Nature Conservation 6: 1–29 (2013)
doi: 10.3897/natureconservation.6.5407
http://www.pensoft.net/natureconservation

RESEARCH ARTICLE

A peer-reviewed open-access journal
Nature Conservation
Launched to accelerate biodiversity conservation

Emerging issues and challenges in conservation of biodiversity in the rangelands of Tanzania

Jafari R. Kideghesho[1], Alfan A. Rija[1], Kuruthumu A. Mwamende[2], Ismail S. Selemani[2]

1 *Department of Wildlife Management, Sokoine University of Agriculture (SUA), P.O. Box 3073, Chuo Kikuu, Morogoro Tanzania* **2** *Range Management Section, Department of Animal Science & Production, P. O. Box, 3004, Sokoine University of Agriculture, Chuo Kikuu, Morogoro Tanzania*

Corresponding author: *Alfan A. Rija* (al.rija10@gmail.com)

Academic editor: *Klaus Henle* | Received 25 April 2013 | Accepted 20 August 2013 | Published 18 November 2013

Citation: Kideghesho JR, Rija AA, Mwamende KA, Selemani IS (2013) Emerging issues and challenges in conservation of biodiversity in the rangelands of Tanzania. Nature Conservation 6: 1–29. doi: 10.3897/natureconservation.6.5407

Abstract
Tanzania rangelands are a stronghold for biodiversity harbouring a variety of animal and plant species of economic, ecological and socio-cultural importance. Efforts to protect these resources against destruction and loss have involved, among other things, setting aside some tracks of land as protected areas in the form of national parks, nature reserves, game reserves, game controlled and wildlife management areas. However, these areas and adjacent lands have long been subjected to a number of emerging issues and challenges, which complicate their management, thus putting the resources at risk of over exploitation and extinction. These issues and challenges include, among other things, government policies, failure of conservation (as a form of land use) to compete effectively with alternative land uses, habitat degradation and blockage of wildlife corridors, overexploitation and illegal resource extraction, wildfires, human population growth, poverty, HIV/AIDS pandemic and human-wildlife conflicts. In this paper, we review the emerging issues and challenges in biodiversity conservation by drawing experience from different parts of Tanzania. The paper is based on the premise that, understanding of the issues and challenges underpinning the rangelands is a crucial step towards setting up of plausible objectives, strategies and plans that will improve and lead to effective management of these areas. We conclude by recommending some proactive measures that may enhance the sustainability of the rangeland resources for the benefit of the current and future generations.

Keywords
Climate change, civil war, habitat degradation, invasive species, illegal hunting, wildfires

Introduction

Rangelands are characterized by low and erratic precipitation, shallow soils, rough topography and extreme temperatures (Holecheck et al. 2003). These characteristics have rendered most of the rangelands unsuitable for rain-fed agriculture and have therefore led to the notion that rangelands are marginal or wastelands. Rangelands represent 24% of the world's land area and act as irreplaceable source of livelihood for the poor, supporting about 200 million households and 50% of world's livestock population (Batelo 2011). However, the notion that rangelands are wastelands seems to be defeated given the number of conflicts among multiple actors who seek to meet their diverse interests in rangelands. Essentially, competition for rangeland resources among different actors is a function of the benefits and values found in these areas.

Rangelands are critical areas for biodiversity in terms of genetic material, species and habitats. The diverse nature of habitats found in rangelands is a function of many species of cultural, economic and ecological importance. Tanzania rangelands cover more than 74% of the country land area extending into Dodoma, Mwanza, Kagera, Shinyanga, Arusha, Kilimanjaro, Singida, Tabora and some parts of Iringa, Lindi, Mtwara, Mbeya and Katavi regions (Fig. 1). They are home to the wildlife species considered to be charismatic, umbrella and keystone, endemic and rare. In the sub-Saharan region, Tanzania followed by South Africa surpasses all other 11-member countries of the Southern Africa Development Co-operation (SADC) for having many vertebrates and high endemism (Cumming 1999). Tanzania ranks second highest in terms of the number of vertebrates and plants (Table 1) in the Afro-tropical realm (i.e. all the countries South of the Sahara Desert, including Madagascar). The country possesses about 74% of all plants found in East Africa (Cumming 1999).

Because of their ecological values and high wildlife concentration, most of the wildlife protected areas in Tanzania are situated in the rangelands. About 40% of Tanzania's land surface is under one or the other form of protection. The major categories of protected areas include national parks, game reserves, game controlled areas, Ngorongoro Conservation Area and Wildlife Management Areas. Despite commitment and political will, the conservation and management of biodiversity in Tanzania have never been an easy task. There are numerous challenges and issues constraining the conservation work. The aim of this paper is to uncover these issues. We draw examples from different rangelands of Tanzania, where most of the biodiversity resources are found. Our motivation behind this paper is based on the premise that understanding of the issues and challenges underpinning the rangeland ecosystems is a crucial step towards setting up of plausible objectives, strategies and plans that will improve and lead to effective management and conservation of these areas. The paper provides some options for action on what should be done to address the existing challenges.

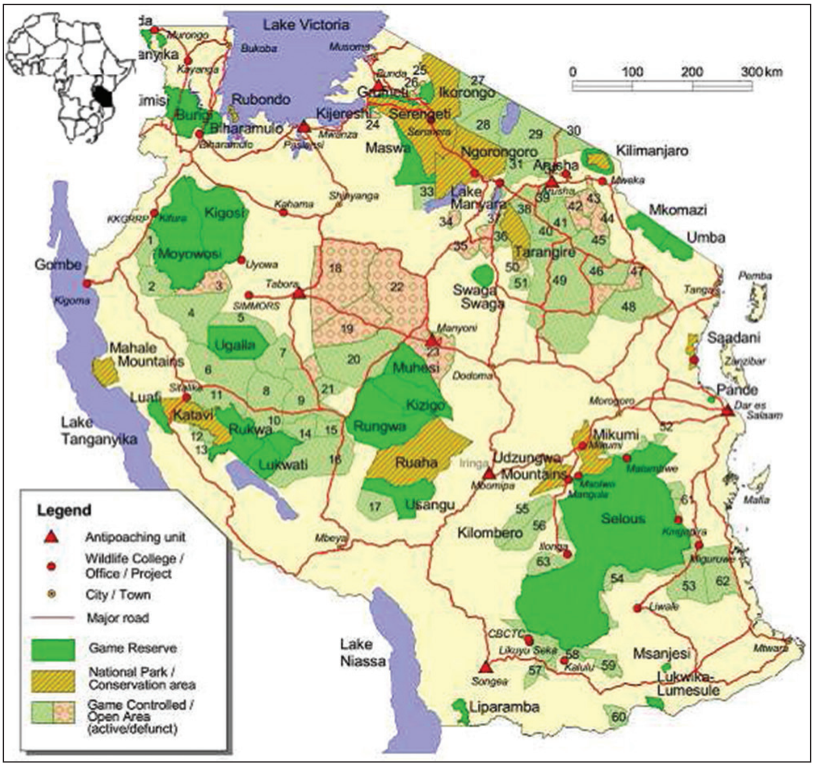

Figure 1. Map of Tanzania showing distribution of different protected areas in the rangelands (Map adapted from Baldus and Cauldwell 2004).

Table 1. The known number of vertebrate animals and plant species in Tanzania (including endemic and threatened species).

Taxonomic group	Known number	Endemic species	Threatened species***	**Rank in the Afro-tropical Realm (2)	**Number of species per** 10 000 Km^2
Mammals	316	15	43	4	70
Birds	1,016*	24	33	2	184
Reptiles	289	61	5	3	64
Amphibians	133	49	0	3	30
Freshwater fish	–	–	19	–	–
Higher plants	10,008 (Flowering 10,000)	1,122	336	3	2,231

Source: *WRI (2001); **Cumming (1999); ***IUCN (2002)

Emerging issues and challenges

Loss of biodiversity is a growing trend in virtually all Earth ecosystems. The Millennium Ecosystem Assessment document shows that losses of biodiversity and the related changes in the environment have been more rapid in the past 50 years than ever before in human history (MEA 2005). Many animal and plant populations have declined in numbers, geographical distribution, or both. Species extinction is a natural part of Earth's history. However, the current losses are the outcomes of human actions. Human activities have increased the extinction rate by at least 100 times more than the natural rate (MEA 2005). Rangelands, like other ecosystems, are vulnerable to loss of biodiversity through five major threats: habitat destruction, overexploitation of species, introduction of exotic species, pollution and global warming. In this section we present the issues and challenges, which have emerged as major drivers or agents in exacerbating these threats in the rangelands of Tanzania.

