under Lake Albert where the rifting over the past 18 million years has taken place. Similarly it is expected that the commercially viable amounts of oil would be under the floor of the rift in the GVL. The oil seeps that come to the surface on Lake Edward indicate there is oil there and this is where SOCO and Dominion Oil have focused their activities when they were operating in the landscape. We have therefore focused our scenario analysis on this region as it is the most likely to be of importance for oil if viable quantities occur there.

Identifying Sensitive Habitat

Initially we aimed to map areas likely to be sensitive to oil and gas impacts or that could be most at risk if an oil spill occurred. We identified the following factors that could be mapped as being indicative of sensitivity:

A. Areas of flowing water (lakes and rivers) will be affected greatly by oil spills and other impacts described in section one and transport any pollution downstream. We therefore measured distance to lakes and rivers as one measure of sensitivity (the shorter the distance the more sensitive the site is).
B. Wetlands are critical areas of biodiversity and at greater risk of oil spills and other pollution than the terrestrial habitats because of the way water can transport the pollution to the wetlands. We therefore also measured distance to the wetlands (the shorter the distance the more sensitive the site is).
C. The steeper the slope of land the more likely it will suffer from erosion and impacts from oil and gas exploration. We therefore mapped the steepness of slopes from the 90 metre DEM (described in the species modelling section above) with higher values indicating more sensitivity.
D. The presence and use of roads will affect species particularly as traffic increases as a result of oil and gas production. We have seen greatly increased traffic in Murchison Falls National Park from the exploration activities of Total E&P Uganda in the park. We mapped distance from the roads using ArcGIS 10.0 (figure 16).

We then combined the data from the first three layers by standardizing them, and inverting the values so that high values represent areas of sensitivity (1/distance) for the distance to wetlands and distance to water. The formula used was as follows:

Sensitivity = ((1/distance to water+1)/Max value distance to water)+ (1/distance to wetland+1)/Max valuedistance to wetland)+ (slope)/Max value slope))/3

This score of sensitivity varied from 0 to 1 in value with the higher values indicating more sensitive habitat (figure 17a).

We did not include the distance to roads layer because this is not immediately a measure of sensitive habitat but is a measure of potential areas of impact if traffic increases to the lake. Instead we mapped where impacts might occur around roads over the map of sensitivity to highlight sensitive areas that would be most affected by traffic on existing roads and tracks (figure 17b)

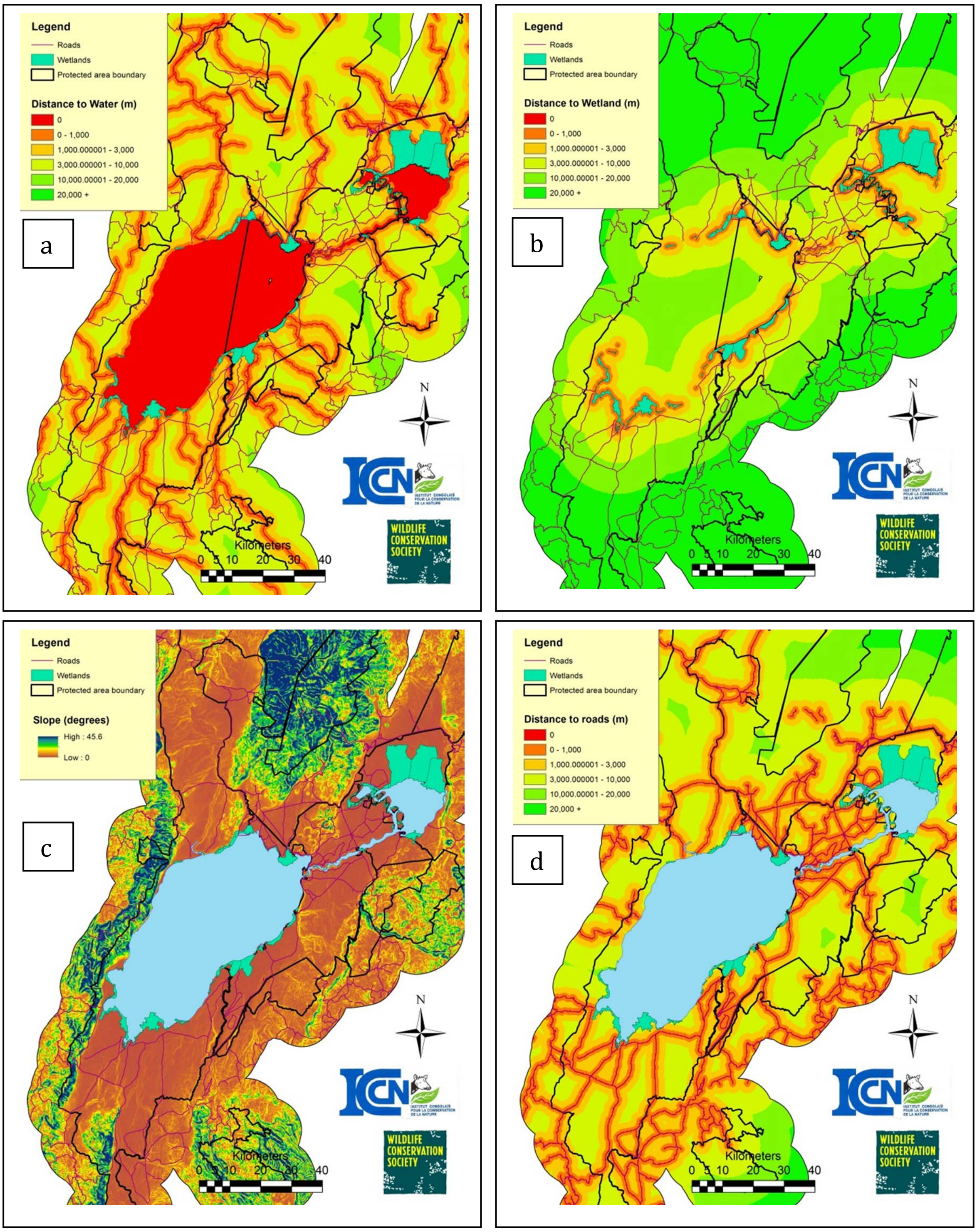

Figure 16. Map of a) distance to water; b) distance to wetlands; c) slope and d) distance to roads around Lakes George and Edward.

