Environmental Conservation (2014) **41** (2): 229–238 © Foundation for Environmental Conservation 2014 doi:10.1017/S0376892914000010

THEMATIC SECTION
Spatial Simulation Models in Planning for Resilience

Bridging climate science to adaptation action in data sparse Tanzania

EVAN H. GIRVETZ[1,2]*, ELIZABETH GRAY[3], TIMOTHY H. TEAR[4] AND MATTHEW A. BROWN[5]

[1]The Nature Conservancy, Central Science Division, 1917 First Avenue Seattle, WA 98101, USA, [2]International Center for Tropical Agriculture (CIAT), PO Box 823-00621, Nairobi, Kenya, [3]The Nature Conservancy, Africa Program, 1917 First Avenue Seattle, WA 98101, USA, [4]The Grumeti Fund, PO Box 0, Mawalla Park, Olasiti Road, Arusha, Tanzania, and [5]The Nature Conservancy, Africa Program, Plot 16002 Mawalla Street, PO Box 13265 (Meru Branch), Arusha, Tanzania

Date submitted: 15 February 2013; Date accepted: 21 November 2013; First published online: 28 January 2014

SUMMARY

In the face of an already changing climate, conservation practitioners and local communities face the major challenge of how to plan for a future climate. In data-sparse areas of the world, where action is often most needed, the daunting scope of the problem can lead to inaction. This paper shows that climate adaptation planning can be accomplished successfully with publicly and globally available data by linking science and stakeholders through a facilitated process. Working with local stakeholders in the western Tanzanian Greater Mahale and Greater Gombe Ecosystems, future climate projections produced using Climate Wizard and analyses of literature provided an understanding of the climate vulnerabilities of local ecosystems and human livelihoods. Facilitated workshops enabled local stakeholders to use this information to develop conceptual models and hypotheses of change for these systems, and to identify possible modifications to conservation plans. Here, climate change planning required the modification of most current conservation strategies, developing some new strategies and abandoning others. The paper indicates that climate adaptation planning is achievable even in data-sparse rural and developing areas, but requires appropriate scientific analyses, engaged stakeholders and a facilitated process.

Keywords: climate change, Climate Wizard, conservation planning, ecosystem-based adaptation, Gombe ecosystem, Mahale ecosystem, Tanzania

INTRODUCTION

Conservation practitioners and natural resource managers face an unprecedented challenge in planning and managing the local and regional effects of climate change. Examples of real-world adaptation planning are becoming more common (Roberts 2008; Charlton & Arnell 2011), but more research and application are needed to improve interpretation of uncertainty and variability of climate models in the context of stakeholder decision-making (Lawler *et al.* 2010). This is particularly acute in developing countries, where people's livelihoods tend to be more vulnerable to climate impacts but information is limited. Recently, there have been great strides made in providing tools and planning approaches useful for on-the-ground decision making. However, considerable work is still needed to understand how best to use currently available science for stakeholder-engaged natural resource climate adaptation planning.

Climate change information has become much more available to a broad audience of planners, and various stakeholder planning processes have been developed. Climate Wizard and similar tools translate general circulation models (also known as global climate models, GCMs) into synthesized information accessible to non-climate scientists for adaptation planning (Girvetz *et al.* 2009). At the same time, several approaches to adaptation planning processes exist for decision making that are being modified for implementation through a climate change lens, including conservation action planning (Poiani *et al.* 2011), adaptation for conservation targets (Cross *et al.* 2012) and the open standards for conservation (Schwartz *et al.* 2012).

One of the places where these data and planning frameworks are needed is in the ecosystems of east Africa, where rich and charismatic biodiversity, as well as vulnerable people's livelihoods, are under threat from climate variability and change (Boko *et al.* 2007). The Albertine Rift is one of the most important places for conservation in Africa. It includes forests, woodlands and freshwater systems that contain a host of diverse and endemic species (Plumptre *et al.* 2007). Focusing on two biologically unique areas of Western Tanzania (Africa), this paper describes how publicly available science was used within a stakeholder engaged process to modify current conservation strategies in order to address three research questions. (1) What type and level of climate change information and scientific literature review is useful for climate adaptation planning? (2) What aspects of different adaptation planning processes are most useful for decision-making? (3) How do existing conservation strategies change

*Correspondence: Dr Evan Girvetz e-mail: e.girvetz@cgiar.org

and when are new strategies needed for adapting to future climate change impacts?

METHODS

Study area

This study focuses on the Greater Gombe Ecosystem (GGE) and Greater Mahale Ecosystem (GME) in the Albertine Rift on the western border of Tanzania with Lake Tanganyika. In these areas, people's livelihoods depend on the natural environment, and while most residents are agriculturalists and fisherfolk, they also depend heavily on the forests, woodlands and freshwater systems to provide food, water and shelter (Hess & Leisher 2011). This resource base is already stressed and degraded by overuse, with pressure on these natural systems increasing as population levels and poverty increase (Tanzania National Bureau of Statistics 2011).

Two of Tanzania's major rivers have recently been experiencing reduced flows due to declining regional rainfall, which has had ecological and economic impacts, such as water shortages, increased fungal and insect infestations, and decreased biodiversity (Orindi & Murray 2005). Over the past century, Lake Tanganyika has become warmer and more stratified (O'Reilly *et al.* 2003). Increased stratification has led to decreased net primary productivity, a decline in fish stocks, and changes in algal biomass, productivity and community composition (Tierney *et al.* 2010). Assuming these impacts will continue due to increased temperatures, profound changes can be expected in nearshore habitat, which may have cascading effects on the highly diverse littoral communities and nursery areas for pelagic fish.