Human-wildlife conflicts

The establishment of protected areas is construed to be the most feasible strategy of maintaining biodiversity (Chape et al. 2008). Most of the protected areas in sub-Saharan Africa are situated in the rangelands. However, given the multiple uses of the rangelands, decisions to allocate lands for conservation have often faced resistance. This type of land use is perceived as an infringement of the rights of other stakeholders. This is the case when the conservation process involves evicting people from these areas and/or denying them access to the resources critical for their livelihoods (Benjamines et al. 2009). Essentially, for decades, the conventional conservation policies seem to have been accorded higher priority to wildlife than humans. This is illustrated by the following reactions from a number of personalities who wanted the Maasai pastoralists be evicted from Serengeti National Park in the late 1950s:

- *"The interests of fauna and flora must come first, those of man and belongings being of secondary importance*" – the then Serengeti Park Manager (Neumann 1992:90).
- *"Retaining the Maasai in the park would diminish the value of the area for wildlife and, therefore, risk the interests of the white tourists"* - Lee Talbot, an ecologist who led the delegation that was sent to Serengeti by the American Committee for International Wild Life Protection (ACIWLP) to investigate the ecological impact of having Maasai within the park (Bonner 1993).
- *The Maasai had no legal right to remain in Serengeti and, if any, should not be greater than the best interests of the rest of the people of the world* - Luis Leakey, a paleontologist (Bonner 1993).
- Grzimek used a pen to fight war against Maasai. The popular books and documentaries like *'No room for animals'* (Grzimek 1956) and '*Serengeti shall not die'* (Grzimek and Grzimek 1960) depicted apparent bias in favour of the wildlife.

The eviction of the Maasai in order to provide room for wildlife conservation has taken place in almost all rangelands of Tanzania, justified by expansion of national parks and creation of game reserves. For example, Mkomazi Game Reserve [initially, since 1951, the Maasai pastoralists were allowed to live in the reserve but they were evicted in 1986 (Tenga 2000)]; the Mkungunero Game Reserve (1996) in the South of Tarangire National Park; Ikorongo-Grumeti (1994) and Kijereshi Game Reserves in western Serengeti (in 2001); Usangu Game Reserve, which was later annexed to Ruaha National Park. Also, Saadani (formerly, a game reserve) was declared by the government in 2000 to be a national park whereby its boundaries were expanded into the village land. This action created tension between the park managers and local communities whose areas have been taken on the premise that they would be compensated. Importantly, the eviction occurred within the past two decades despite the changed focus of policy aiming at involving local communities in conservation. The expansion of the national park boundaries has further been justified on the basis of redefining the national park borders that have been encroached by the local communities. For example, between 2004 and 2007 Tarangire National Park borders were redefined at the eastern side and extended southward which led to the demolishing of human abodes (almost more than 200 households) and farms. The villages mostly affected by expansion of the park boarders include Gijedabong, Mamire, Mwinkatsi and Endamalamboda. All the identified villages are located in the south-western part of the park (Rija pers. obs. 2006). This has led to an increased hostility between the villagers and park authorities resulting in a lawsuit filed by the villagers over discontentment of the eviction and land 'grabbing' by the Tanzania National Park (TANAPA) (Davis 2011). A similar scenario has been observed at the Arusha National Park following an attempt to annex the forest patch adjacent to it. The eviction has overtime worsened the conflicts between these parks and surrounding local communities. Hence, the effort has led to an increased poaching from these protected areas.

Under this scenario where the eviction and prohibitive policies symbolize the conservation process, resentments from local communities and, therefore, conflicts have become the salient features in virtually all rangelands of Tanzania (Goldman 2011, Kaswamila 2010). For example, the Maasai in eastern Serengeti resented the proposed park boundaries through violence and sabotage/vandalism. They resisted the government conservation by spearing the rhinos, setting fires with malicious intent and terrorising civil servants (Neumann 1992). In Western Serengeti, the Ikoma hunters deliberately disobeyed the colonial conservation laws and vowed to kill the wildlife rangers by poisoned arrows particularly when they attempted to stop them from hunting (Neumann 1998). The expansion of Serengeti National Park in the 1960s, which took Kurya's grazing, arable and hunting land, culminated into resurgence in the 1970s (Packer 1994). The Kurya declared their independence and pulled down a Tanzania flag, replacing it with a leopard banner. Although, the government forces ended this insurrection, the hostility between Kurya and the park including its staff is still widespread. In recent years, the conflicts in the western Serengeti Park have been intensified following the upgrading of the previously Game Controlled Areas to Game Reserves. Since December 2011, there has been an ongoing massive organized poaching of elephants inside the Tarangire National Park that has led to at least 30 elephants killed in year 2012 alone (Manendo, Park Warden-pers. comm. 2012). Although the recent surge in elephant poaching is principally driven by external market demands for ivory, involvement of local people who once tolerated the wildlife suggests waning park-local community relationships. This has come about due to increasing opportunity costs on the part of local communities, such as livestock depredation, crop damage, zoonotic diseases, damage to infrastructure and attacks by dangerous wildlife species (Rija 2009).

Poverty

Globally, Tanzania is often described as a rich and stable state, though it is among the very poor countries. The country is blessed with abundant natural resources, which include forests and woodlands, wild animals, rivers, lakes and wetlands (MNRT 2012). Tanzania is also endowed with a variety and huge reserves of minerals which include Gold, Nickel, Tanzanite, Diamond, Copper, Iron ore, Coal, Limestone, Soda ash, Gypsum and Phosphate (URT 1997b). Despite the enormous resources wealth and political stability, the country's performance economically has not been impressive.

Tanzania is classified as one of the least developed countries in the world with external aid accounting for about 40% of the national budget (Dempster 2007). The *Tanzanian Poverty and Human Development Report of 2005* estimated that 36% of the population live below the 'basic needs' poverty line' (URT 2005). The UN Human Development Report (2007/2008) ranked Tanzania 159th out of 177 countries. *In addition*, The World Bank report (2012) reveals that the percentage of the population who lived on less than $1.25 and $2 a day at 2007 international prices was estimated at 67.9 and 87.9%, respectively.

Poverty at the national level has an impact on funding of the biodiversity sector. The notable impact was observed between the 1970s and 1980s where the global economic recession and, consequently, underfunding of the sector caused rampant poaching of rhino and elephants. Poverty at household level reduces ability of people to improve on existing livelihood strategies, thus forcing them to opt for coping strategies that are unsustainable and ecologically destructive. For example, because of poverty, peasants barely can afford to purchase and use agricultural inputs to increase crop production on their lands. Food insecurity and income poverty resulting from this scenario may lead to conversion of more wildlife habitats into croplands as well as killing of wild animals for protein (Hackel 1999, Loibooki et al. 2002, Kideghesho et al. 2005, Wittemyer et al. 2008). Household poverty also limits access and usage of electricity as a source of energy. Wood fuel (firewood and charcoal) has remained the most dominant and reliable source of energy for cooking and heating, both in urban and rural areas accounting to over 90% of daily total energy consumption that is required by more than 85% of the country's population (URT 2003). The ever increasing fuel energy demands put more woodlands areas under pressure thereby driving significant land cover change of most unprotected rangelands.

Human population growth

The rangelands that were mainly devoted to pastoralism and wildlife conservation had sparse human population. However, the recent population saturation in fertile and high rainfall areas together with escalating poverty have motivated in-migration to rangelands where people can access land for cultivation, though there is high risk of crop failure. Furthermore, wildlife (as a source of game meat) is a potential asset for tourism; presence of water bodies (rivers and lakes), good pastures and some mineral deposits have acted as important population pull-factors to rangelands (Baillies et al. 2004, Wittemyer et al. 2008), though such supposition is still contested (Joppa et al. 2009). A good example of this scenario is the western part of Serengeti National Park. Over the last six decades, the area had recorded a rapid demographic growth. Between 1948 and 1978, the human population in the Eastern Lake Victoria basin increased from 1.5 to 3.3 million although this growth had minimal effect on the areas adjoining Serengeti National Park (MNRT 1985). An increase of human settlements on the fertile lands found closely to Lake Victoria stimulated the movement to the periphery of the park. Between 1957 and 1967, the human population adjacent to Serengeti National park grew at the rate of 10% per annum. The natural rate of increase was 3.4% while immigration contributed the remaining 6.6% (MNRT 1985). To-date population growth around the park has continued to be a serious issue (Kideghesho et al. 2005, Wittemyer et al. 2008).

The rapid human demographic growth increases demand and competition for resources that has resulted in an increased exploitation of resources at the highest level beyond the capacity of the available resources. The demands were associated with wildlife and habitat destruction including land for settlements, cultivation and livestock grazing; plants for fuel wood, building poles, and timber; and water points for livestock and domestic use. Essentially, demographic growth is the prime cause of wildlife poaching and habitat loss (Campbell et al. 2001, Loibooki et al. 2002, Kideghesho et al. 2005).

The role of human population growth in generating conflicts in the rangelands can be summarized under the following three problems associated with living closely to the protected areas as experienced within the Serengeti ecosystem:

a) Disruption of ecological processes that are essential in maintaining biodiversity
Human impact causes depressing activities of migratory herbivores with a consequence of detrimental effects on the vegetation dynamics (McNaughton and Banyikwa 1995). Also, the disruption of migratory corridors can render the migration in the Serengeti, one of the world's Endangered Biological Phenomena (EBP).

b) Increased hunting for home or market consumption
Poaching statistics in Serengeti and Tarangire illustrate the relationship between human population growth and its pressure on the wild resources (Campbell et al. 2001, Loibooki et al. 2002, Rija 2009).

Table 2. Size and rate of increase of local communities and modelled number of meat hunters West of the Serengeti in Tarime, Serengeti, Musoma Rural, Bunda, Bariadi, Maswa and Meatu Districts, and Kalemela and Mkula Wards in Magu District, within 45 km from the boundary of protected area (Source: Campbell and Hofer 1995).