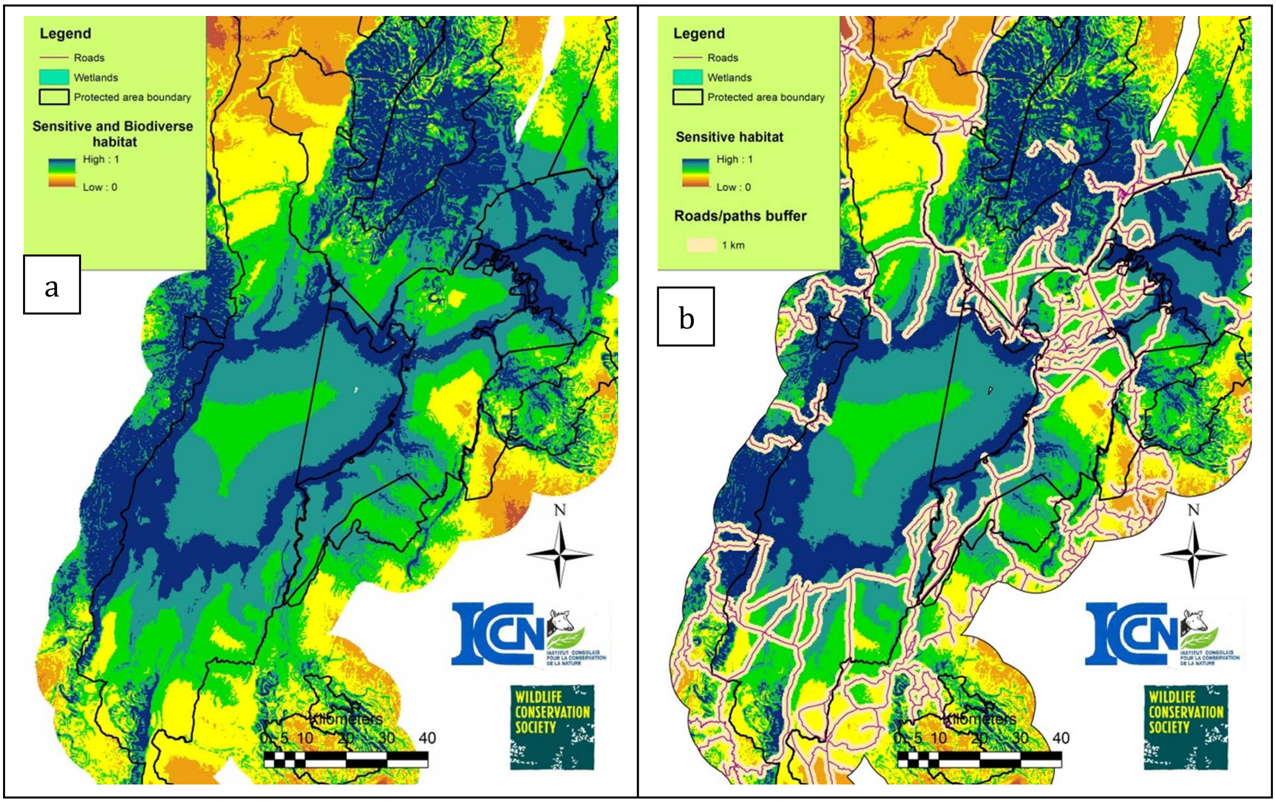

Figure 17. Sensitive habitat mapped around Lake Edward and George in the GVL (a) and the same map with roads mapped together with a 1km buffer of impacts on wildlife (b). Blue and green areas are likely to be more sensitive to oil impacts.

This analysis highlights how sensitive the areas around the lakes are and that these sensitive areas extend out into the lake as well as potential access routes down the escarpment to the lake. We used a 1 km buffer around the roads/tracks in figure 17 but this is only an estimate. Work WCS has made in Murchison Falls National Park indicate that elephants sometimes avoid roads up to 2-3 km away and they will avoid drill sites up to 5-6 km (A.J. Plumptre unpublished data).

An additional layer that it would be useful to incorporate would be the prevailing winds and currents so that predictions could be made of where oil may flow if there was a leak from a drilling platform in the lake. Winds generally blow from south east to north-west across Lake Edward but this analysis would need to have estimates of where the platforms might be located.

Combining Sensitivity and Biodiversity

It is possible to incorporate the biodiversity layers analysed in section 2 with the sensitivity analysis to identify area of sensitivity with higher biodiversity values. We made this analysis for the GVL using the following calculation of the layers:

Sensitive areas of high biodiversity = ((Sensitivity) + (Species richness/Max value species richness))/2

The results show that around the lakes the more biodiverse and sensitive areas are at the river mouths into the lakes, and along the rivers as they extend from the lakes (figure 18).

The steep escarpment on the west of Lake Edward also ranks high because of its susceptibility to erosion and the medium biodiversity level predicted for this region as well as the high biodiversity predicted fir Mt Tsiaberimu. Rwenzori massif also ranks highly because of its rich biodiversity and steep slopes but it is unlikely any mining for oil would take place here.

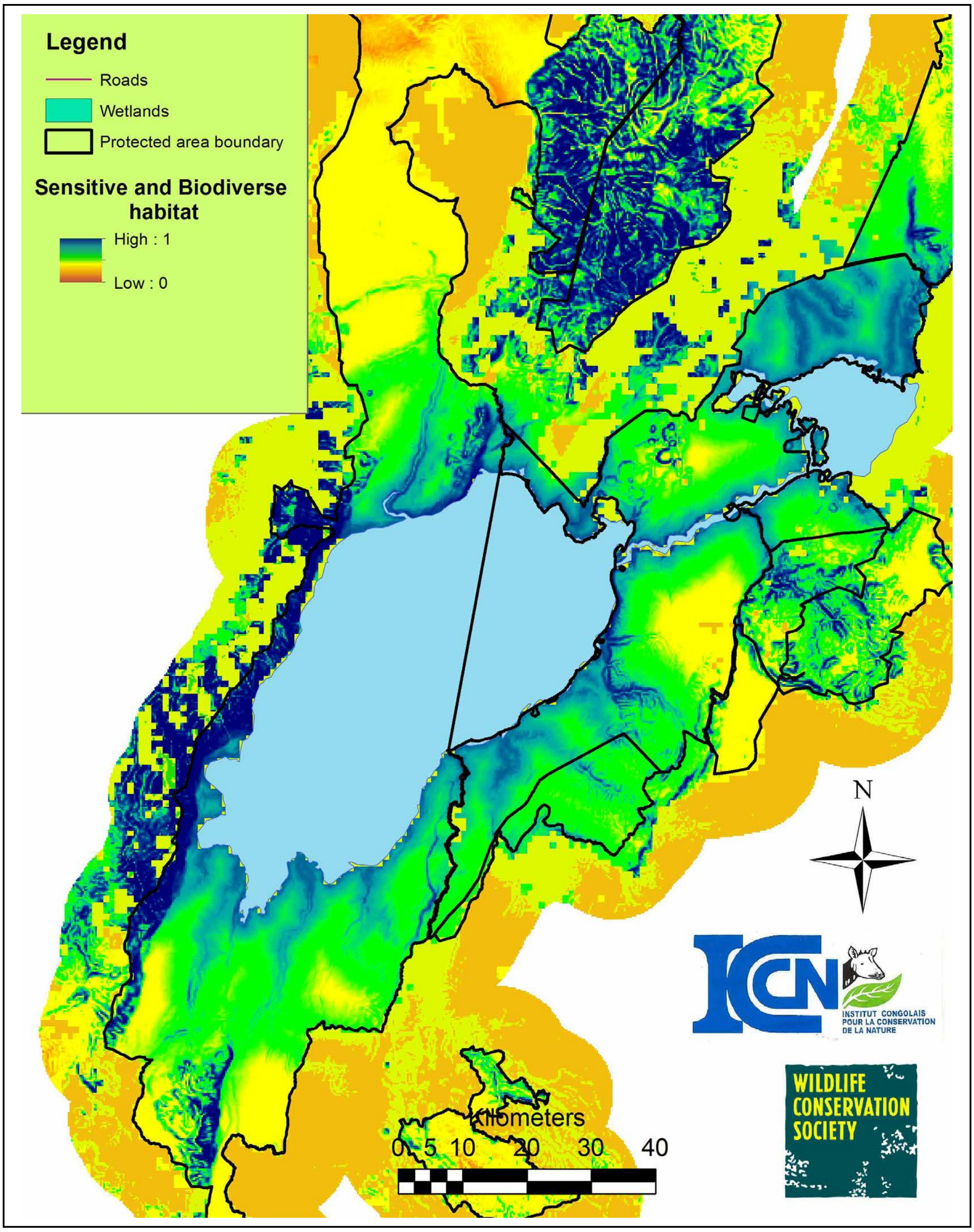

Figure 18. a) Map of sensitive areas with high and low biodiversity. The blue areas are both at species rich and more at risk of oil impacts.