Chimpanzees and elephants are two conservation species of special interest in the project areas. Both species are long-lived, and projecting how their distribution and population dynamics will be impacted by a changing climate is challenging. Climate change impacts are expected to interact synergistically with other stresses, such as land use change. Increasing drought and reduced dry season runoff has the potential to reduce elephant populations (Dudley *et al.* 2001). As temperatures increase, primates may need to adopt energy-saving patterns like reducing travel or living in smaller groups: for example Lehmann *et al.* (2010) modelled changes in chimpanzee time budgets due to projected future climate changes and found that in surviving chimpanzee populations, resting time almost doubled due to the combined effect of an increasingly leaf-based diet and increased temperature.

Some of the most profound and direct impacts of climate change to people in the project area over the next few decades will be on agricultural and food systems (Brown & Funk 2008; Funk *et al.* 2008). The negative impacts associated with climate change also are projected to have a number of more indirect effects on people's livelihoods, including the possibility of an increased spread of disease (Myers & Patz 2009), a more difficult time finding wood to generate energy due to changes in forest distribution and structure, and increased potential for damaging wildfires.

Climate vulnerability assessment

Climate change analyses examined future annual and seasonal projected conditions in western Tanzania using the Climate Wizard tool for a small suite of indicators (Girvetz *et al.* 2009; http://ClimateWizard.org): (1) temperature; (2) precipitation; (3) the aridity index plus (AI^+; ratio between available water [based on precipitation] and potential evapotranspiration [based on temperature and the number of daylight hours; E. H. Girvetz & C. Zganjar, unpublished data 2012]); and (4) climatic moisture surplus (the amount of precipitation that falls in a specific time period above and beyond potential evapotranspiration, a surrogate for change in runoff [Wolock & McCabe 1999]). Future climate change projections were assessed using an ensemble average of 16 GCMs run under three different greenhouse gas emissions scenarios, namely B1 (lower), A1b (middle) and A2 (higher), for the future time periods of 2040–2069 (mid-century) and 2070–2099 (end-century) compared to a historic baseline time period of 1961–1990. Seasons were defined as three-month time periods (Dec–Feb; Mar–May; Jun–Aug; Sep–Nov), which roughly correspond to western Tanzania's early rainy season (warm/wet), late rainy season (transitioning to cool/dry), cool/dry season, and late dry season (transitioning to warm/wet).

Information assembled from a review of the scientific literature was used in conjunction with the climate model data to consider impacts to species, ecosystems and human livelihoods. These preliminary results were then vetted and refined by local experts and stakeholders. Due to the limited availability of climate impact studies for the region, climate impacts documented in the east African region were modified to reflect the local characteristics of western Tanzania.

Stakeholder engaged adaptation planning

Three stakeholder engaged workshops were conducted to transform the climate vulnerability assessment into tangible climate adaptation strategies that could be implemented in the field (planning for both study areas was considered together at the workshops, but treated as two independent planning processes): the three workshops were attended by 21, 26 and 61 participants, respectively, composed of local stakeholders (for example staff working in local villages, landowners and government officials), elected politicians, and, in the final workshop, representatives from funding agencies.

The key objectives of the first three-day workshop were to use the vulnerability assessment to increase local awareness of climate change and its projected impacts, and to determine how these impacts would affect species and ecosystems of concern. Workshop participants shared personal observations about climate change, while learning

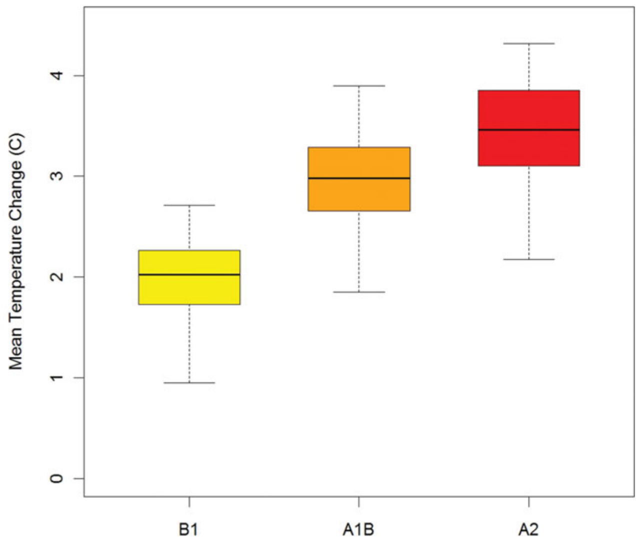

Figure 1 Projected seasonal change in mean temperature from historic (1961–1990) to end-of-century (2070–2099) across all climate models for the three greenhouse gas emission scenarios (B1, A1B, A2). The dark central line in each box represents the 50th percentile or median prediction of all sixteen global climate models (GCMs). The top and bottom of the box represent the 75th and 25th percentiles, respectively. The top and bottom 'whiskers' plot the maximum and minimum values from different GCM runs for each scenario.

what scientists know about climate change projections and impacts. The stakeholders then designed a 'conceptual model' for each project area, namely a visual diagram that showed the connection between key systems and species, key threats, and likely climate change impacts (following Cross *et al.* 2012). The final part of this workshop involved creating specific hypotheses of change and stating how climate change was likely to impact key systems and species, and selecting key indicators to monitor (following Poiani *et al.* 2011).