Distance class (Km)	Area (Km^2)	1988 population (× 1000)	Estimated no. of hunters, 1988 (× 1000)	1978 population (× 1000)	Estimated no. of hunters 1978 (× 1000)	Mean annual % rate of population increase	Annual % rate of increase of hunters 1978–1988
0–5	3 429	92.77	12.99	62.30	8.44	4.06	3.99
5–10	3 355	134. 09	9.13	99.60	7.26	3.02	2.96
10–15	3 289	136.95	5.17	111.74	4.07	2.06	2.01
15–20	3 312	128.65	2.55	103.49	2.07	2.20	2.22
20–25	3 338	96.91	0.91	76.32	0.75	2.42	2.39
25–30	3 420	92.30	0.42	68.57	0.32	3.02	3.03
30–35	3 444	129.84	0.28	92.30	0.22	3.47	3.32
35–40	3 422	127.50	0.14	97. 84	0.10	2.68	2.84
40–45	3 449	116.91	0.80	83.65	0.06	3.40	3.47
Total	30 457	1055. 91	31.66	795.80	23.29	2.83	3.11

c) Increased pressure from local people to open protected lands for community use
The expansion of cultivation and settlements forced re-alignments of the boundaries of Maswa Game Reserve for three times and thus causing 15% loss of the original area (MNRT 1985). Also, the pastoralists in some villages in Bunda and Serengeti Districts are appealing for Government to authorize the access to critical grazing and water points in Grumeti and Ikorongo Game Reserves (Kideghesho pers. obs. 2006). Manchira and Rubana Rivers in the two reserves, respectively, are critical water sources for communities who are constantly complaining on the denied access. *However*, these communities have been illegally admitted to access these resources due to lack of an alternative (Table 2).

Blockage of migratory corridors

Generally, wildlife corridors play vital ecological roles in enhancing biodiversity and survival of a large number of species. In addition, the function of wildlife corridors include serving as areas of habitat, connecting wildlife populations separated by human activities (such as roads, development, or logging), facilitating the re-establishment of populations that have been reduced or eliminated due to random events (such as fires or disease), and allowing an exchange of individuals between populations, preventing the negative effects of reduced genetic diversity potentially associated with long-term population isolation (Henle et al. 2004, Frankham 1996). Also, wildlife corridors increase the area and diversity of habitats over and above the area of the two habitat patches connected.

Wildlife corridors, however, are under serious threat. First, there is human population pressure attributed to a number of population-pull factors in the rangelands

Table 3. Threats facing five wildlife corridors linking Lake Manyara NP and outside systems (Sources: Shemweta and Kideghesho 2000; Jones et al. 2009).

Corridor	Link protected area	Key species	Human threats
Kwakuchinja-Mbugwe Wildlife Corridor	Tarangire National Park	Zebra and Wildebeest	Settlements and crop cultivation
Mayoka-Magara-Mwada-Vilima Vitatu	Tarangire National Park	Buffalo and Eland	Cotton field expansion in Mwada
Jangwani	Mto wa Mbu Game Controlled Area	Zebra and Wildebeest	Settlements, cultivation and campsites
Upper Kitete-Lositete	Ngorongoro Conservation Area	Elephant, Buffalo, Hippos	Intensive crop cultivation mainly maize and wheat.
Laja	NCA and Marang Forest	Elephants	Livestock grazing, deforestation, mining

and push-factors in the areas of high agricultural potential. Secondly, there is lack of by-laws to protect the corridors against unsustainable use and activities that are incompatible with biodiversity conservation. Lake Manyara Basin is one of the areas, which have been experiencing an increasing population pressure. The major population pull-factors at this area include demand for agricultural land, construction of Minjingu Phosphate factory, establishment of fishing camps, small mining activities (at Marang Forest Reserve), growth of tourism, and other economic opportunities. Population push factors from the areas with acute land shortage, such as Kilimanjaro region, have also affected the lake Manyara basin. The major outcome of all the identified factors is an increased threat in the existing five wildlife corridors, which provide ecological links between Lake Manyara National Park and outside systems (Jones et al. 2009) as revealed in Table 3.

The blockage of wildlife corridors linking Lake Manyara National Park and other areas has led to some undesirable ecological impacts. The biggest impact is the reduced population and local extinction of some large mammal species, both within the park and along the corridors (Newmark 1996). However, the impact of other factors including poaching should not be underestimated. A study by Gamassa (1989) on the Wildlife Corridor at Kwa Kuchinja Mbugwe (KWC) indicated that there is a 72% decline of species diversity of large mammals along KWC. Boshe (1989) in Hassan (1998) uncovered that seven species that were previously regarded as regular users of the KWC were locally extinct: cape eland (*Tragelaphus oryx*), hartebeest, (*Alcelaphus buselaphus*), buffalo (*Syncerus caffer*), oryx (*Oryx gazella*), lesser kudu (*Tragelaphus imberbis*), cheetah (*Acynonyx jubatus*), and leopard (*Panthera pardus*). In the Lake Manyara National Park, the following nine species were reported to be locally extinct: African wild dog (*Lycaon pictus*), cape eland (*Tragelaphus oryx*), hartebeest, oribi (*Ourebia ourebi*), black rhinoceros (*Diceros bicornis*), lesser kudu , cheetah, mountain reedbuck (*Redunca fulvorufula*) and common reedbuck (*Redunca arundinum*) (Hassan 1998, Kideghesho 2001).

HIV/AIDS pandemic

The HIV/AIDS problem has emerged as one of the worst pandemics in history. The pandemic has some undesirable impacts to virtually all the sectors and parts of Tanzania. The problem has caused an increase of orphan children, the breaking of families and marriages, a rise in poverty and the increased disappearance of labour force. The wildlife sector is by no way exempted from this scenario. Although there are no empirical data that quantify the impact of the pandemic on the wildlife sector, some reports (e.g. Ngoti and Baldus 2004) show existing or potential influences.

The fact that HIV/AIDS exacerbates poverty implies that people are compelled to adopt certain strategies that will enable them to cope with the impacts of poverty. The most accessible strategies in the rangelands entail illegal and/or unsustainable use of natural resources (viz. wild foods, wildlife, medicinal plants, timber and fuel wood). Furthermore, the pandemic lowers the efficiency of managing and enforcing conservation laws. The impacts of HIV/AIDS pandemic on biodiversity can be explained by the following mechanisms.

An increased poaching of wildlife to meet subsistence and income needs: HIV/AIDS pandemic has caused many deaths and debilitation to families and economies in Tanzania. Ultimately, scourge has made natural resources become the main source of income generation to substitute other lost income earning opportunities (Ngoti and Baldus 2004, Thaxton 2007). As breadwinners die, orphans opt for poaching as a more viable strategy for survival through meeting subsistence needs and income to cater for other needs including medical services (Thaxton 2007).

Increased poaching to cater for health needs: For example, the poaching of giraffe has never been an issue that has drawn significant conservation or management attention in the past; but recently, the poaching of giraffe has been widely observed in Tanzania. A critical good example is the mass poaching of giraffes at Monduli District and the West Kilimanjaro Wildlife corridor (striding between Arusha and Kilimanjaro National Parks) in the period between 2004 and 2008, which was fuelled by the beliefs of traditional healers (witch doctors) that brain and bone-marrow of a giraffe could cure HIV-AIDS (Anon. 2004, Anon. 2010).

Increased and unsustainable rates of harvesting medicinal plants to treat some HIV-associated opportunistic diseases: HIV/AIDs pandemic and associated opportunistic diseases, such as tuberculosis, high blood pressure, and diabetes, have increased overexploitation of some species because such species are believed to bear a medicinal value. For example, the recent human population influx at Samunge Village, Loliondo (*Kwa Babu*[1]) where thousands of people from all over East Africa have been attracted for herbal concoction from a shrub *Carissa edulis,* which is believed to treat Herpes sim-

[1] Kwa Babu *is Swahili meaning 'grandfather's domicile'. The words became popular recently (2011/12) following the claims from a retired Lutheran Pastor Ambilikile Mwasapile that he had revelation of medicine from God through a dream that can cure all chronic diseases including AIDS, diabetes, asthma, and several other diseases with only one dose offered in a cup (ca. 250ml). The retired pastor also said that many more people would come for the medicine from all over the world such that it could take someone two months in a queue to get the dosage.*

Figure 2. Top left: People on their way to Loliondo-Samunge village for the dosage of the said miracle cure; Bottom left: Thousands of people to and from the Loliondo-Samunge village; Top right: Retired Pastor Ambilikile Mwasapile giving dosage of the medicine to patients; Bottom right: People at Loliondo-Samunge village waiting for the dosage of the miracle medicine.

plex according to Tolo et al. (2010). In addition to overexploitation of these species, environmental impacts, such as pollution due to littering of human wastes and plastics and habitat degradation due to increased deforestation for firewood as well as physical impacts of vehicles were apparent (Figure 2).

Increased rates of illnesses and deaths among park rangers, senior officials, community game guards and other conservation personnel have ultimately weakened the performance of the sector. This is likely to be the case because wildlife staffs are likely to fail to execute their duties including law enforcement in case they fall sick. Also, poachers may take advantage of this situation and poach when wildlife staff members are looking after their sick relatives or attending funerals. Economically, HIV/AIDS pandemic imposes huge financial costs to government, conservation agencies and communities.