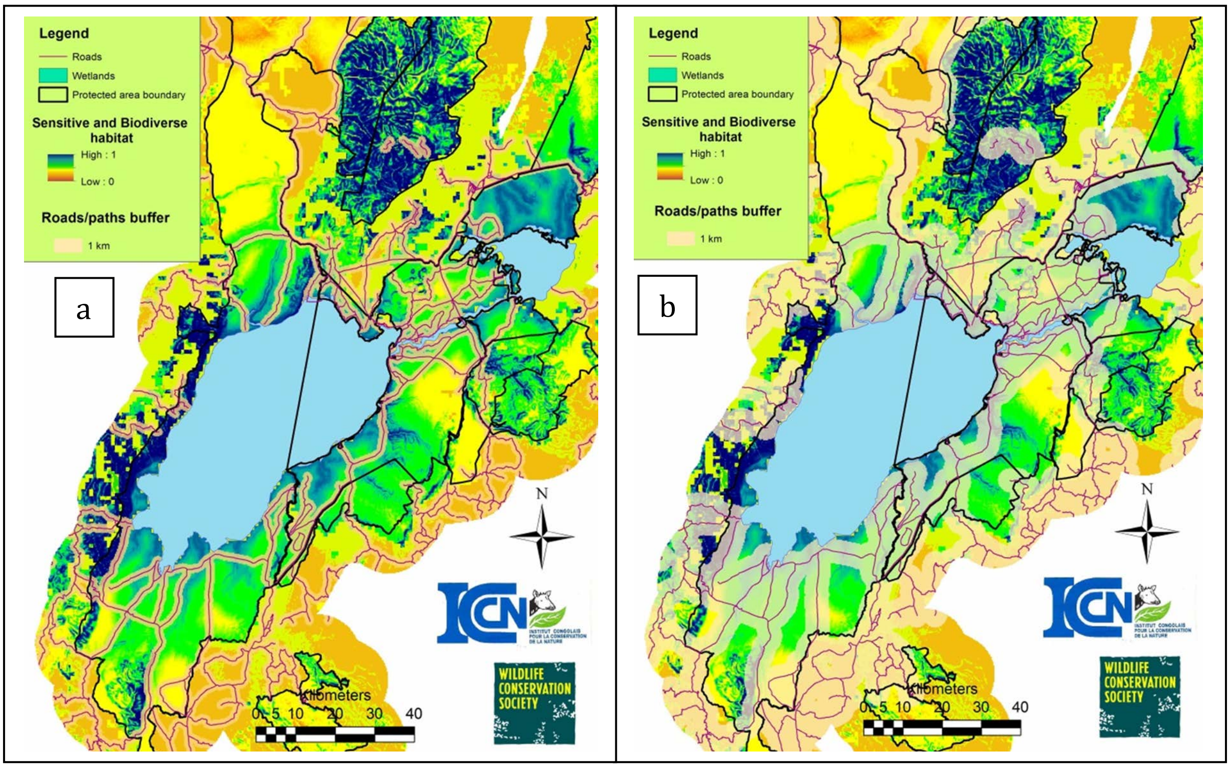

Figure 19. Map of sensitive and biodiverse areas overlaid with roads with a) a 1km buffer and b) a 3 km buffer.

Impacts of Access Roads

We do not really know how far from roads wildlife is affected by traffic in these savannah parks in Uganda and DR Congo. We have estimates that individual elephants respond to roads by up to 2-3 km from the road in Murchison Falls National Park and we therefore mapped the coverage of a 1 km effect of the roads and a 3 km effect of the roads (figure 19).

Figure 19 overlays the map of figure 18 with roads with a 1 km and 3 km buffer to visually show how varying the extent of the impact of traffic on roads could affect the parks. These figures show that certain access routes such as the road to the Kyavinyonge fishing village on the northern end of Lake Edward would travel through areas of medium sensitivity and biodiversity unlike the route from Kasindi to the lake shore which travels through more highly sensitive habitat. The roads in the corridor linking northern Queen Elizabeth National park to Virunga Park are likely to have a major impact on this corridor and it is recommended here that these roads are not developed actively for oil exploration and production. The road to Rwenshama in the south of Queen Elizabeth National park would also provide a route with fewer impacts to the lake shore than from Ishasha sector. Access to the southern end of Lake Edward is more complex. The road to Nyakakoma Fishing village in the east passes mainly through medium value habitat but this area is also a critical corridor to encourage migration of wildlife from Queen Elizabeth National Park to Virunga Park. On the other hand having activity in this area provided it was well controlled might instead provide better protection for the area. There is clearly a need however to measure the impacts of these roads currently on wildlife and then obtain measures of impacts on the same species in places such as Murchison Falls National Park and Kabwoya Wildlife Reserve in Uganda where oil exploration is taking place on roads that have been upgraded in these protected areas.

Of particular concern is the way the roads cross corridors linking different protected areas in the landscape, notably the corridors linking Virunga NP and Queen Elizabeth NP which have been shown to have played a vital role in conserving elephant numbers in the landscape (Plumptre *et al.* 2007). These corridors are already degraded by human activity and further impacts with increased traffic from vehicles could end their role as functional corridors for wildlife.

OBJECTIVE 4: Documentation of Impacts arising from existing oil/geothermal projects, mapping their effects on biodiversity conservation and community livelihoods in the Greater Virunga Landscape

Oil and gas and Geothermal companies active in the landscape at present have maintained that their activities had had minimal adverse impact to date and substantial beneficial impact. In order that PAA's are able to verify the truth themselves and hold companies to account, and given the limited resources they have for doing so, it is vital at this stage to objectively document the type of activities and resultant impacts that have already taken place. Although, at present, companies have only been engaged in exploration activities, which are associated with a lower expectation of severe impacts, documenting existing negative impacts will enable decision makers to better predict future consequences, particularly in the case of cumulative impacts. In conjunction with its partners, ICCN, UWA and RDB, and other stakeholders, WCS draws on its experience in monitoring impacts in the Murchison-Semliki Landscape in Uganda to assess what existing impacts (both adverse and beneficial) have already occurred in the Greater Virunga Landscape as a result of the various exploration activities

The documentation of existing impacts was intended to be achieved by carrying out stakeholder consultation in areas of existing oil and gas or geothermal exploration in the Greater Virunga Landscape to understand the following:

- Whether environmental and social impact assessments (ESIA) were carried out and correctly anticipated impacts and provided adequate mitigation to ensure no significant adverse impacts resulted from the operations;
- To understand if further unanticipated adverse impacts occurred and whether these were adequately mitigated, or whether these impacts persist in the landscape (social and ecological);
- Whether any formal monitoring or site audits took place, or whether decommissioning was correctly carried out;

- To what extent stakeholders were consulted and engaged in the process and are able to monitor impacts themselves.

Unfortunately very little information on the exploration activities and their impact on the GVL was available. In most cases no formal process has been followed, and ESIA's were only obtained for the planned oil wells in QENP by Dominion (only 1 was drilled). No license conditions, waste management plans, decommissioning plans, audits, monitoring reports or stakeholder engagement plans have been available and in most cases it is not clear if these have been completed.

In the absence of such information it is also difficult for the stakeholders to understand the type of impacts that may result beyond simple visual evidence. No analysis of contamination or pollution or of indirect impacts is possible.

In the face of this lack of documentation, WCS contacted representatives from the following group of stakeholders in the three countries in compiling this report:

- Protected Area Managers in the three countries,
- relevant government environmental agency representatives;
- tourism industry representatives,
- conservation organisations
- community representatives or development organisations;

The information supplied by the respondents has been added to the documented information available on the impacts of oil and gas and geothermal exploration to date in the Greater Virunga Landscape, however in every case it was clear that the respondents had a poor understanding of the type of impacts that could have arisen, particularly of indirect impacts on the communities within the GVL.

The areas where exploration or production activities associated with Oil and gas or geothermal development are known to have taken place are described for the three countries Uganda, DRC and Rwanda which comprise the Greater Virunga Landscape.