The key objectives of the second workshop were to review existing conservation strategies and revise them in one of three ways in light of climate change: (1) modify existing strategies to increase their effectiveness; (2) identify existing conservation strategies that do not require revision; and (3) identify new strategies that are required to fill gaps created by the incorporation of climate impacts.

The third workshop had the goal of increasing direct support for successful implementation of adaptation strategies and influencing policies and actions at the local, regional and national levels that might further successful strategy implementation.

RESULTS

Historic and projected changes in climate

Future climate projections indicated a temperature increase of 1.3–2.3 °C by mid-century, and 1.7–3.8 °C by 2085 (Fig. 1). Precipitation was projected to increase in all climate models for western Tanzania, with an increase of 0.3–15.6% by 2055 and 12–28.6% by 2085. The GCMs indicated that rainfall may increase during the rainy season (December–May), decrease during the dry season (June–August), and remain roughly the same during September–November.

Aridity is projected to increase (decreasing AI^+) annually, even in the face of increasing precipitation, regardless of the emissions scenario, with the most severe impacts in the period September–November (Fig. 2). The wet season was the only season where models closely agreed on no change in aridity. Climatic moisture surplus (surrogate for runoff) projections showed a wide range of changes annually (both increasing and decreasing), however there was good agreement among GCMs that this surplus would decrease during the dry season.

Stakeholder engaged adaptation planning

During the first workshop, participants agreed upon which potential impacts from climate change were likely to be seen in their project area (Tables 1 and 2), and created conceptual ecological models that visually depicted climate impacts to the system (Figs 3 and 4). In addition, they further broadened this model by developing explicit hypotheses of change for the most critical ecosystems and species, and identified indicators for monitoring climate change impacts across the project area (Table 3).

During the second workshop, participants used the conceptual models and hypotheses of change to identify areas where climate change adaptation would require either modification of existing strategies or development of new strategies to ensure project success, and subsequently crafted an initial set of action steps necessary to begin strategy implementation. Seven of the 10 strategies currently being implemented in the GGE project area were revised to make them more robust to climate change impacts (Table 4). In the GME project area, six of the eight strategies were revised to make them more robust to climate change impacts. In addition, the project teams identified new climate change adaptation strategies that were important to implement for overall project success, which were related to fisheries, education and policy.

In the final workshop, participants discussed how to advance implementation of climate change adaptation in western Tanzania, including which parties were best placed to lead the implementation of strategies focused on land-use planning, fisheries, connectivity, wildfire, energy, education and policy. Results of discussions revealed that successful implementation of climate adaptation strategies in western Tanzania will require close collaboration and coordination between local communities and village councils, district, regional and national government, non-governmental organizations, research institutions, donors, and the private sector. This workshop concluded with a commitment from the national government of Tanzania and workshop participants