Emergence of new economic opportunities and competing development needs

Besides harbouring biodiversity resources and supporting livestock production, the macro- and micro-economic potentiality of rangelands is still untapped in Tanzania. Among the potential resources in the rangelands are mineral deposits. The reality that mining activities in the rangelands cause severe environmental destruction cannot be questioned and this has prompted concern of the conservationists and the general public. The most recent debate on this issue revolves around the government plans to grant licence for uranium mining at the area between the Selous Game Reserve and Selous-Niassa Wildlife Corridor. The area is exceptionally rich in wildlife species including elephant (*Loxodonta africana*), buffalo, eland, sable antelope (*Hippotragus niger*), hippo (*Hippopotamus amphibius*), Lichtenstein hartebeest (*Alcelaphus lichtensteinii*), common waterbuck (*Kobus ellipsiprymnus*), bushbuck (*Tragelaphus scriptus*), common duiker (*Sylvicapra grimmia*), common reedbuck, wildebeest (*Connochaetes taurinus*), zebra (*Equus burchellii*), impala (*Aepyceros melampus*), klipspringer (*Oreotragus oreotragus*), warthog (*Phacochoerus aethiopicus*), bush pig (*Potamochoerus larvatus*), leopard and lion (*Pathera leo*), spotted hyena (*Crocuta crocuta*), jackal (*Canis aureus*) and civet (*Civettictis civetta*). Several packs of wild dogs are observed in all parts of the corridor.

Despite its biodiversity and wildlife potential, the Selous–Niassa Wildlife Corridor is threatened by an increasing human population and activities, which are incompatible with conservation interests. The most recent menace is likely to come from the mining activities following the prospects of the three international mining companies namely, Mantra, Uranex and Uranium Resources. The environmental implications that are likely to arise from this economic opportunity include: blockage of the wildlife corridor and interference with migratory routes of animals and acting as a population pull factor to the area. The latter may have as a consequence a) an increase of pressure on the natural resources and potentially more illegal logging, cultivation and poaching, b) loss/disturbance of biodiversity due to vegetation clearance, disturbance to biodiversity through blanketing of vegetation cover, c) increased potential for accidents to wildlife and people, d) health impacts to fauna from the drinking of contaminated water and from heavy metals taken up with forage, and e) potential for accidents to animals falling in un-rehabilitated pits.

Further, Tanzania's government has also implemented or allowed implementation of a number of development projects in the rangelands, which had proved (or are likely) to be detrimental to biodiversity. Examples include the following;

a) Construction of Tanzania-Zambia Railway (TAZARA) in 1970s.
The project had caused the fragmentation of Selous Game Reserve (SGR) and Magombera Forest Reserve (MFR) (Maganga 1994). Unlike MFR, the impact of the railway on SGR was less visible because of its large area. The MFR had 15 km^2; however, about 50% of its area was reduced by ILLOVO sugar cane Company, thus lowering its conservation effectiveness (Marshall 2005). Given its ecological importance as the critical habitat for an endangered sub-species of red colobus monkey (*Colobus badius gordonorum*), reptiles and amphibians (Menegon et al.

2009), the MFR had to be annexed to SGR as a measure for improving its conservation effectiveness (Baldus 1992).

b) Investment policies, which allowed the construction of tourist hotels and lodges in the northern tourist circuit in the 1990s.
These were deliberate efforts by the government towards improving the country's economy through the game viewing tourism. However, these policies had some negative impacts on wildlife. Some of the hotels were built on the wildlife migratory routes and water catchment areas, for example: Sopa Hotel in Ngorongoro Conservation Area and Serena Hotel on the rim of Lake Manyara National Park (Runyoro, pers. comm.).

c) The Proposed Mto wa Mbu-Mugumu road passing through Serengeti National Park.
Other than acting as a big population pull factor to Serengeti area (see impacts of population growth in sections 2.4 and 2.5 above), it may directly affect biodiversity through clearing of vegetation, road kills and blockage of the migratory corridor for wildebeest, Grant's gazelle and zebra moving between Serengeti and Maasai-Mara National Reserve in Kenya. The lessons from Mikumi National Park and other protected areas elsewhere where public roads pass across indicate negative effects and ecological impacts associated with roads. Drews (1995) reports that over 50 different animal species including endangered species have been killed by road accidents at Mikumi national park just within a two-year period of the field study. Furthermore, the author estimated a minimum of 3 kills per day during the same period. Similarly, various animal species were concentrating in some areas; avoiding habitats close to the road. This suggests some negative ecological impacts roads have on the animals in Mikumi National Park (Newmark 1996). These data suggest that the inception of the proposed road through the Serengeti area will have consequences such as increasing animal physiological stresses, mortality and sustainability of the ecosystem (Lunde 2013, Fyumagwa et al. 2013).

d) Proposed Lake Natron Soda Ash Plant
A proposal by Tata Chemical Industries Ltd in collaboration with the Tanzanian Government to construct a $450 million factory that would produce 500,000 tonnes of soda ash per year and employ 150 permanent staff sounds economically promising. However, its ecological impacts cannot be underestimated.

Lake Natron is the only regular breeding site for Lesser Flamingos (*Phoenicopterus minor*) in the Eastern part of Africa. The 1.5–2.5 million Lesser Flamingos represents three quarters of the world population. The area is isolated and undisturbed and has adequate food and nesting sites for flamingos. It is both an Important Bird Area and a Ramsar Site. Also, the project may cause a negative impact on mammal populations and vegetation in the northern area of Gelai to Longido. In addition, the opening of the area to hundreds of workers may give rise to the bush meat and charcoal trade.

Climate change

Climate change is increasingly being recognized as a global crisis threatening human survival and biological resources. There is growing evidence that climate change, particularly increasing temperatures, is already having significant impacts on the world's physical, biological and human systems, and it is expected that these impacts will become more severe in the future (Gitay et al. 2002, Balmford et al. 2003, de Wit and Stankiewicz 2006, Wilson and Maclean 2011). Studies suggest that many plants and animals are unlikely to survive within uncertain climate change limits (Thomas et al. 2004, Maclean and Wilson 2011). By 2050, climate change will lead to the extinction of 15–37% of a total sample of 1,103 land plants and animals (Thomas et al. 2004). In Tanzania, the impacts of climate change have been felt in virtually all ecosystems, including the rangelands. For instance, the severe droughts in the 1990s and 2000s had forced the pastoralists to shift their herds towards southern Tanzania in search of pastures. This had led to the destruction of habitats, reduced biodiversity, and destruction of water sources as observed in Ihefu and Great Ruaha River (Kashaigili et al. 2009).

In their book - *Serengeti 111: Human Impacts on Ecosystem Dynamics* - Sinclair et al. (2008) predicted the impacts the anthropogenic activities and natural changes will exert on the global climate and atmospheric chemical composition over the next five decades. They contended that even in the absence of local anthropogenic activities, the risk to the isolated and complex ecosystems like Serengeti will be extremely high. An alteration of vegetation, hydrology, quality of forage to herbivores, species diversity, migration patterns, disease outbreaks to human, fauna and flora, change or destruction of habitats, among others, are potential impacts envisaged from high carbon emissions into the atmosphere. These changes have direct consequences for the health of the Serengeti ecosystem (Sinclair et al. 2008).

The rise of temperature and change of rainfall patterns in Serengeti provide further illustration of the impacts of climate change on the biodiversity. Studies have shown that the temperature at Amboseli and areas neighbouring Serengeti have increased by 0.275°C per annum between 1976 and 2000 (Altmann et al. 2002). In the recent years the flow of the Mara River, which cuts right across Serengeti National Park, has become increasingly inconsistent (Mango et al. 2011) raising concerns over the health functioning of the Serengeti ecosystem. Using a simulation model, Sinclair et al. (2008) predicted the potential effects that average annual precipitation and changes in the precipitation variables will bear on the wildlife, humans and livestock numbers. These predictions are summarized in Table 4. The impacts of climate change on biodiversity may be manifested indirectly through exacerbating other factors or agents contributing to the loss of biodiversity. The factors include poverty, which may force the victims to adopt coping strategies which are destructive to biodiversity, such as illegal hunting and encroachment (e.g. Loibooki et al. 2002), wildfire, human-wildlife conflicts, and soil erosion and siltation of water bodies that may increase eutrophication of lakes thereby impacting aquatic and terrestrial wildlife negatively.