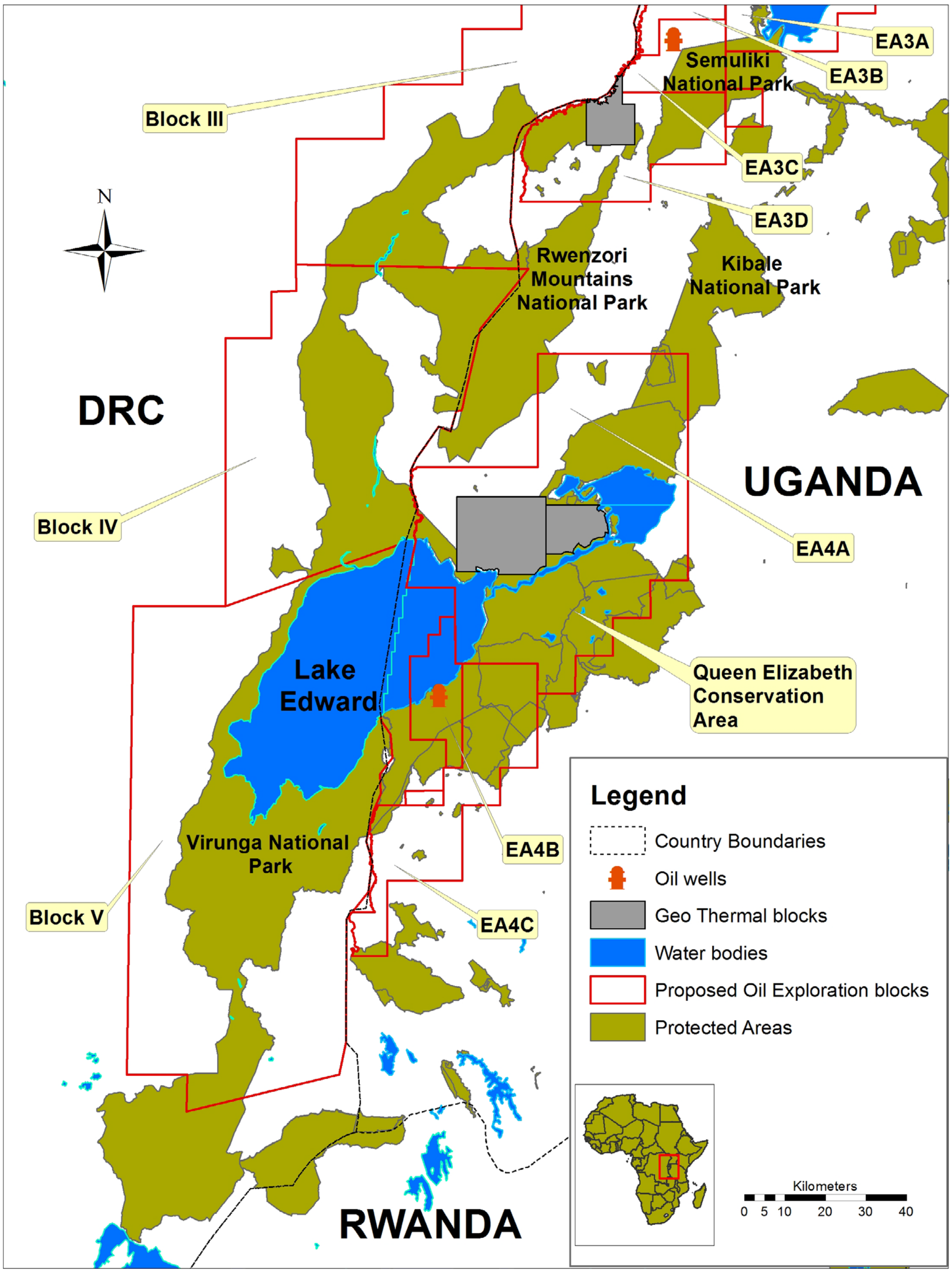

Figure 20. Map showing Oil exploration license areas in Uganda and DRC and major geothermal locations in Uganda (WCS 2015)

Uganda

Uganda has the most advanced exploration in oil and gas of the three countries, with a number of oil exploration blocks designated in the Landscape from EA3b comprising the Semliki Basin, to EA4b in the Ishasha sector of QENP (see figure 20), although the majority of exploration has taken place further north in the Murchison-Semliki Landscape. Geothermal exploration has also taken place within exploration blocks in Semliki and Queen Elizabeth (figure 20). In 2007, WCS commissioned a review of both oil and gas and geothermal exploration impacts, and in 2010 a more general review of ESIA's within Uganda. Details from these reviews are included in the appropriate sections below. This section has been contributed to by UWA officers from the Queen Elizabeth Conservation Area, Semliki National Park and from UWA headquarters whose assistance is greatly appreciated.

Oil Exploration

Two areas of the GVL in Uganda have been subject to exploration activities, however to date the exploration has not resulted in confirmed oil deposits, unlike exploration activities in the adjoining Murchison-Semliki Landscape. The Ugandan government is seeking bids in a new licensing round that includes these blocks and so further exploration may be expected to recommense from 2016 onwards.

Semliki Valley

(i) Background

The first exploration in Uganda since Independence took place in Semliki Community Wildlife Area (block EA3B) just to the North of the GVL, with 2D seismic resulting in drilling in 2003/4 of exploration wells Turaco 1, 2 and 3 by Hardman International, with all wells subsequently abandoned. No EIA's for the projects have been available, although Johnson (2007) cites an Environmental Audit Report and Abandonment Plan containing actions on how the site should be decommissioned. This block is not currently allocated.

(ii) Impacts

A site visit organized by WCS took place in November 2006 observing that decommissioning had not included restoration with the following outstanding issues noted (Johnson 2007):

- concrete hard-standing covered the site;
- waste pits and flaring pits were present and uncovered, some filled with liquid waste, others empty with growth of contaminant-tolerant plants;
- the camp contained discarded equipment and litter (see figure 21);
- large sections of the perimeter fence were broken/absent, i.e. not adequately restraining entry to the site by people or animals (see figure 22).

Figure 11. Abandoned equipment at Turaco 3 (Isaiah Owiunji)

Figure 22. Abandoned waste pit, Turaco 3 (Isaiah Owiunji)

There was clear evidence at the time that contamination of soil and groundwater had already taken place and that animals and birds had ingested potentially toxic materials and wastes.

Interviews conducted under this current study portray an image of recovery of vegetation in the exploration area. Disturbance to fauna and flora during exploration was said to have been minimal and no signs of impact were obviously visible currently. The only negative effect reported in the Semliki area was the diversion of water at Wasa Bridge which caused loss of vegetation. Poor alignment of the bridge was reportedly responsible for increased erosion by the river hence causing this section of the river to widen as it hits hard on the side of the bridge wall.

These sites should be further investigated. Whilst the former impacts may not have led to visible impacts, there may have been less visible but long term impacts with the potential to negatively affect human, livestock and wildlife health arising from contamination.

Queen Elizabeth Protected Area

(i) Background

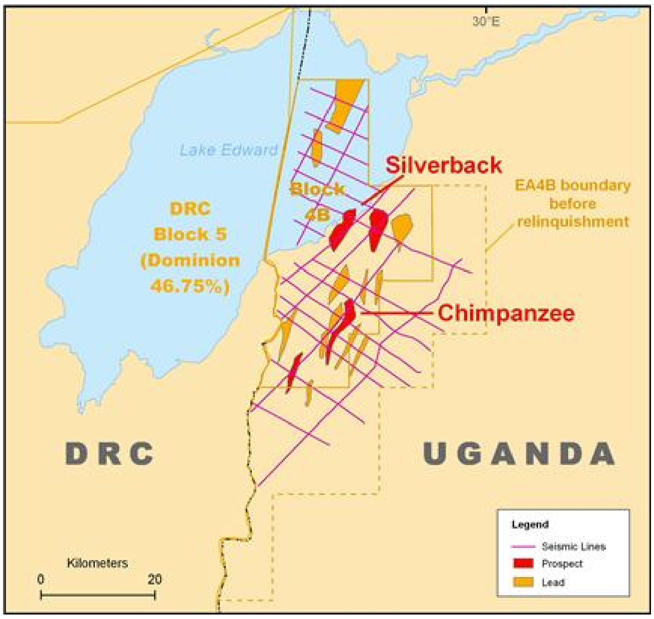

Figure 23. Oil prospects in QENP (Dominion Oil)

Geological and aerial surveys took place in 2008 in Queen Elizabeth National Park (block EA4B), followed by 2D seismic over 502km resulting in a mapping of potential prospects by Dominion Petroleum Uganda Ltd (figure 23). As a result one initial exploratory well was drilled to the south of Rwenshama Village in 2010, Ngaji 1, following competent EIA studies (Johnson 2010) but the well did not yield results. Two further planned wells did not progress and this block is not currently allocated. The results of this wildcat well and early exploration are clearly that the oil deposits are primarily underneath Lake Edward and largely within the DRC borders.

(ii) Impacts

The Conservation Area Manager for Queen Elizabeth Protected Area (QEPA) pointed out that pad decommissioning of Ngaji 1 was generally carried out well and all potentially hazardous waste was removed from QEPA and buried in Mpundu, Kikarara (outside the National Park but within community areas). However the potential for murram (spread on road surface) and run-off (from the drill site and roads) to be contaminated is unknown as no follow-up or testing of soils or water has been carried out. Evaporation of water from the pits on the drill sites and disposal of resultant oil may not have been followed through. There are therefore still some concerns at the present time that soil and water contamination may have taken place within the park.

Other waste materials, including hazardous waste from the site operations, were reportedly taken to a Waste Management Facility in Rukingiri District through a sub-contractor. No further details were available on whether the wastes were appropriately handled or contamination issues arose.