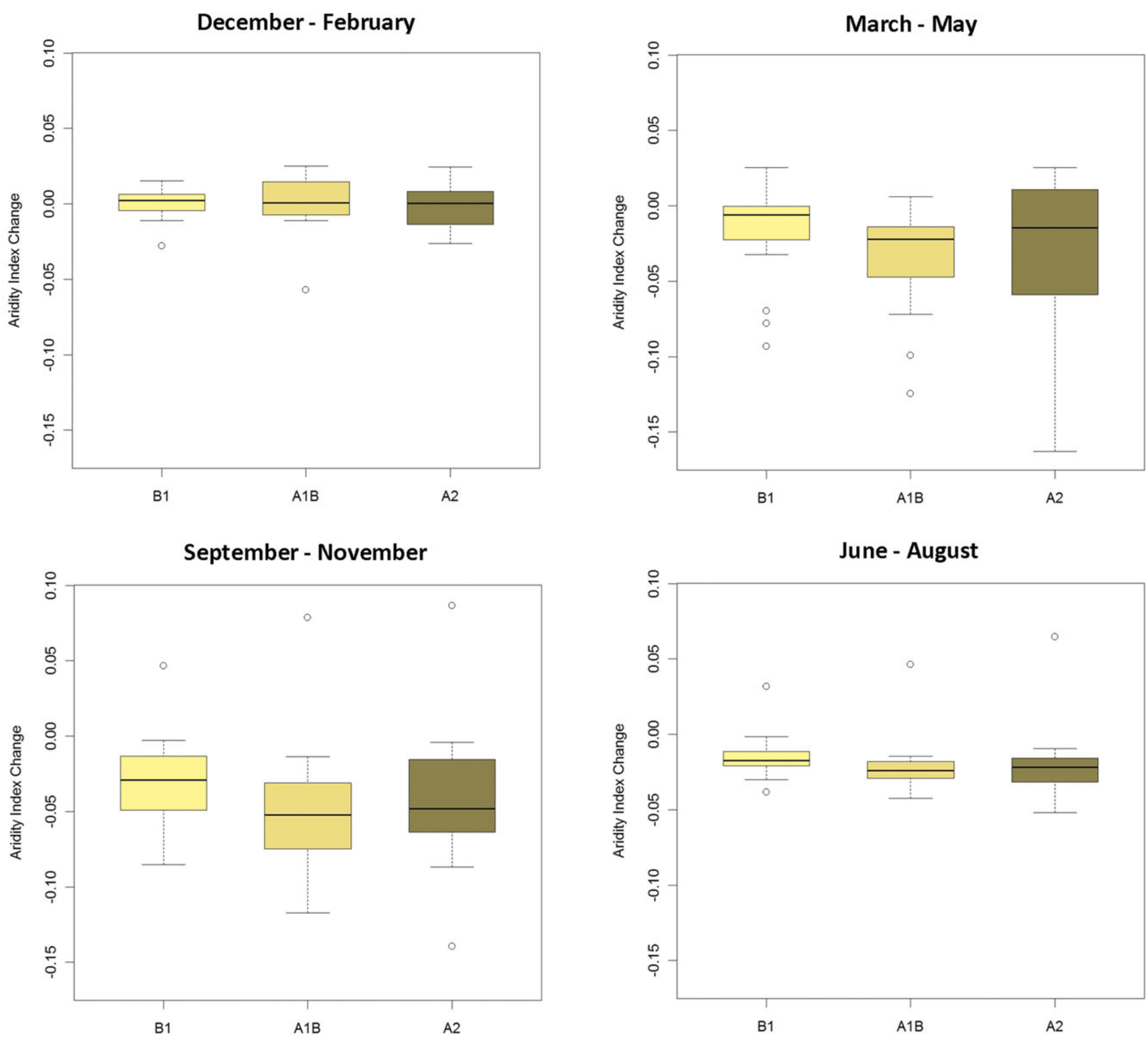

Figure 2 Projected seasonal change in the aridity index plus (AI+) from historic (1961–1990) to end-of-century (2070–2099) across all climate models for the three greenhouse gas emission scenarios (B1, A1b, A2). The dark central line in each box represents the 50th percentile or median prediction of all sixteen global climate models (GCMs). The top and bottom of the box represent the 75th and 25th percentiles, respectively. The top and bottom 'whiskers' plot the maximum and minimum values from different GCM runs for each scenario. The open circles represent outliers.

to work more closely together and to assist each other in the development of local, regional and national climate change adaptation policies and programmes that benefit the region's natural resources, economy, and human livelihoods.

DISCUSSION

This paper demonstrates that climate adaptation planning can be successfully accomplished in a data poor rural area of an economically developing nation. Climate adaptation planning takes a combination of useful scientific analyses, engaged stakeholders and a facilitated process. Following this approach, we demonstrate that it is possible to develop climate change adaptation strategies that have the degree of buy-in and support assumed necessary for successful on-the-ground implementation.

The climate change analysis and scientific literature review point to a need to plan for more frequent and severe droughts due to lower precipitation and reduced moisture surplus during the dry season. Increased precipitation during the wet season has potential to increase erosion of top soil. Increased temperatures and aridity can cause increased frequency and intensity of fire. Miombo woodlands are adapted to aridity, drought and fire (Werger & Coetzee 1978), making them less vulnerable to these changes, whereas the other forests types

Table 1 Overview of potential climate impacts to ecosystems in the study areas based on the climate change analysis and literature review. This list was used to develop simple conceptual models that ultimately informed conservation strategy revisions in a subsequent workshop.

Ecosystems and keystone species	*Potential climate impacts*
Terrestrial	More frequent and severe droughts
	Increased erosion of topsoil
	Changes in size and distribution of vegetative communities
	Increased spread of fire, disease and invasive species
Riverine and wetlands	Lowered water levels, especially during the dry season
	Increased sedimentation and pollution, especially during the wet season
	Changes in the timing and amount of water flow in all seasons
Lake Tanganyika	Increased water temperatures in surface waters
	Increased stratification in deep waters
	Increased sedimentation to nearshore waters
	Decreased overall productivity for all habitats
Chimpanzees	Foraging ranges and population distributions more fragmented
	Decrease in suitable habitat leading to decreased population numbers
	Changes in diet due to changes in food availability
	Changes in grouping patterns leading to increased mortality
Elephants	Decrease in population numbers due to the increased frequency and length of droughts
	Altered movement patterns including changes in migratory routes due to changes in food and water availability

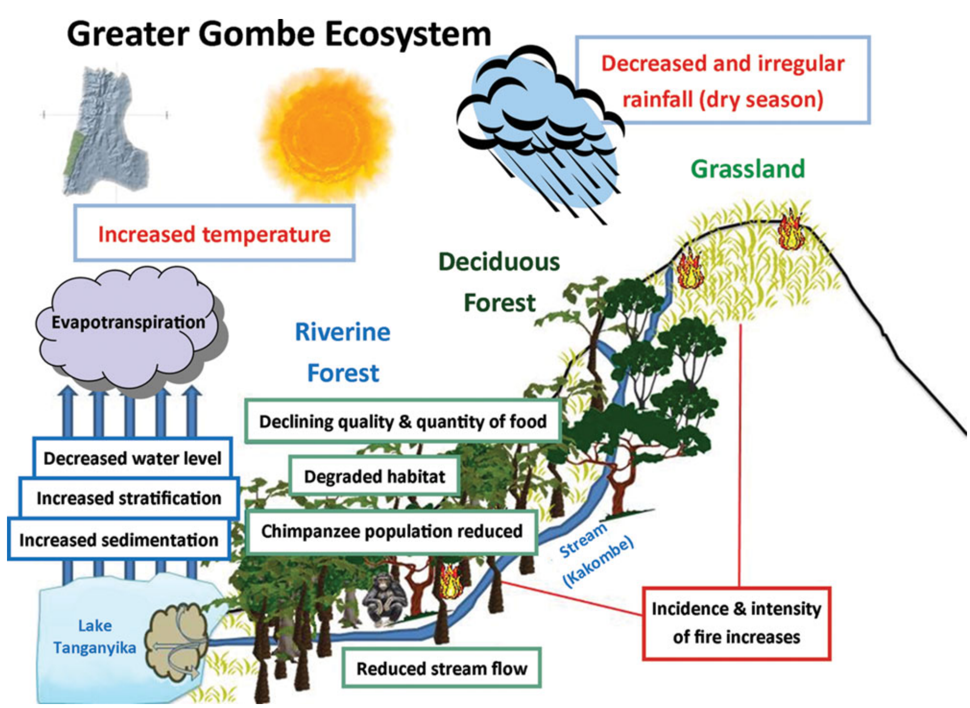

Figure 3 Greater Gombe Ecosystem conceptual model developed through the stakeholder-engaged planning process.