Table 4. Predicted effects of mean precipitation (a) and changes in variability of precipitation (b) in relation to wildebeest population, hunting offtakes and human and livestock population**.** Figures reported are steady-state values at the end of a 50-year simulation

a) Predicted effects of changes in mean annual rainfall			
	Base case	**Increase in mean rainfall**	**Decrease in mean rainfall**
Mean annual rainfall (mm/yr)	830	1 200	400
Wildebeest population:			
Resident population	14 890	21 450	28 330
Migrating population	1 257 000	1 809 000	613 500
Hunting offtake:			
Resident population	55	81	5 489
Migrating population	20 690	30 890	9,971
Human population	135 700	253 800	68 020
Livestock number	80 050	113 600	0

b) Predicted effects of changes in the variance of rainfall			
	Base case: no variance	**Moderate rainfall variance**	**Moderate variance with persistence**
Standard deviation of annual rainfall	0	176	176
Persistence of deviation	0	0	0.5
Wildebeest population:			
Resident population	14 890	32 870	21 260
Migrating population	1 257 000	1 173 300	1 196 000
Hunting offtake:			
Resident population	55	5 125	1 896
Migrating population	20 690	19 890	19 950
Human population	135 700	159 150	147 830
Livestock number	80 050	7 188	32 950

Source: Sinclair et al. (2008)

Invasion by alien invasive species

Next to habitat destruction and fragmentation, invasive alien species are among the world's most significant threats to indigenous biodiversity, their introduction and establishment will ultimately lead to severe leveling off of biodiversity. These species are increasingly spreading both in natural and non-natural systems (McNeely et al. 2001). Many rangelands of Tanzania including national parks and other forms of protected areas have also not been immune to infestation by invasive species (Foxcroft et al. 2006). As a consequence, the invasive species have now been recognized in the conservation agendas countrywide. The most important areas that are highly infested by these species include the Ngorongoro Conservation Area Authority, Serengeti National Park, and a number of other non-protected areas. The available literature shows that invasive alien species continue to engulf grazing lawns of the Ngorongoro crater (Henderson 2002). These include *Datura stramonium* , *Acacia mearsii* , *Caesalpinia* *decapetala , Eucalyptus camaldulensis, Lonicera japonica, Argemone mexicana*. At the Serengeti National park the invasive species *Cylindropuntia exaltata*, *Opuntia stricta var. dillennii*, *Opuntia monocantha* and *Pistia stratiotes* remain a significant threat to the ecosystem (Foxcroft 2003). The major impacts of the invasive species include disruption of the general ecology of an ecosystem, changing the fire regime, water and nutrient cycling and affecting the bio-geochemical processes of landscapes (Cronk and Fuller 1995).

Theories of invasion predict increasing invasiveness with increasing habitat disturbances (Vermeij 1996, Williamson 1999, Davis et al. 2000) as well as global climatic change (Dukes and Mooney 1999, Kolar and Lodge 2001). There have been increasing habitat disturbances in most protected areas cores and edges due to livestock grazing. For example, a recently annexed Ihefu to Ruaha National Park is potentially a victim of invasive species that in future may invade other parts of the park. In Mkomazi National Park in northern Tanzania, past livestock grazing at the area may have facilitated occurrence of undesirable plant species into the park (Homewood and Brockington 1999). *Parthenium hysterophorus* is one of the most serious invasive alien species that is already a threat to Ethiopian rangelands and is spreading southward into the East African countries (McNeely et al. 2001). In Tanzania, this species has been observed mostly in the urban landscapes (Rija pers. obs. 2011) and along roadsides of the countryside (Klark pers. comm. 2011). Although the population size of the species in most areas is still low, the species has the ability to dramatically increase and spread widely un-noticed, potentially affecting biological diversity in rangeland ecosystems. Further, edge encroachment is still a big challenge for many national parks because of an illegal grazing that may introduce invasive species from other areas outside. The mounting pressures on the rangelands due to the growing human population coupled with climate change impact are set to affect rangeland ecosystems even more. In this respect, the future of the Tanzanian rangelands remains uncertain.

Civil wars

Civil wars are a salient feature in Africa. Unlike many other African countries, Tanzania had never experienced such wars; however, the country has felt the impact of these wars. The country has been surrounded by conflicts and hosted refugees from Democratic Republic of Congo, Burundi, and Rwanda. The number and lifestyle of refugees have caused some notable environmental and ecological problems particularly in the areas occupied by refugee camps. The number of refugees in Tanzania was about 1.2 million in 1994; this is the largest number in Africa compared to all other countries (The Citizen, Wednesday September 29, 2010). Refugees brought with them sophisticated equipment including automatic weapons that were readily available for conducting criminal acts including illegal hunting of wildlife. This big population has created an increased demand for the rangeland resources including firewood, medici-

Table 5. Trends in major species of animal populations in the Burigi Game Reserve 1990–2000 (Source: TWCM 1990, 1998, Jambiya et al. 2007). D* = Population declined and NC* = No change, according to Stoner et al. (2007).

Animal species	Burigi Game Reserve				Moyowosi-Kigosi Game Reserve			
	1990 Estimates	1998 Estimates	2000 Estimates	Trend status	1990 wet season	1994 wet season	1998 wet season	Trend status
Buffalo *Synceros caffer*	2670 ± ?	44 ± ?	78 ± 41	D*	7070 ± 4790	6652 ± 3666	6926 ± 3778	D*
Bushbuck *Tragelaphus scriptus*	229 ± 33	18 ± 15	153 ± 194?	D*	-	197 ± 72	65 ± 36	NC*
Eland *Tragelaphus oryx*	878 ± 336	237 ± 102	-	D*	-	-	-	-
Elephant *Loxodonta africana*	-	-	-	-	392 ± 376	1583± 700	2262 ± 716	I*
Giraffe *Giraffa camelopardalis*	127 ± 79	300 ± 119	75 ± 27	NC	1043 ± 292	1465 ± 246	1131 ± 302	NC*
Hartebeest *Alcelaphus lichtensteini*	324 ± 137	0	-	D*	549 ± 190	1112 ± 237	512 ± 133	NC*
Hippo *Hippopotamus amphibius*	-	-	-	-	1518 ± 680	784 ± 271	574 ± 196	NC*
Impala *Aepyceros melampus*	5,130 ± ?	2,795± 801	1157 ± 289	D*	-	-	-	-
Reedbuck *Redunca redunca*	147 ± 49	98 ± 31	84 ± 16	D*	486 ± 59	5168 ± 674	1524 ± 152	NC*
Roan Antelope *Hippotragus equinus*	466 ± 169	15 ± 15	-	D*	-	1738 ± 381	617 ± 359	NC*
Sable Antelope *Hippotragus niger*	279 ± 125	32 ± 20	9 ± 7	D*	-	985 ± 272	242 ± 146	NC*
Sitatunga *Tragelaphus spekei*	490 ± 128	0	0	D*	310 ± 99	512 ± 85	32 ± 20	D*
Topi *Damaliscus korrigum*	6, 399 ± 298	160 ± 109	74 ± 37	D*	1803 ± 773	9410 ± 3488	5061 ± 772	NC*
Waterbuck *Kobus ellipsiprymnus*	822 ± 218	94 ± 61	-	D*	835 ± 228	920 ± 153	437 ± 141	NC*
Warthog *Phacochaerus aethiopicus*	2,628 ± 188	71 ± 61	54 ± 40	D*	1137 ± 237	1251 ±143	299 ±118	NC*
Zebra *Equus burchelli*	6,552 ± 1,127	606 ± 140	656 ± 147	D*	1412 ± 618	3971 ± 1830	787 ± 248	NC*

nal plants and wild meat. The two most-hard hit regions by the refugee saga include Kigoma and Kagera regions particularly in Moyowosi-Kigozi and Burigi-Biharamulo game reserves respectively, where refugees were and are still housed in camps. Currently however, there is a state repatriation order for all illegal immigrants to their home countries. The outcome of the influx of refugees was habitat destruction and illegal hunting of wildlife, which led to a drastic decline in population of 13 wild ungulates by almost 90% in Burigi-Biharamulo Game Reserves (Table 5). In this reserve, animals like topi (*Damaliscus korrigum*), giraffe, buffalo, eland and other medium to small sized animals including roan and sable antelopes, impala, warthogs and zebra have been severely depleted within just a decade, between 1990 and 2000 (Stoner et al. 2007). Some species, such as sitatunga (*Tragelaphus spekei*) and sable antelope are feared to have gone extinct in the same reserve. Similarly, bushbuck, sitatunga, warthog, buffalo and impala showed persistent population declines at Moyowosi-Kigozi game reserve, an important rangeland in western Tanzania during the same decade. However, the population of some animals such as zebra elephant, giraffe (*Giraffa camelopardalis*), reedbuck and topi have shown a slight increase and they were relatively stable in this reserve (Stoner et al. 2007).

Over exploitation of wildlife due to poaching and unregulated legal hunting

Illegal hunting of wildlife remains a persistent threat to the wildlife across the country. Despite poaching becoming increasingly high and widespread, its impact on the wildlife populations has not caught the attention of policy makers as it is assumed to be minimal (Barnett 2000). This is partly because many rangelands experiencing intensive poaching remain un-researched because the majority of them fall outside protected areas. Also, the available literature are sporadic and biased towards certain geographic locations and protected ecosystems particularly Serengeti (e.g. Hofer et al. 2000, Loibooki et al. 2002, Marealle et al. 2010) and Katavi (Caro 2008, Martin and Caro 2012) leaving other equally impacted ecosystems, such as Tarangire, Mikumi, and Ruaha, under-researched. Illegal hunting is a big problem in the Simanjiro plains, a seasonal refuge for wildlife dispersing from Manyara and Tarangire National Parks (Rija 2009). In our recent field visits (June, 2013) in some villages, Misima, Msomela, Mbagwe and Kinkwembe in Handeni District in north-eastern Tanzania, we were surprised with the huge number of illegally killed animals brought in the villages. At Misima village alone, 15-20 animals per day were landed in a local black market (Rija and Mwamende pers.obs. 2013) with similar such cases occurring around Swagaswaga (Madulu 2001) and Kiteto rangelands, respectively in central and northern Tanzania. These data suggest that the extent of illegal hunting is higher than previously known. Moreover, unregulated legal hunting poses an additional threat to the wildlife population. Many rangelands that support legal hunting have experienced significant declines due to uninformed excessive quota allocated to them and from unscrupulous hunters who kill in excess of their allocated quotas (Baldus and Cauldwell 2004). Controlling resident legal hunting is especially difficult because many local wildlife offices are particularly understaffed, thus most hunting goes unsupervised resulting in more animals killed than is indicated on the hunting permits (Rija 2009). Coupled with the selective nature of sport hunting (Caro et al. 2009), both illegal hunting and local licensed hunting have the potential to drive individual species to population decline (Stoner et al. 2007, Caro 2008) and local extirpation (Rija 2011) with unknown consequences on the ecosystem functions of the rangelands.