Water was pumped to the wellpad and camp from a borehole at Rwenshama, but it was not clear whether this had been left in place for the community to use, whilst the accommodation camp at Bukorwye was handed over to QENP Management for use by Park Officers and Rangers. However the structures were temporary and only a few blocks remain. No impacts were noted.

Efforts to obtain environmental monitoring reports or audits for either the drill sites or for the waste disposal sites were unsuccessful and it is not clear whether any monitoring was done. In addition, we learnt that a permanent waterhole which supported biodiversity including toads, frogs, tortoises and buffaloes was destroyed during the drilling phase of Ngaji-1 well. Sand bags placed on the edge of the waste water retention pit were reportedly not removed and are still on site to date.

Figure 24.Tree climbing lion in Ishasha Sector, QENP (WCS 2011)

During seismic surveys, lines cut in the around the northern circuit of the Ishasha sector of QENP were reported to have caused wildlife to temporarily move out of the area until seismic activities ceased. This could probably explain the slight change in lion ranges during exploration and drilling as reported in WCS' oil impacts monitoring study (see Omoya and Plumptre, 2011).

Whilst this study was unable to ascertain whether changes in lion home range was caused by oil activities, the lion density is closely linked to prey density and so movement of prey away from the area could affect their ranging (Treves *et al.* 2009).

Road improvements by Dominion and government opened access and increased traffic through the park (this road used to be avoided due to bad conditions) including to the DRC border. Whilst road improvements were well-received by the local people, the long-term impacts can be detrimental due to accelerated resource extraction, increasing competition and price increases. No follow up with the local people has taken place, nor have the impacts of opening access on biodiversity in this particular location been documented. However, improving roads in areas rich in natural resources is generally associated with increased resource access and illegal activities (see section 3 above).

In Maramagambo forest reserve, seismic lines opened in 2008/9 had remained open and despite 'dog-legging' of the entrance, were known at the time to local hunters (site visit by WCS in 2009). These, together with improved roads, potentially facilitated further resource extraction. However, according to Atakama Consulting (2009) it appears that the seismic tracks in the forest have now largely regrown.

Oil activities are generally believed to come with employment and business opportunities and cessation of activities due to failure to find oil was a disappointment to the local communities. Oil exploration attracted two local investors to establish hotels in the area but construction halted midway and hopes for making money from oil people travelling on oil related businesses were quashed. These two structures were not destroyed but are understood to remain derelict.

Geothermal Exploration Locations

From early exploration of geothermal potential in Semliki National Park, progress has been slow. Preliminary geothermal studies were first conducted in the 1920s when the Geological Survey of Uganda came into being (Kato 2013) and early exploration took place from 1954 when four exploration wells were drilled in Buranga (Kato, 2013).

More recently the potential has been re-investigated with a first phase of exploration investigating 3 main prospects of Buranga, Kibiri (outside of the GVL) and Katwe-Kikorongo, which commenced in 1993. These sites are shown on the map in figure 25. Of interest is the currently untapped potential clustered in the GVL in the south of Uganda which may be expected to be investigated in the future. These surveys were followed by further isotope surveys between 1999 and 2003. Prospect exploration drilling was conducted in Katwe-Kikorongo in 2003. This exploration is still ongoing with further data acquisition in 2010.

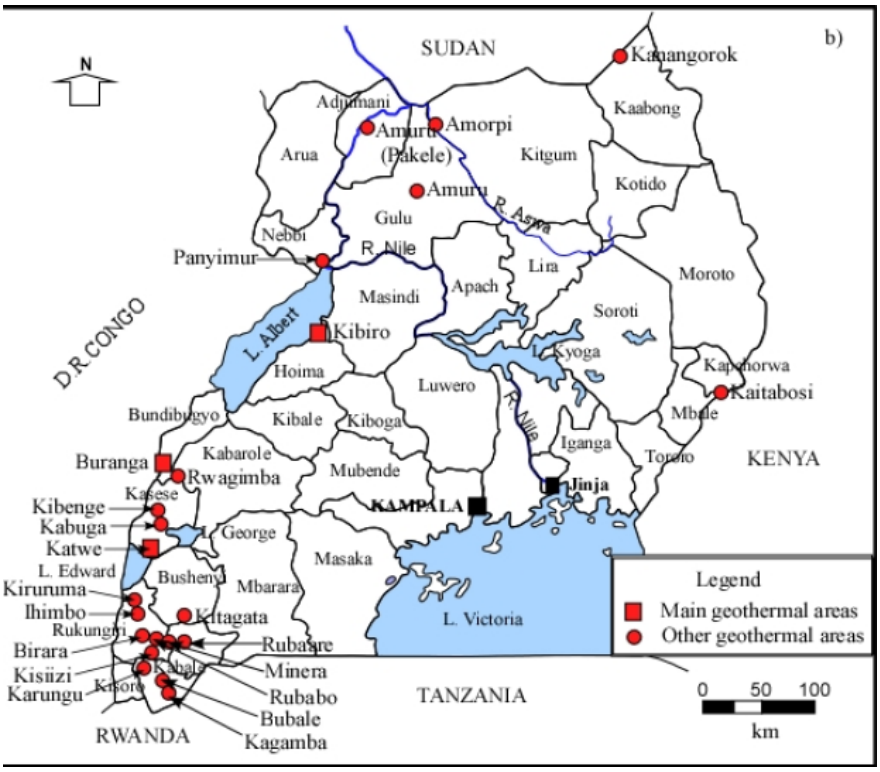

Figure 25. Geothermal locations in Uganda (Source: Bahati and Natujunda, 2009)

Semliki National Park

(i) Background

The Buranga geothermal site is located close to the Sempaya Hot Springs within Semliki National Park. The Hot Springs (figure 26) are an important tourism attraction and clearly signal that the area also has geothermal potential.

Figure 26. Sempaya Hot Springs (Isaiah Owiunji)

The Buranga site was drilled in 1954 and a number of electromagnetic, satellite and digital elevation models (DEM) studies have since been undertaken on the site.

More detailed satellite and aerial exploration was followed by geological, geochemical and isotopic surveys which took place between 1993 and 1994 in Buranga, leading to the conclusion that the extent of the geothermal reservoir could be larger than previously thought (Kato 2013) with a temperature sufficient for electricity generation. The site is currently in advanced surface exploration stages (Natujunda and Bahati 2015).

(ii) Impacts

Impacts from the drilling in Buranga in the 1950's cannot be confirmed, as the site had reverted to forest, although the concrete wellcaps of the four wells drilled were still in place by the time studies recommenced in the 1990's (no protection such as fencing was given to the site).

The studies have involved satellite and aerial technologies which have minimal impacts on biodiversity. Noise from aeroplanes is a possible cause of disturbance to fauna and human presence during groundtruthing is likely to have an effect on vegetation and animals, especially through line cutting and disturbance to the vegetation around the Hot Springs, but no details of this have been available at the time of the study.

The geothermal surveys are alleged to have minimal impacts on the environment, with activities limited to vehicle movements, foot access and drilling of shallow holes to install electrodes and magnetometers (figure 27). However these do have local impacts on vegetation, soils and fauna. The impacts of vegetation clearance are obviously greater in a forest area where clearance generally opens access for hunting and resource extraction. Impacts on soils can be managed with site restoration but otherwise can damage the soil structure and lead to localised erosion decreasing the likelihood of successful vegetation and habitat regeneration. No details were available of impacts on these sites.