are likely to experience changes in distributions from fire (Moyer *et al.* 2006), especially montane forests (Agrawala *et al.* 2003). Increased moisture surplus during the wet season and decreased moisture surplus during the dry season is expected to alter the timing and amount of water flow. Increased erosion may lead to increased sedimentation and pollution especially during the wet season.

It was clear from this study that useful information about impacts to ecosystems and people was important in decision-making, but specific quantitative numbers about climate change were not necessarily needed. In general, it did not appear useful in the planning process for stakeholders to learn that climate models project a 0.3–15.6% precipitation increase by end-century. However, participants did respond to the direction and general magnitude of projected changes. Participants altered strategies as a result of understanding that when temperature and precipitation change were analysed together, there was high climate model agreement that aridity was projected to increase (particularly in September through November), which resulted in greater fire risk, thus leading

https://doi.org/10.1017/S0376892914000010 Published online by Cambridge University Press

Table 2 Key potential climate change impacts to people's livelihoods in the study areas, agreed upon during the workshops and used to revise conservation strategies.

Livelihoods and human health	*Potential climate impacts*
Agriculture	Reduced length of growing season
	Less productive soils due to increased erosion
	Lower harvests due to loss of natural cues for when to plant and harvest
	Overall decline in smallholder farm productivity due to multiple interacting factors
Fisheries	Decline in primary productivity
	Decline in protein supply via smaller and fewer fish in catches
	Loss of some specific species of fish
	Reduction and loss of nearshore fish breeding habitat
Water resources	Reduced water availability and accessibility due to lowered groundwater tables and changes in overland flow
	Increased water demand due to higher temperatures, more drought, and more people
	Decreased water quality due to increased sedimentation and pollutants
Human health	Increased spread of vector-borne diseases such as malaria, dengue, schistosomiasis and tick-borne diseases
	Increased frequency of water and food-borne diseases such as cholera
	Higher frequency and intensity of new epidemics
	Increased mortality from disease, especially of women and children
	Increased occurrence of ailments such as heat stress and asthma

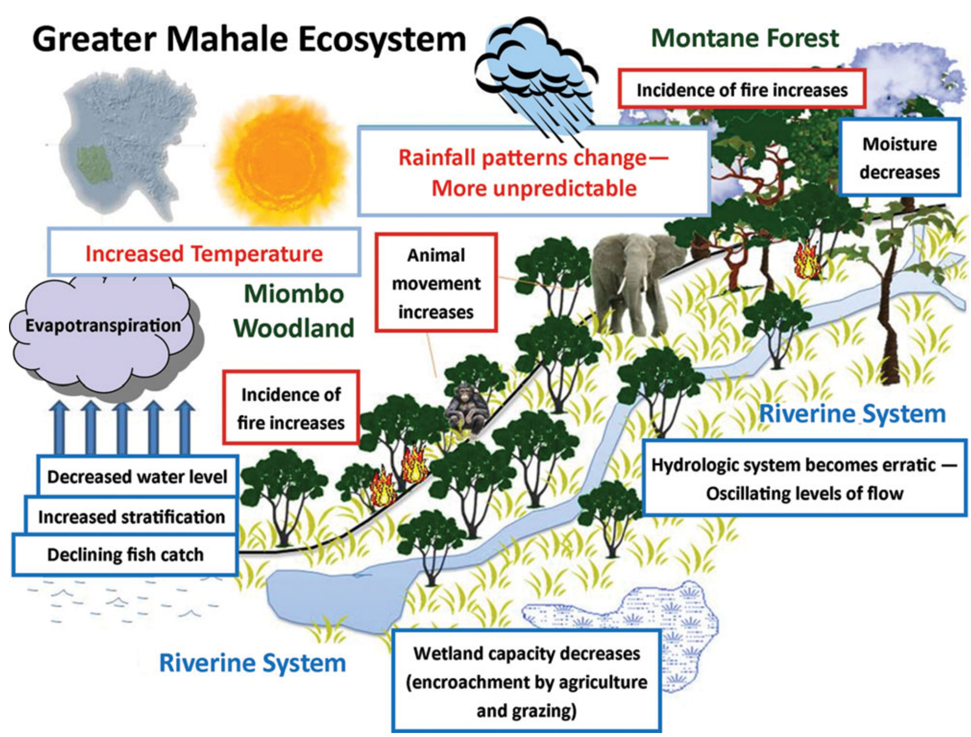

Figure 4 Greater Mahale Ecosystem conceptual model developed through the stakeholder-engaged planning process.

to a greater likelihood of chimpanzee-human conflicts. This observation was consistent with studies investigating how people interpret environmental information, which show that abstract numbers have limited impact on people's attitudes, yet information made relevant to everyday life is significantly more important to changing behaviours (see for example Ham 1992). For quantitative-natured scientists, it is important to translate this information into a useful concept and avoid presenting complex data that can lead to confusion or complete dismissal of what may be important information. However, this finding may be dependent on the audience, here a mix of community-based and policy stakeholders, but others may require different types of information (such as more quantitative data) to overcome institutional constraints or requirements.