Wildfires

Wildfires are perhaps the most driving force of rangelands dynamics but one that remains under-appreciated by the government policies probably because of lack of

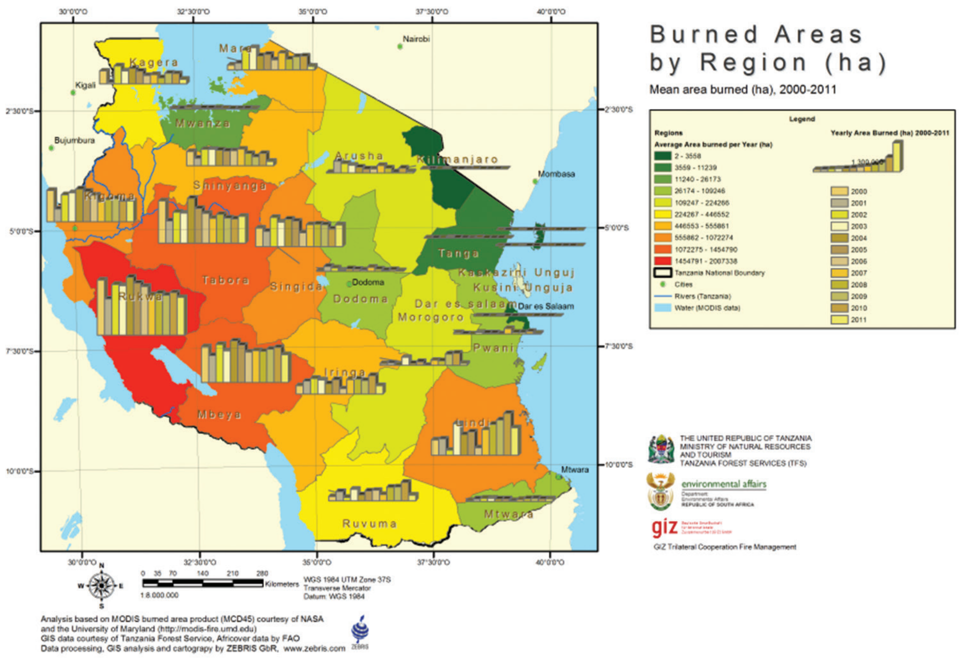

Figure 3. Map of Tanzania showing distribution of wildfires across the country. Wildfires destroy thousands of hectars of miombo woodlands and forests killing an unknown numbers of species and threatening the functioning of ecosystems (Map adapted from Rucker and Tiemann 2012).

empirical information. There is no fire policy in existence and fire issues are dealt on ad-hoc basis by individual ministerial sectors particularly in the ministries responsible for managing natural resources (wildlife, forests and livestock). Preliminary analysis of eleven years (from 2000–2011) of burned areas indicates however that the mainland Tanzania loses over 11 million ha of forests and woodlands annually (Rucker and Tiemann 2012). About 70% of burned area in Tanzania is woodlands and shrubland cover types, most of which fall under protected areas (national parks, game reserve and game controlled area) constituting more than 8 million ha burned annually (Rucker and Tiemann 2012). Although some of these burns are captured during prescribed burning to manage habitats by park and reserve managers, increasing evidence point out that most late blazes are caused by local communities (Butz 2009). The most fire affected rangelands are located in Katavi ecosystem, Lindi, Rukwa, Tabora, Mbeya and most western regions (Fig 3). A task force investigating factors contributing to the significant burn statistics in these regions found that traditional hunting of rats done by resident communities (in Rukwa and Katavi regions), illegal hunting of wildlife, farming practices and arsonism contribute significantly to most wildfire incidences (NTF 2012). Fire havoc causes countless loses of biotas, human lives, ecological services and changes of local climates. The actual effects of wildfire on Tanzania's biodiversity are difficult to understand, however, given that most such incidences go unmonitored. The government of Tanzania has welcome the report by Rucker and Tiemann (2012) and a task force on integrated fire management (under the Ministry of Natural Resources and Tourism) is working towards formulating a unified fire policy for Tanzania. This is a positive step towards controlling wildfire and its impacts on the rangeland biodiversity in the country.

Habitat degradation and loss and associated risks of species extinction

Unsustainable land use and associated land cover changes continue to influence on the dynamics of Tanzania rangelands' resources. However the paucity of information on the extent and intensity of deforestation across the miombo and savannah biomes make it particularly more difficult to curtail the problem. Limited access to electrification for the majority of the human population in rural areas (about 80%) means that high energy demands are met through clearing forests and woodlands for biomass fuel (URT 2003). About one million tonnes of charcoal is burnt in Tanzania annually, with almost 70% consumed in the city of Dar es Salaam alone (Msuya et al. 2011). Demands for biomass energy claims in excess of 150 ha of forests and woodlands each year (Msuya et al. 2011) driving forest land cover change along the highway and near the city (Ahrends et al. 2010). However, these data on woodland deforestation are only indicative and may not reflect actual situation on a countrywide scale given that charcoal and firewood is consumed in significant amounts across all other Tanzanian cities. Further, in some parts of Tabora and southern (Iringa and Mbeya) regions deforestation stands at >3% annually in the miombo woodlands (Mangora 2005) because of shifting cultivation and excessive use of woods for curing tobacco (Sauer and Abdallah 2007). For example, the land converted from natural vegetation to cultivated land increased to 11.2% (between 1995 and 2000) from 4.7% (between 1984 and 1995) in some parts of Tabora (Yanda 2010). Such land use change has severe consequence on local biodiversity (Mangora 2005, Sauer and Abdallah 2007) as well as on local climates. Furthermore, clearing of woodlands in protected area is to a great extent instigated by brick burning, lumbering, charcoal making (e.g. in Swagaswaga Game Reserve, Madulu 2001) and agricultural expansion near national park boarders (Mwamfupe 1998, Vanderpost 2006, Wittemyer et al. 2008). Deforestation and habitat loss, if not checked, may have far reaching impacts on species survival and ecological functioning of protected areas (Newmark 1996, 2008).

Recommendations on potential solutions

The rangelands play critical roles in human survival and development. They support a variety of species of economic as well as socio-cultural and ecological importance. However, there are numerous challenges facing biodiversity conservation in rangelands. This paper has uncovered these challenges and attempts to develop effective measures of addressing them. Hereunder, we recommend some measures to address these challenges.

Human-wildlife conflicts should be an important issue on the policy agenda in the management of rangeland biodiversity. Most of the conflicts are a consequence of the prohibitive and restrictive policies. Transforming biodiversity resources such as wildlife from a liability to an asset, the communities will be motivated to align their behaviour with conservation goals. Further, local communities should be actively involved in the decision-making and planning of conservation including the development-related interventions. This will greatly reduce the conflicts and poverty.

Conservation education with urban and rural communities should be emphasized. Failure of implementation of conservation strategies has been partly because of the limited awareness of the people of the role of biodiversity in ecosystem and human health and limited financial resources. Conservation education may help re-align the people's minds toward protection of biodiversity and thus conservation would trickle down from people's own initiatives. Transforming communities into conservators requires clear understanding of the value that nature and the consequences of having non-functional ecosystems.

Poverty is one of the root causes of the biodiversity loss, and thus should be tackled. Those who destroy biodiversity in order to survive should be provided with adequate alternative livelihood strategies. The current conservation policies seeking to empower local communities economically are encouraging, but their implementation is yet to engender the expectations. The scientific studies that will lead to understanding of and, therefore, addressing the impediments towards thwarting poverty reduction effort is key to rectifying the deficiencies towards prosperity. Critical to sound poverty reduction strategies is to maximize good governance through (i) directly supporting the participatory pro-poor policies, (ii) facilitation of sound macroeconomic and public expenditure management, (iii) ensuring accountability and the transparent use of public funds; (iv) encouraging the growth of the private sector, (v) promoting effective delivery of public services, and (vi) effectively implement a rule of law.

Moreover, the conservation policies should take the issue of population growth as a challenge that calls for pragmatic approaches for its solution. Proactive population policy, education on family planning and implementation of poverty reduction strategies are one of several steps. Furthermore, the issue of HIV/AIDS epidemic in Tanzania needs multi-sectoral intervention because of its cultural, social, economic, political and technological dimensions. Despite the fact that the policy guidelines and strategic framework for the response of HIV/AIDS epidemic and management of its consequences in Tanzania are in place, the reality is that the war against it need efforts geared at ensuring public and private participation. This should be complemented by promotion of the high level advocacy and education, protection of human and communal rights of people infected with and affected by HIV/AIDS. Enhancing health care and counselling of HIV/AIDS patients, ensuring the welfare of the bereaved orphans and survivors of HIV/AIDS, and handling of social, economic, cultural and legal issues, which are related to the epidemic is also important.

Given the negative impacts caused by a number of civil wars that lead to loss of rangelands biodiversity, it is imperative that superior strategies for the conflict prevention and peace building are developed and implemented. Both local and international communities, when necessary, should intervene to fight social vices that lead to civil wars, such as inequalities, corruption and nepotism. There is a need for the establishment of a global network on conflict prevention and peace education in collaboration with the respective ministry of education, civil societies and religious organization.