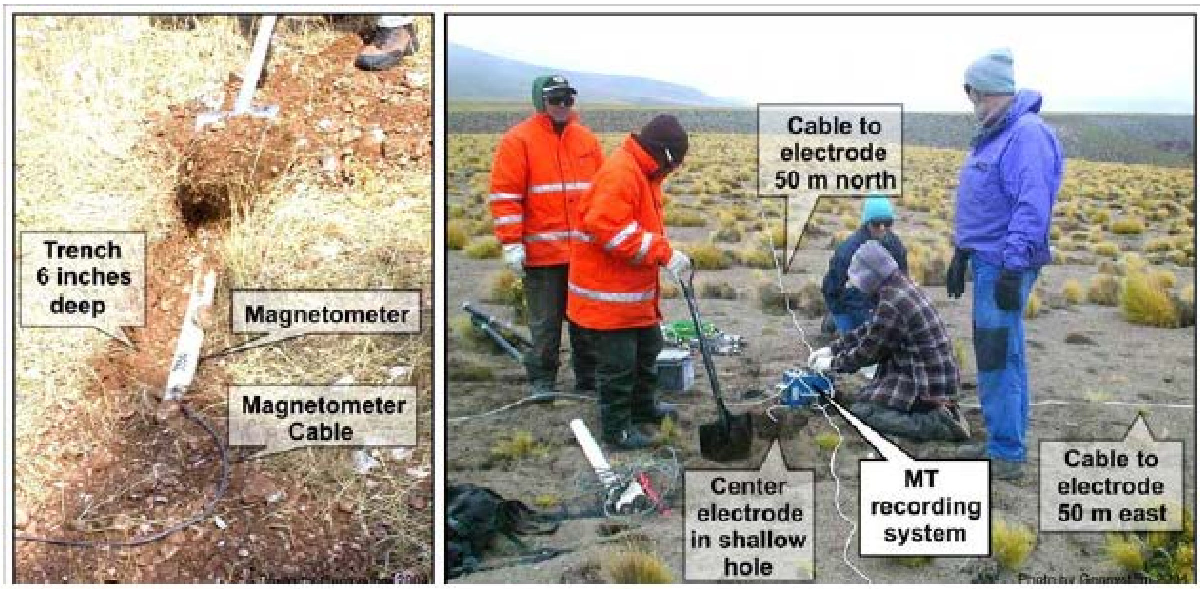

Figure 27. Illustration of geothermal survey activity (Source: Cumming and Mackie, 2007; photo credit: Geosystem)

Queen Elizabeth Protected Area

(i) Background

Exploration is presumed to have commenced in the 1990's, with geological, geochemical and isotopic surveys between 1993 and 1994 in the Katwe-Kikorongo Geothermal Concession (concurrently with the sites in Semliki National Park). By 2006, exploration drilling to assess the geothermal potential had taken place at a site just south of the main road between Kabirizi and Kotogo, which is located within Queen Elizabeth National Park. According to a review by ISCR (Icelandic Geosurvey) the potential from Katwe is limited and further data acquisition was not recommended.

The current status of this site is unclear, as it is understood that there was further activity in 2013/2014 and that this is set to continue despite the apparent limited potential.

(ii) Impacts

The impacts of the earlier geothermal ground surveys were not noted and the sites were unknown.

Figure 28. Suspected diesel leak at Katwe-Kikorongo site (Isaiah Owiunji)

The drilling site and well pad from 2006 was not decommissioned properly and Johnson (2007) notes that cuttings were piled near the drill site and that rubbish and contamination were evident (figure 28). The presence of roads or other access and effects on communities were not assessed.

The site has still not been restored and it is unclear what the current plans are, however it is presumed that contamination is still present and affecting soils and water. No information is available on impacts arising from the recent further exploration activities.

Democratic Republic of Congo

Oil exploration in Eastern DRC is a much more recent undertaking with oil concessions first signed by the DRC government in 2007. Geothermal activities have been established for some time in DRC with a geothermal power plant established in Katanga Province in 1952 (no longer functional). This power plant is not within the GVL and has not been assessed here. It was not possible to gain information from ICCN officers during the writing of this report, in particular the ongoing conflict within DRC regarding the future of oil development has resulted in a reluctance of conservation officers to discuss the issues and so WCS staff have relied on published and WCS internal information to write this summary.

Oil Exploration Locations

The DRC government had agreements with Oil of DR Congo (blocks I and II), Total E&P (block III) and SOCO International Limited (block V) for exploration activities in the Albertine Graben (figure 29). The three concessions are described below.

Blocks I and II

These border Lake Albert, with block II just to the north of (and thus potentially impacting) the GVL to the West of the Semliki River and the southern end of Lake Albert. The current license was awarded in 2010 for 5 years and Oil of DR Congo carried out 2D seismic surveys both onshore and offshore in 2013-2014. Drilling of the first exploration wells was expected to take place in 2014, but no further updates have been available.

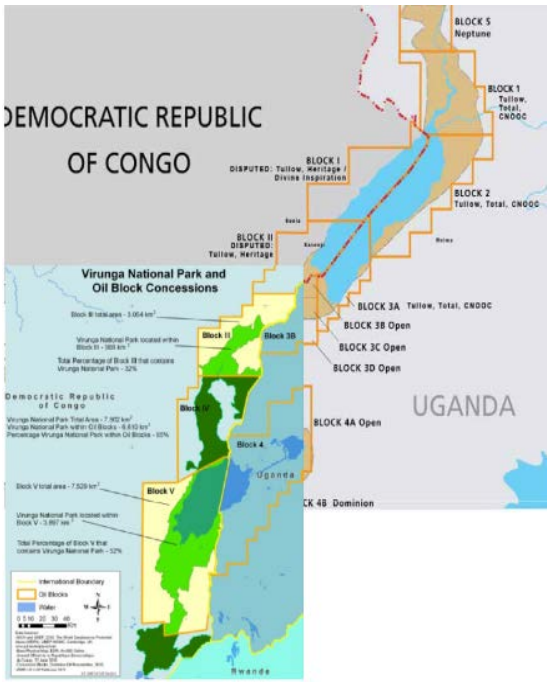

Figure 29. Oil blocks in the Virunga National Park (source: Global Witness 2014)

Blocks III and IV

Total undertook not to carry out exploration activities in the Virunga National Park. A new 3-yr concession license was signed in 2012 after the earlier license expired and Total has focussed on data acquisition and survey work, including 2D seismic, to the West of the Semliki River and on the Blue Mountain Escarpments outside of Virunga. Total plans to drill exploratory wells but conflict and insurgency have added to the delayed progress.

Block V

(i) Background

SOCO International commenced survey work (including seismic in July 2014 - figure 30) in the Virunga Park, but in the midst of armed conflict, their activities were themselves beset by conflict and led to fierce opposition by international pressure groups (WWF and Global Witness), resulting in the company agreeing to stop activities unless the DRC government and UNESCO can reach agreement. There are fears in the international community that this could lead to degazettment of parts of the WHS as has happened in Tanzania (in 2012 UNESCO accepted a boundary change of the World Heritage Site in the Selous Game Reserve to allow Uranium mining).

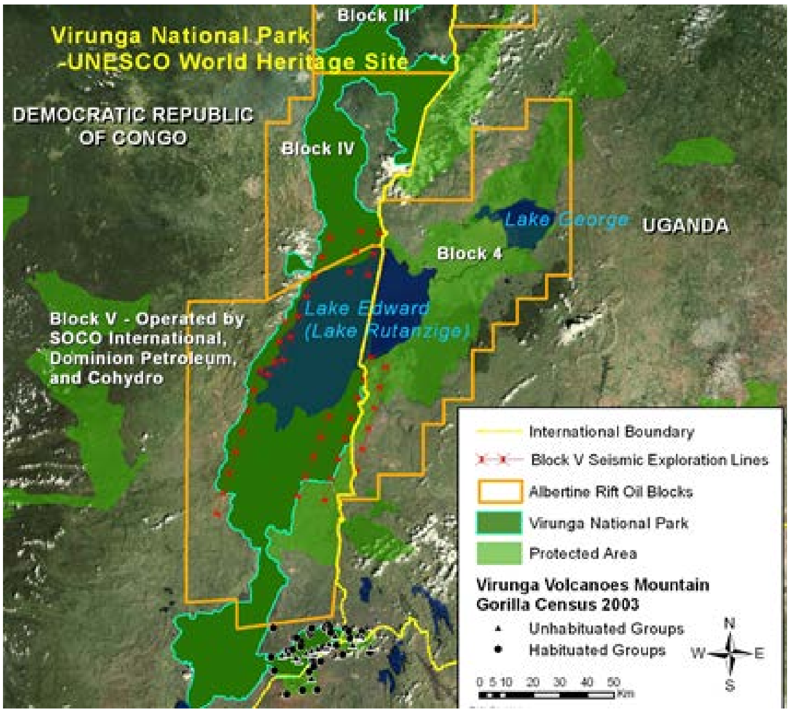

Figure 30. Map extract showing seismic lines in Block V DRC and EA4b Uganda

(ii) Impacts

On the 7th of November 2013, Serge Lescaut, SOCO's Central Africa director announced that the oil company would wait for the results of the Strategic Environmental Assessment (SEA) commissioned by the DRC government and supported by the EU before recommencing work. A second phase of the SEA was expected to be completed by November 2014, again funded by the European Union, on behalf of the Ministry of Hydrocarbon in DR-Congo. However the company commenced to plan for acquisition of seismic data on Lake Albert and the adjacent lowland savanna in April 2014 and in June 2014 SOCO released a joint statement with conservation campaigners WWF, following mediation by the OECD, in which the company promised to halt its work in Virunga once seismic testing had been completed, which was before the completion of the SEA (Save Virunga website 2015). Further detail on the results and impacts of the exploration activities has not been available and the SEA has not been made available to the authors of this report.