Increasing local stakeholder engagement in the development of climate adaptation actions was an objective of this process. Our hypothesis was that increased engagement

Table 3 Hypothesis of change due to future climate for different ecosystems used to revise conservation strategies in the Greater Gombe and Greater Mahale Ecosystems.

Ecosystem	*Climate factor*	*Hypothesis of change*
Evergreen forests (including riparian)	Increased temperature	Higher temperatures will decrease soil moisture content, leading to water stress for plants and changing evergreen forest function, size and species composition
Evergreen forests (including riparian)	Increased temperature	Increased temperatures will cause people to move from other landscapes to evergreen forest, which will lead to high encroachment and ultimately result in reduced size of the forest via habitat conversion
Miombo woodland	Increased temperature and change in the frequency, timing and intensity of rainfall	Increased temperatures and more variable and intense rainfall will alter current soil moisture and hydrological cycles that will change woodland structure and composition, leading to a rise in fire frequency/incidence, and eventually reducing the amount of Miombo woodland
Riverine and wetland systems	Increased temperature, and rainfall decrease during the dry season	Increased air temperature and decreased seasonal rainfall will lead to reduction in water levels and increases in water temperature in rivers and wetlands, ultimately stressing aquatic biodiversity
Riverine and wetland systems	Changes in the seasonality and intensity of rainfall	An increase in sporadic but more intense rainfall events will cause rivers and wetlands to overflow, leading to riverbank erosion and downstream sedimentation, destroying breeding sites of aquatic biodiversity both in the rivers and in the nearshore habitat of Lake Tanganyika
Lake Tanganyika	Water temperature increase (corresponding to air temp increase), and changes in the seasonality and intensity of rainfall	Increases in water temperature and reductions in seasonal rainfall will drive Lake Tanganyika to become shallower and more stratified, resulting in less upwelling events which will reduce primary productivity and impair fisheries productivity
		Increased sedimentation to near shore habitats will reduce nearshore fisheries productivity as well as deep water fisheries by reducing productivity of nearshore breeding sites
Chimpanzees	Increased temperature and more severe dry season	Increases in temperature and more severe dry seasons are expected to decrease food quality and quantity for chimpanzees, causing them to expand their forage range, which will expose them to a greater risk of human and territorial conflict, leading to increased mortality
Elephants	Increased temperature and decreased rainfall during the dry season	Increased temperatures and decreased rainfall during the dry season are expected to alter, elephants behaviours to become more restricted to water points, exposing them to increased poaching and causing local habitat degradation

and buy-in would lead to increased feasibility of strategy implementation. Stakeholders were engaged during the entire process from the analysis of climate data through development of conservation strategies, to policy negotiations and implementation of specific actions (although policy negotiations and strategy implementation are not discussed in this paper). It is our observation that good facilitation via clear communication of expected outcomes and a straightforward and transparent process to achieving these outcomes were important for engaging stakeholders. We adapted currently existing processes (see Poiani *et al.* 2011; Cross *et al.* 2012), to best address the specific needs of this stakeholder group. In particular, repeat workshops (three over the course of 1.5 years) provided the time needed for local staff to become not only comfortable with new climate change concepts and terminology, but also become adept enough to critically analyse and interpret this information. Repetition of assumptions and conclusions drawn from previous workshops appeared to help build the high degree of stakeholder acceptance to the scientific climate change information and its relevance.

The final workshop included representatives from the Tanzania Government (such as the Vice-President's Office, and Ministry of Natural Resources and Tourism). Active participation of government representatives helped to validate the work the stakeholders had accomplished in the first two workshops, and create needed support for implementing on-the-ground strategies. A key realization during this third workshop was that some national policies needed to be strengthened in order to support these local efforts. This further highlighted the need for better integration between district, regional, and national planning approaches.

Ultimately, only time will tell if the conservation strategies agreed upon as a result of this process will be successful in the face of climate change. It was our assumption that raising awareness of climate change risks, increasing local commitment and buy-in to strategy implementation, and strengthening local, regional and national collaboration

Table 4 Original, revised and new strategies for the Greater Gombe Ecosystem (GGE). Strategies were revised for a variety of reasons associated with rethinking original desired outcomes in the context of this new information on the potential impacts from climate change.

Category	*Original strategy*	*Revised strategy*	*New strategy*
Land-use planning	Support village governments to protect and conserve 5280 ha of range, including 642 ha of evergreen forest, for the Mitumba chimpanzee community by 2018, in the area defined by the Mitumba chimpanzee community polygon outside the Park	Support village governments to protect and conserve 14671 ha of range, including 3812 ha of evergreen forest, for the Mitumba, Kalande and Zashe chimpanzee communities, by 2018, in the area defined by these three communities' range-polygons outside the Park	–
	Support village governments to protect and conserve 7012 ha of range, including 1152 ha of evergreen forest, for the Zashe chimpanzee community by 2018, in the area defined by the Zashe chimpanzee community polygon	–	–
	Support village governments to protect and conserve 2379 ha, including 132 ha of evergreen forest, for the Kalande chimpanzee community by 2018, in the area defined by the Kalande chimpanzee community polygon outside the Park	–	–
Agriculture	No conversion to farmland outside of agricultural zones as defined by appropriate land use plans in the GGE by 2013	No conversion to farmland outside of agricultural zones as defined by appropriate land use plans in the GGE by 2020	–
Wildlife	Incidence of incompatible wild fire reduced by 80% by 2013	Incidence of incompatible wild fire reduced to 50% of 2002 levels by 2013	–
Deforestation	No incompatible firewood extraction from village forest reserves and water source reserves by 2013	No incompatible firewood extraction from all forest reserves, water source reserves and general land by 2015	–
	65% of steep slopes over 45% gradients have tree cover with trees that are 8–10 years old by 2018	70% of steep slopes over a 45% gradient have tree and/or grass cover that is 5–10 years old by 2018	–
Wetlands	90% of springs are buffered in the GGE with a minimum buffer of 60 m by 2018	90% of springs are buffered in the GGE with a minimum buffer of 60 m by 2020	–
Corridors	Establishment of a functioning corridor connecting the Kwitanga chimpanzee community with the Gombe chimpanzee population by 2018	Establishment of a functioning corridor connecting the Kwitanga chimpanzee community with the Gombe chimpanzee population by 2025	–
Poaching	No chimpanzees killed deliberately by humans in the GGE by 2013	–	–
Fisheries			100% of breeding sites are protected around the GGE to increase fish production by 2015
Education			Improve knowledge sharing to increase understanding of climate change to 80% of communities