All development policies, projects or activity should be subjected to Environmental Impact Assessment (EIA) in order to identify their potential impacts. The proactive effort should be made to restore the degraded or damaged range areas, which are preceded by the development activities, such as those in the mining areas as well as in refugee-affected areas.

The problem of climate change and its potential impacts on rangeland biodiversity should be addressed by the adoption of a variety of mitigation and adaptation measures. The measures include limiting or controlling anthropogenic activities such as deforestation, adoption of proper land management practices (including agroforestry), changing energy technologies (e.g. the use of efficient wood stoves and biogas), ensuring proper fire management as well as developing fire reduction strategies for rangelands. Other strategies should involve adopting the integrated land and water management practices, and enhancing synergies between the conservation and sustainable use of biodiversity and climate change. There is an urgent need for the government to assess and identify invasive species and develop effective strategies for their control. This can be done by educating the public about the types of invasive species found in Tanzania and raise awareness of their relevance so that their control can start at the grass root. More research is required to understand vulnerability of different rangeland ecosystems to new invasions by the alien invasive species.

The current conservation approach based mostly on protected area systems is ineffective and limited to protecting species outside protected area. There is dire need for an 'inclusive conservation approach' geared towards conserving biodiversity in the wilderness (protected areas), non-protected areas and in urban areas where people live and work (Rija 2010). Most conservation threats emanate from protected area matrices and are conducted by people from urban areas. For example, the rhino killings in the Serengeti National Park by poachers in 2012 were spearheaded by people from cities far away. Extending conservation efforts into non-protected areas including cities would render effective biodiversity conservation countrywide.

We call upon increasing collaborative efforts between local and international scientists in addressing the challenges facing biodiversity conservation across Tanzania's rangelands. Such efforts should target toward enhancing capacity of local scientists and practitioners particularly in advanced research skills and monitoring techniques of biological resources (Rija and Hassan 2011). These skills are essential to ensuring sustainable conservation of biodiversity especially in wildlife reserves.

Acknowledgements

This paper was written following a discussion between JRK and AAR on the threats facing Tanzania's rangelands in the course of teaching Range Ecology and Management course to the undergraduate students pursuing Bachelor of Science degree in Wildlife Management at SUA. We thank two anonymous reviewers for providing comments on the manuscript.

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Nature Conservation 6: 31–48 (2013)
doi: 10.3897/natureconservation.6.5205
http://www.pensoft.net/natureconservation

APPLIED ECOLOGY

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Land-use changes, farm management and the decline of butterflies associated with semi-natural grasslands in southern Sweden

Sven G. Nilsson[1], Markus Franzén[1,2], Lars B. Pettersson[1,3]

1 *Biodiversity Unit, Department of Biology, Lund University, Ecology Building, SE-223 62 Lund, Sweden* **2** *UFZ Helmholtz Centre for Environmental Research, Department of Community Ecology, Theodor-Lieser-Straße 4, D-06120 Halle, Germany* **3** *Swedish Butterfly Monitoring Scheme, Lund University, Ecology Building, SE-223 62 Lund, Sweden*

Corresponding author: *Lars B. Pettersson* (lars.pettersson@biol.lu.se)

Academic editor: *L. Penev* | Received 26 March 2013 | Accepted 30 October 2013 | Published 18 November 2013

Citation: Nilsson SG, Franzén M, Pettersson LB (2013) Land-use changes, farm management and the decline of butterflies associated with semi-natural grasslands in southern Sweden. Nature Conservation 18: 31–48. doi: 10.3897/natureconservation.6.5205

Abstract

Currently, we are experiencing biodiversity loss on different spatial scales. One of the best studied taxonomic groups in decline is the butterflies. Here, we review evidence for such declines using five systematic studies from southern Sweden that compare old butterfly surveys with the current situation. Additionally, we provide data on butterfly and burnet moth extinctions in the region's counties. In some local areas, half of the butterfly fauna has been lost during the last 60–100 years. In terms of extinctions, counties have lost 2-10 butterfly and burnet moth species. Land use has changed markedly with key butterfly habitats such as hay meadows disappearing at alarming rates. Grazed, mixed open woodlands have been transformed into dense coniferous forests and clear-cuts, and domestic grazers have been relocated from woodlands to arable fields and semi-natural grasslands. Ley has increased rapidly and is used for bale silage repeatedly during the season. Overall, the changed and intensified land use has markedly reduced the availability of nectar resources in the landscape. Species that decline in Sweden are strongly decreasing or already extinct in other parts of Europe. Many typical grassland species that were numerous in former times have declined severely; among those *Hesperia comma*, *Lycaena virgaureae*, *Lycaena hippothoe*, *Argynnis adippe*, and *Polyommatus semiargus*. Also, species associated with open woodlands and wetlands such as, *Colias palaeno*, *Boloria euphrosyne* and the glade-inhabiting *Leptidea sinapis* have all decreased markedly. Current management practise and EU Common Agricultural Policy rules favour intensive grazing on the remaining semi-natural grasslands, with strong negative effects on butterfly diversity. Abandoned grasslands are very common in less productive areas of southern Sweden and these habitats may soon become forests. There is an urgent need for immediate action to preserve unfertilized, mown and lightly grazed grasslands. It is also crucial to encourage that management of abandoned grasslands resumes before it is too late. In order to mitigate risks of further species loss and to work towards recovery of threatened butterfly populations using best known practises, we recommend twelve types of management measures favourable for many butterflies.

Keywords
Land management, conservation, agroecology, semi-natural grasslands, management recommendations, butterflies, Sweden

Introduction

During the last 100 years, agriculture has experienced profound changes in Europe. In particular, it has become increasingly mechanized because of the pressure for higher yields and the rising price of labour (Dahlström et al. 2008; Tscharntke et al. 2005). As a consequence, considerable areas of traditionally managed grasslands that once were unfertilized, mowed late in summer and then grazed have become intensively used land or abandoned (Dahlström et al. 2008; Eriksson et al. 2002; van Swaay et al. 2013). Intensification includes applying inorganic fertilizer, draining and often increasing the grazing pressure. In Sweden and many other parts of Europe, grasslands on low productive soils have been transformed into forests either by being planted with coniferous trees or by being abandoned. This changed management has had a substantial negative effect on flora and fauna, and many species are declining and are on the verge of regional extinction (Mace et al. 2008). Indeed, the declining European semi-natural grasslands are associated with a unique set of species that since long has been adapted to these habitats (Hoekstra et al. 2005). Traditionally, conservation efforts in these habitats have mainly focused on plants, but during the last 30 years, butterflies have gained more attention (Erhardt 1985; Thomas 1984), and the knowledge about butterflies is today relatively good with well-established monitoring programs in many European countries (van Swaay et al. 2013). Most studies report declines and a vanishing butterfly fauna (van Dyck et al. 2009) as a consequence of habitat destruction (Warren et al. 2001), unsuitable management and lack of interest to preserve key sites and declining populations (Dover et al. 2011; Konvicka et al. 2008). However, there are also a few studies reporting positive results from conservation actions and recovering butterfly populations (Thomas et al. 2009). Here we highlight a number of local studies from southern Sweden that cover land use changes and associated consequences for butterflies and burnet moths during the last 100 years. Using Red List data for Swedish counties (Gärdenfors 2010), we also compare these effects of land use in Sweden with regional extinction rates in a number of Swedish counties.

Focus area

Most of southern Sweden is characterised by a forest-dominated landscape, with small-scaled farmland covering about 5 % (Anon. 2012; SNA 1996). Fertile plains cover

10 % of the area and are dominated by intensive agriculture with large fields. In the forest-dominated parts of the landscape, small to mid-sized villages are sparsely scattered throughout the landscape with small fields around them. Soils are typically oligotrophic with low calcium content and lakes and mires are abundant. Fields are often bordered by deciduous trees or mixed forest stands, but coniferous forest plantations dominate the landscape. The area has experienced drastic changes in landscape composition during the last two centuries, with changes accelerating since the 1950s (Nilsson and Franzén 2009; Nilsson et al. 2008). Traditional semi-natural meadows, of which nearly all once were hay meadows, have been transformed to intensively grazed pasture or forest. Likewise, many pastures and previously grazed woodlands in the area have been abandoned and planted with coniferous forests (Nilsson 2006). Open, arable farmland is mainly found near hamlets and is used for crop and ley. Ley has increased and ley fields are today harvested for bale silage repeatedly during the season, often beginning as early as in May (Nilsson and Franzén 2009). These new harvesting methods have also had major effects on the availability of nectar resources in the landscape as the onset of the harvest cycle in May or early June commonly takes place before flowering peaks in summer (Dahlström et al. 2008; Nilsson et al. 2008). Most ley fields and other arable fields are fertilized and most of the regions' semi-improved grasslands are intensively grazed for animal production. The floral and host plant diversity of these parts of southern Sweden is also affected in more subtle ways as the region is exposed

Figure 1. Open habitats associated with a rich butterfly fauna in southern Sweden: **A** Taxås nature reserve in Kronoberg County, Småland, a pasture with one part experiencing late grazing **B** An abandoned pasture in Blekinge **C** A recently abandoned meadow in Småland. *Photos: Markus Franzén*.

to considerable nitrogen deposition from the atmosphere (wet deposition: 10–12 kg ha-1 year-1; Öckinger et al. 2006b) causing a decrease in floral and butterfly diversity (Bobbink et al. 1998; Öckinger et al. 2006b). Nevertheless, despite decreases in semi-natural grasslands, changed harvesting regimes and continuing atmospheric nitrogen deposition, the small-scaled nature of many parts of the landscape still harbours some of the most diverse and attractive pastoral landscapes of Sweden (Figure 1). Small-scale farms still occur with their cattle grazing the landscape's pastures and the butterfly fauna still remains richer than in most other parts of Sweden.