During their work in Virunga, SOCO are said to have supported community projects including the upgrading of the road from Ishasha to Nyakakoma; installation of water pumps in fishing villages and construction of a telephone communication mast in the National Park. This is a worrying trend as clearly these activities are also intended to benefit the oil company, but through classing them as community projects the company can avoid these developments being fully assessed as part of the oil development.

Stakeholders have reported that the company was not transparent with information and there was no chance to observe impacts or review EIAs if conducted at all. However, from the limited observations made, it was reported that the company mostly used existing facilities (roads, airstrip) and accessed offroad testing sites on foot with no details available on the extent of line cutting that may have taken place.

The surveys (aerial and seismic) conducted on Lake Edward and the surrounding lowland are reported to have had no significant impacts on biodiversity, however as there were no audit or monitoring reports it is not clear that these reports have any significance. Any biodiversity surveys that SOCO may have undertaken on the flora and fauna of Lake Edward have not been received (SOCO stated that an inventory of hippopotamuses, ichthyological studies and malacology studies would be completed prior to seismic survey). During survey work the communities were prevented from accessing parts of the lake for their safety, however it is reported that these exclusion sites were limited in size and that they had adequate other fishing grounds and were not significantly impacted.

Unfortunately it was not possible to access the DRC oil explorations or carry out stakeholder engagement within the DRC due to the objection of the Park Authorities and insecurity. As a consequence, no further assessment of any potential impacts arising from either the activities themselves or the conflicts that arose around the oil exploration can be made at this time.

Geothermal Exploration Locations

Geothermal potential in DRC is well established with a large number of sites recorded. However very little detail is available on progress in the exploration or licensing of potential sites within the GVL, and no detailed studies beyond initial sampling have taken place though the government is in the process of establishing a committee to look into geothermal development in DRC (Muanza, 2015). No further assessment has been possible.

Rwanda

Requests for information to respondents in Rwanda were not responded to within the timeframe of this report. Further information gathering from stakeholders in the exploration areas is therefore recommended.

Oil and Gas Exploration Locations

Lake Kivu, straddling the border of Rwanda and the Democratic Republic of Congo (DRC), is just outside the GVL, but development in this area could potentially still impact the GVL through urbanization and industrialization of the area and the likely increase in resource extraction resulting from any sizeable population increase. Developments are summarized but the impact of exploration is not expected to have any major impact on the GVL at the current time.

The Rwandan government has operated a pilot gas-fired power plant at the lake since 2008, but now the U.S. energy firm Contour Global, through its subsidiary KivuWatt, has constructed the lake's first industrial-scale gas-fueled power project. The Ministry of

Hydrocarbons in DRC is also reviewing bids for their first Kivu gas concession.

The Rwanda government also issued licenses to Vanoil Energy for exploration into potential oil prospects under Lake Kivu. In 2014 the agreement was revoked due to non-activity as Vanoil had only completed reconnaissance studies including how the lake would react to seismic waves. The government has since invited other firms to bid and in 2015 is reported to be finalising new laws for the sector. The volatility of methane and CO2 deposits in the Lake are believed to be the main issue with a potentially high risk of explosion and asphyxiation (Lake Nyos in Cameroon exploded in 1986 and is the only known natural example of this phenomenon). No further details are available at this time.

Geothermal Exploration Locations

Rwanda has two geothermal zones, one of which, in the north-western region, falls within the GVL (encompassing Gisenyi, Karisimbi and Kinigi). The geothermal prospect areas for Rwanda are shown in Figure 31.

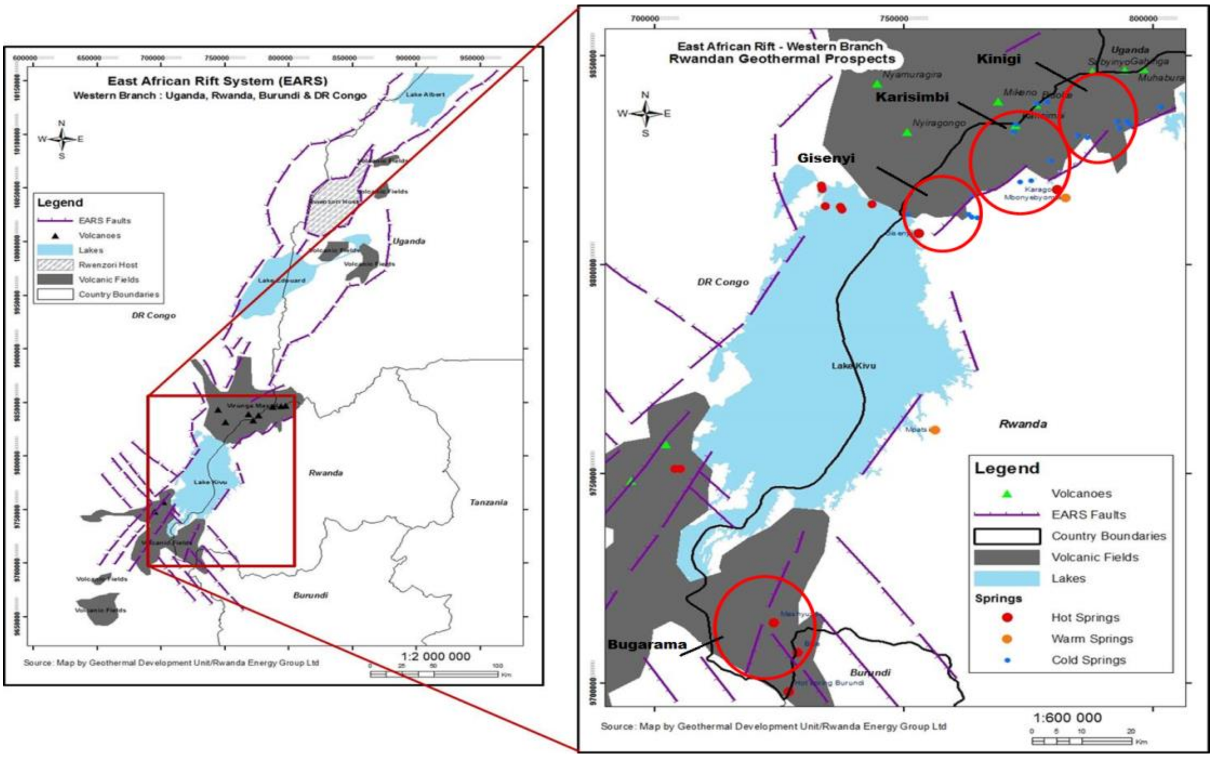

Figure 31. Geothermal potential in Rwanda (institute of Earth Science and Engineering (IESE, 2011)

The Karisimbi area is located near the Karisimbi volcano within the National Volcano Park and Virunga volcanic chain complex. Detailed surface geo-scientific studies and Environmental and Social Impact Assessment (ESIA) have been completed. Two out of three planned deep exploratory wells were drilled between 2013 and 2014 before it was concluded that there was no evidence of a geothermal system (the third planned well was reportedly not drilled). Efforts to obtain the ESIA have been unsuccessful and it is important to follow up on the scale of impacts, the success in managing those impacts on the GVL and its populations and the current situation with regard to decommissioning of these sites.

The Kinigi and Gisenyi prospects had not had any exploratory drilling at the time of this study, but have been subject to surface studies, with further additional studies to select drilling targets planned to commence in 2015 (further details on the status of this study not yet available). It is not known if EIA's or baseline studies were conducted prior to these studies and reports on impacts were not available.