Table 5 Original, revised, and new strategies for the Greater Mahale Ecosystem (GME). Strategies were revised for a variety of reasons associated with rethinking original desired outcomes in the context of this new information on the potential impacts from climate change.

Category	*Original strategy*	*Revised strategy*	*New strategy*
Agriculture	By 2018, all agricultural activities are confined to agricultural zones as determined in village land-use management planning, and affected forests, rivers and wetlands regenerate and are protected	By 2018, all agricultural activities are confined to national agricultural zones and village agricultural zones as determined in village land-use management planning, and affected forests, rivers and wetlands regenerate and are protected	–
Poaching	By 2018, poaching is reduced by 50% overall and by 75% in newly designated protected areas within five years of their establishment; appropriate legal hunting is sustainable with benefit sharing (communities and wildlife protection)	By 2018, poaching is reduced by 50% overall and by 75% in newly designated protected areas within 5 years of their establishment	–
Fisheries	By 2012, fisheries management is improved, the use of illegal fishing methods is progressively declining and the rate of extraction of fish is at a sustainable level	By 2015, fisheries management is improved, the use of illegal fishing methods is progressively declining and the rate of extraction of fish is at a sustainable level	–
Wildfire	Reduce wildfire incidents in GME by at least 50% by 2018	Reduce wildfire incidents in GME by at least 65% by 2018	–
Land-use planning	No settlement in the core conservation area and periphery by 2018	No settlement and human activities in the core conservation area and adjacent buffer zone (village forest reserves) by 2018	–
Wetlands	Reduce incompatible human activities within wetland buffer zones and catchments by 80% by 2018	–	–
Corridors	By 2018, connectivity of key areas within the ecosystem is maintained/restored	–	–
Energy	By 2015, improve uptake of existing energy alternatives and more fuel efficient stoves	By 2018, reduce the extensive use of charcoal and fuelwood to sustainable levels by introducing energy saving and affordable cookstoves	–
Policy			Support development of a national policy framework for climate change in Tanzania

were all factors necessary (but not necessarily sufficient) to successfully adapt to climate change. To these ends, this facilitated stakeholder-driven conservation planning process was successful and has laid out a set of conservation strategies to help people and ecosystems in Western Tanzania adapt to the climate change impacts projected to come.

CONCLUSION

Climate change has been viewed as a complicated science that is difficult to penetrate and make real to local people for climate adaptation planning. One of the benefits of this analysis and workshop process was that the best climate change expertise for this area shifted from an external suite of experts to the people that live in the region. All the workshop participants, through their engagement and involvement, have spent considerable time contemplating potential impacts of climate change on their community and natural resources. This was accomplished in part by using historical information as a benchmark to help bridge past, current and future time frames, making it easier for local people to assess potential future impacts.

In this process, the general concept of historical ecology and natural ranges of variability helped guide the assessment of vulnerability, then this information was tied to conservation strategies, ecosystem services and adaptive management, to develop on-the-ground actions. Although developing climate adaptation responses is not trivial, it can be accomplished even in data-sparse regions. To do so, we recommend combining targeted climate change data, relevant scientific information and local knowledge as part of a facilitated stakeholder-engaged decision process in order to best plan for the resiliency of ecosystems and human livelihoods in the face of a changing climate.

References

Agrawala, S., Moehner, A., Hemp, A., van Aalst, M., Hitz, S., Smith, J., Meena, H., Mwakifwamba, S.M., Hyera, T. & Mwaipopo, O.U. (2003) Development and climate change in Tanzania: focus on Mount Kilimanjaro. Report COM/ENV/EPOC/DCD/DAC(2003)5/FINAL. Organization for Economic Cooperation and Development, Paris, France: 72 pp. [www document]. URL http://www.oecd.org/env/cc/21058838.pdf

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R. & Yanda, P. (2007) Africa. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. J.P. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson, pp. 433–467. Cambridge, UK: Cambridge University Press.

Brown, M.E. & Funk, C.C. (2008) Climate. Food security under climate change. *Science* **319**(5863): 580–581.

Charlton, M.B. & Arnell, N.W. (2011) Adapting to climate change impacts on water resources in England: an assessment of draft water resources management plans. *Global Environmental Change-Human and Policy Dimensions* **21**(1): 238–248.

Cross, M.S., Zavaleta, E.S., Bachelet, D., Brooks, M.L., Enquist, C.A.F., Fleishman, E., Graumlich, L.J., Groves, C.R., Hannah, L., Hansen, L., Hayward, G., Koopman, M., Lawler, J.J., Malcolm, J., Nordgren, J., Petersen, B., Rowland, E.L., Scott, D., Shafer, S.L., Shaw, M.R. & Tabor, G.M. (2012) The adaptation for conservation targets (ACT) framework: a tool for incorporating climate change into natural resource management. *Environmental Management* **50**(3): 341–351.

Dudley, J.P., Criag, G.C., Gibson, D.S., Haynes, G. & Klimowicz, J. (2001) Drought mortality of bush elephants in Hwange National Park, Zimbabwe. *African Journal of Ecology* **39**(2): 187–194.

Funk, C., Dettinger, M.D., Michaelsen, J.C., Verdin, J.P., Brown, M.E., Barlow, M. & Hoell, A. (2008) Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development. *Proceedings of the National Academy of Sciences USA* **105**(32): 11081–11086.

Girvetz, E.H., Zganjar, C., Raber, G.T., Maurer, E.P., Kareiva, P. & Lawler, J.J. (2009) Applied climate-change analysis: the Climate Wizard tool. *PLoS One* **4**(12): e8320.

Ham, S.H. (1992) *Environmental Interpretation: A Practical Guide for People with Big Ideas and Small Budgets*. Denver, CO, USA: Fulcrum Publishing.

Hess, S. & Leisher, C. (2011) Baseline study for the Tuungane Health and Conservation Project. Report. The Nature Conservancy, Arlington, VA, USA: 79 pp. [www document]. URL https://www.conservationgateway.org/Documents/Tuungane Baseline Report.pdf

Lawler, J.J., Tear, T.H., Pyke, C., Shaw, M.R., Gonzalez, P., Kareiva, P., Hansen, L., Hannah, L., Klausmeyer, K., Aldous, A., Bienz, C. & Pearsall, S. (2010) Resource management in a changing and uncertain climate. *Frontiers in Ecology and the Environment* **8**(1): 35–43.

Lehmann, J., Korstjens, A.H. & Dunbar, R.I.M. (2010) Apes in a changing world: the effects of global warming on the behaviour and distribution of African apes. *Journal of Biogeography* **37**(12): 2217–2231.

Moyer, D., Plumptre, A., Pintea, L., Hernandez-Aguilar, A., Moore, J., Stewart, F., Davenport, T., Piel, A., Kamenya, S., Mugabe, H., Mpunga, N. & Mwangoka, M., eds (2006) Surveys of chimpanzees and other biodiversity in Western Tanzania: Report to United States Fish and Wildlife Service. Wildlife Conservation Society, Jane Goodall Institute & University of California at San Diego, San Diego, CA, USA: 65 pp. [www document]. URL http://weber.ucsd.edu/~jmoore/courses/methprimconsweb08/MoyerEtAl2006WCSTanzania.pdf

Myers, S.S. & Patz, J.A. (2009) Emerging threats to human health from global environmental change. *Annual Review of Environment and Resources* **34**: 223–252.

O'Reilly, C.M., Alin, S.R., Pilsnier, P.-D., Cohen, A.S. & McKee, B.A. (2003) Climate change decreases aquatic ecosystem productivity of Lake Tanganyika, Africa. *Nature* **424**: 766–768.

Orindi, V.A. & Murray, L.A. (2005) Adapting to climate change in East Africa: a strategic approach. Report. Gatekeeper Series 117, International Institute for Environment and Development, London, UK.

Plumptre, A.J., Davenport, T.R.B., Behanyana, M., Kityo, R., Eilu, G., Ssegawa, P., Ewango, C., Meirte, D., Kahindo, C., Herremans, M., Peterhans, J.K., Pilgrim, J.D., Wilson, M., Languy, M. & Moyer, D. (2007) The biodiversity of the Albertine Rift. *Biological Conservation* **134**(2): 178–194.

Poiani, K.A., Goldman, R.L., Hobson, J., Hoekstra, J.M. & Nelson, K.S. (2011) Redesigning biodiversity conservation projects for climate change: examples from the field. *Biodiversity and Conservation* **20**(1): 185–201.

Roberts, D. (2008) Thinking globally, acting locally: institutionalizing climate change at the local government level in Durban, South Africa. *Environment and Urbanization* **20**(2): 521–537.

Schwartz, M.W., Deiner, K., Forrester, T., Grof-Tisza, P., Muir, M.J., Santos, M.J., Souza, L.E., Wilkerson, M.L. & Zylberberg, M. (2012) Perspectives on the open standards for the practice of conservation. *Biological Conservation* **155**(0): 169–177.

Tanzania National Bureau of Statistics (2011) *Tanzania Demographic and Health Survey 2010*. Dar es Salaam, Tanzania: National Bureau of Statistics: 482 pp.

Tierney, J.E., Mayes, M.T., Meyer, N., Johnson, C., Swarzenski, P.W., Cohen, A.S. & Russell, J.M. (2010) Late-twentieth-century warming in Lake Tanganyika unprecedented since AD 500. *Nature Geoscience* **3**(6): 422–425.

Werger, M.J.A. & Coetzee, B.J. (1978) The Sudano-Zambezian region. In: *Biogeography and Ecology of Southern Africa*, ed. M.J.A. Werger, pp. 301–462. The Hague, The Netherlands: W. Junk.

Wolock, D. M. & McCabe, G. J. (1999) Explaining spatial variability in mean annual runoff in the conterminous United States. *Climate Research* **11**(2): 149–159.