CONCLUSIONS

This study has shown that most of the Greater Virunga Landscape is critical for the conservation of its threatened and endemic species of the Albertine Rift. It has also shown that the areas likely to be sensitive to oil and gas exploration as well as geothermal exploration, areas close to rivers, lakes and on steep slopes and areas with high biodiversity, are concentrated in the areas where oil drilling may take place – on Lake Edward. While the habitat around Lake Edward is less biodiverse, particularly for threatened and endemic species, it is more sensitive to impacts because of the lacustrine nature of the area. Oil spills here will travel further because of the flowing water and have more impacts than if there was a spill on land far from a river. It would also be harder to clean up and restore a spill in these sensitive habitats compared with a spill on land. So although the clearly important areas for biodiversity conservation in the GVL are in the mountain regions, Virunga volcanoes, Bwindi and Rwenzoris, the lake areas are more sensitive to impacts and increase the risk of any oil exploration on them. Given that Lake George is part of a Ramsar site we would argue that this site should never be explored and drilled. Given the issue of Virunga Park being a World Heritage Site, including the lake, and the sensitive nature of the habitat and very rich biodiversity of the park there are many reasons why oil extraction should not take place within the park and the Greater Virunga Landscape as a whole.

This report also documents the potential impacts of oil/gas and geothermal exploration in the GVL and what we could find of the existing impacts to date. The results of re-visits to existing sites give cause for concern because clean-up has not been completed. The lack of access to EIA documents and the ability to check whether recommendations of the EIA were implemented is also a great concern. Auditing of all existing developments based upon their EIA reports is recommended.

Finally it is recognised that there is a need to build the abilities of protected area authority staff to recognise and document impacts of any developments in the GVL. The fact that many reported that impacts had been minimal and yet when teams visited sites on the ground there was evidence of negligence shows that they need to be trained in what is expected of companies and to ensure they meet their requirements in the EIA reports.

The Greater Virunga Landscape is one of the most biodiverse landscapes on Earth. Few other sites can compete with it for both the species diversity and the number of threatened and endemic species. This place is one of the truly unique places on Earth and considerations should be given to other options than developing the oil and geothermal potential of the area (within the protected areas). A petition, started in 2015, led by Global Witness, to halt all exploration activity in Queen Elizabeth NP and Lake Edward, and subsequent press releases have been made because of the global importance of the GVL and the likely impacts of oil and gas exploration on its integrity. This report supports this finding because of the sloppy nature of existing developments that have been implemented to date which do not bode well should development take place in the landscape.

REFERENCES

AWE Environmental Engineers, 2008. Ngassa 2 ESIA. Tullow Uganda Oil Pty

Atakama Consulting (2009) Environmental and Social Impact Statement: *Proposed Oil Exploration Drilling At Ngaji-1 In Exploration Area 4b, Uganda* Dominion Uganda Ltd.

Atakama Consulting (2009) Environmental and Social Impact Statement: *Proposed Oil Exploration Drilling At Nkobe-1 In Exploration Area 4b, Uganda* Dominion Uganda Ltd.

Atakama Consulting (2009) Environmental and Social Impact Statement: *Proposed Oil Exploration Drilling At Kiremu-1 In Exploration Area 4b, Uganda* Dominion Uganda Ltd.

Bahati, G and Natukunda, J. F. (2009). "Status of geothermal exploration and development in Uganda". A paper presented at *Short Course IV on Exploration for Geothermal Resources*, organized by UNU-GTP, KenGen and GDC, at Lake Naivasha, Kenya, November 1-22, 2009

Cumming, W. and Mackie, R. (2007). *MT survey for resource assessment and environmental mitigation at the glass mountain Kgra*. Cumming Geoscience GSY USA, Inc.

Elith, J., Graham, C. H., Anderson, R. P., Dudik, M., Ferrier, S., Guisan, A., Hijmans, R. J., Huettmann, F., Leathwick, J. R., Lehmann, A., Li, J., Lohmann, L. G., Loiselle, B. A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, J. McC., Peterson, A. T., Phillips, S. J., Richardson, K. S., Scachetti-Pereira, R., Schapire, R. E., Sobero´n, J., Williams, S., Wisz, M. S. and Zimmermann, N. E. (2006). Novel methods improve prediction of species' distributions from occurrence data. *Ecography*, 29, 129-151.

Elith, J., Phillips, S.J., Hastie, T., Dudı´k, M., Chee, Y.E. & Yates, C.J. (2011). A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*, 17, 43–57.

Fielding, A.H. & Bell, J.F. (1997) A review of methods for the assessment ofprediction errors in conservation presence ⁄ absence models. *Environmental Conservation*, 24, 38–49.

Freeman, E.A. and Moisen, G. (2008). A comparison of the performance of threshold criteria for binary classification in terms of predicted prevalence and kappa. *Ecological modeling*, 217, 48–58

Global Witness (2016) *Protecting Virunga National Park from Oil Companies.* Downloaded from: https://www.globalwitness.org/en/campaigns/oil-gas-and-mining/protecting-virunga-national-park-oil-companies. Accessed on 22/01.2016

Graham, C., & Hijmans, R., (2006). A comparison of methods for mapping species ranges and species richness. *Global Ecology and Biogeography*, 15, 578–587

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., and Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, 25, 1965–1978.

IPIECA (1991). *Guidelines on biological impacts of oil pollution*. IPIECA Report Series, Volume 14

Johnson L. (2007). *Assessing the impacts of energy developments and developing appropriate mitigation in the Uganda portion of the Albertine Rift.* WCS Uganda, UWA.

Johnson, L. (2010) *Oil Impact Mitigation Uganda* – EIA Review 2010 WCS Kampala

Johnson L., Speedie C. and Prinsloo S. (2011). *Oil development, impacts and mitigation: A training aid, DVD format, 2nd edition.* WCS Uganda.

Kato, V. (2013). "Geothermal exploration in Uganda status report". Presented at *Short Course VIII on Exploration for Geothermal Resources*, organized by UNU-GTP, GDC and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, Oct. 31 – Nov. 22, 2013

Manel, S., Williams, H.C. and Ormerod, S.J. (2001). Evaluating presence–absence models in ecology: the need to account for prevalence. Journal of Applied Ecology 38 , 921–931

Muanza, P. M. (2015). "Presentation of Geothermal Potential and the Status of Exploration in Democratic Republic of Congo". *Proceedings World Geothermal Congress 2015.* Melbourne, Australia, 19-25 April 2015

Natukunda, J. F. and Bahati, G. (2015)." Geothermal Energy Exploration at Buranga Geothermal Prospect, Western Uganda". *Proceedings World Geothermal Congress 2015.* Melbourne, Australia, 19-25 April 2015

Omoya, E. and Plumptre, A.J. (2011). Monitoring the impact of oil drilling on lions in Ishasha sector, Queen Elizabeth National Park. WCS Albertine Rift Programme. Kampala, Uganda.

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*(3-4), 231–259.

Phillips, S. J., & Dudı, M. (2008). Modeling of species distributions with Maxent : new extensions and a comprehensive evaluation. *Ecography*, Vol 31 pp, 161–175.

Plumptre, A.J., Kujirakwinja, D., Treves, A., Owiunji, I., and Rainer H. (2007) Transboundary conservation in the Greater Virunga Landscape: its importance for landscape species. *Biological Conservation* 134, 279-287

Rosen JW. (2005). Lake Kivu's Great Gas Gamble. http://www.technologyreview.com/photoessay/536656/lake-kivus-great-gas-gamble/. Downloaded on 22.01.16

Save Virunga *Update on Oil Activities in DRC* June (2015). http://savevirunga.com/mapping-oil-threat/last-update/. Downloaded on 22.01.16

Treves, A. Plumptre, A.J., Hunter, L. and Ziwa, J. (2009). Identifying a potential lion, *Panthera leo*, stronghold in Queen Elizabeth National Park, Uganda and Parc National des Virunga, Democratic Republic of Congo. *Oryx* 43: 1-8

Warren, D.L., R.E. Glor, and M. Turelli. (2010). ENMTools: a toolbox for comparative studies of environmental niche models. *Ecography*, 33, 607-611.