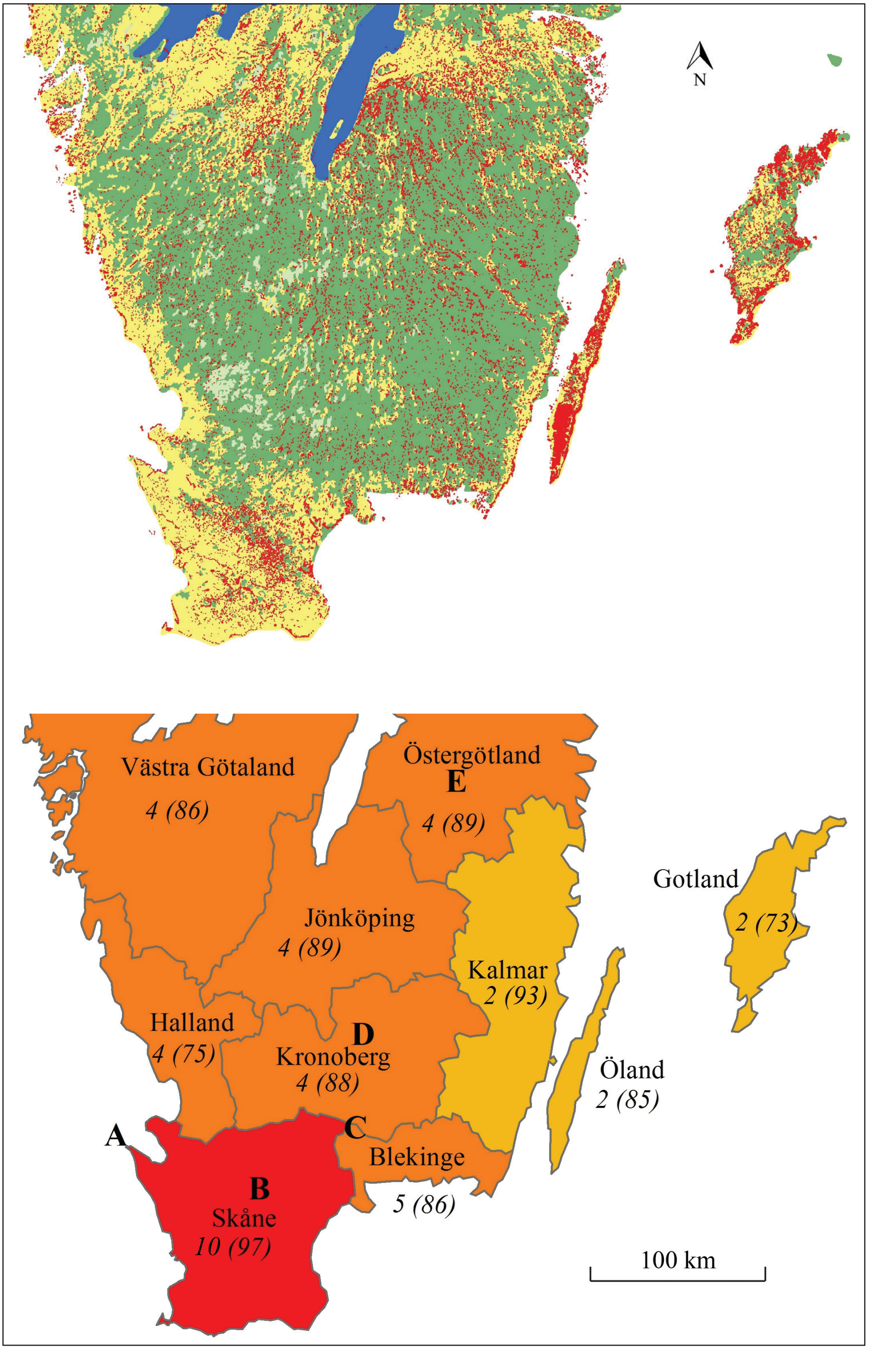
Main grassland types in the area

Administratively, the studied area is split into nine counties (Figure 2) which, together with the Baltic island Öland, form the basis for our analysis of extinction events (cf. Gärdenfors 2010). The study area contains a wide variety of grasslands, ranging from fertilized and managed swards still being traditionally managed by farmers and local enthusiasts in late summer (Franzén and Nilsson 2008; Franzén and Ranius 2004a; Nilsson et al. 2008). Extensively grazed woodlands or tree-rich pastures are not uncommon in the area and mirror some of the 19th century grazing commons, although many of today's tree-rich pastures are formerly open ones that have become more closed over time (Nilsson et al. 2008; Öckinger et al. 2006b). Overall, semi-natural grasslands that are intensively grazed and that have sometimes been fertilized earlier are the dominating grassland habitat. Cattle and horse grazing dominate, but sheep grazing has increased in the area.

Extent of habitat types in the area

The proportion of the landscape that consists of pastures and hay meadows in this area is approximately 5% (Data from the Swedish Board of Agriculture; Anon. 2008). In terms of area, the amount of pasture in some of the counties covered range from

Figure 2. Upper map: Main habitats in southern Sweden (dark green= forest; light green = wetlands; yellow = arable fields; blue = water; red = semi natural grasslands; data from (SNA 1996) and the Swedish national survey of semi-natural meadows and pastures (TUVA database, https://etjanst.sjv.se/tuvaut/site/index.htm [Access date 2013-03-25]). **Lower map**: Delimitations of the nine counties and the province (Öland, which forms a separate province but administratively belongs to the county of Kalmar) in south Sweden that were studied. The number of extinct butterfly and burnet moth species in each region (Gärdenfors 2010) are given together with the total number of observed butterfly and burnet moth species in region (in brackets; data from Catalogus Lepidopterorum Suecicae, http://www2.nrm.se/catalogus.html [Access date 2013-03-25]). A redder colour indicates a higher number of extinct species. Thus, the county of Skåne has 10 extinct butterflies and burnet moths out of a total of 97 observed species. The capital letters denote the areas where the five different local studies was performed; **A** (Franzén and Johannesson 2007) **B** (Andersson 2002) **C** (Öckinger et al. 2006b) **D** (Nilsson et al. 2008) **E** (Douwes 2004). Study C was performed in Skåne, Blekinge and Kronoberg. Only Swedish territory is shown on the map.


N
Västra Götaland
4 (86)
Östergötland
E
4 (89)
Gotland
2 (73)
Jönköping
4 (89)
Kalmar
2 (93)
Halland
4 (75)
D
Kronoberg
4 (88)
Öland
2 (85)
A
C
Blekinge
5 (86)
B
Skåne
10 (97)
100 km

21,000 hectares in the county of Kronoberg (part of the Swedish province Småland), to 77,000 hectares in the county of Kalmar (covers eastern parts of Småland as well as the island Öland). On average, these southern Swedish counties each contain about 43,000 hectares of pasture (Data from the Swedish Board of Agriculture; Anon. 2012). The extent of hay meadows with traditional late harvest is very low, and is about 7,800 hectares for Sweden as a whole (Anon. 2012). Furthermore, about 35% of these 7,800 hectares come from farms smaller than 2 hectares (Anon. 2008), demonstrating that much of the traditional hay harvest is done by local enthusiasts rather than being part of regular farm economy. The area used as hay meadows is also highly variable between counties as demonstrated by its range of 75 hectares in Blekinge to 1,998 hectares in Skåne (Anon. 2012). On average, the area is 566 hectares per county but heavily influenced by the large area in Skåne. In contrast, the area used for short- and long-term ley ranges from 16,000 to 123,000 hectares, with 38,000 in the focal area (Anon. 2012). The extent of these habitat types within Natura 2000 in the focal area of Småland, Kronoberg County, is 928 hectares pasture (4.4% of the total pasture area) and 70 hectares hay meadows (35% of the total hay meadow area) according to the latest (2012) data from the Swedish Board of Agriculture.

Butterfly and burnet moth trends in the area

Five studies during the last decade have documented distinct decreases in butterfly and burnet moth species richness in southern Sweden (Table 1, Figure 2). It should be noted that burnet moths are generally included in butterfly surveys in Sweden because of the two groups' similar habitat requirements and ecology and we follow this tradition here (Franzén and Ranius 2004a, b; Nilsson and Franzén 2009; Pettersson et al. 2012). In Skåne and Östergötland, two early studies documented declines in butterfly species richness, from around 70 butterfly species in the Ringsjö area of Skåne in the 1870s to half as many in the 1990s (Andersson 2002). In the Östergötland study Douwes (2004) found a decrease of the butterfly fauna but the area still harboured a high number of butterfly species.

After these two pioneering papers, long term declines in countryside butterfly diversity have been documented in detailed studies from the focal area of the present report (Table 1). From Kullaberg in north-western Skåne, a 45% loss from the initial 50 butterfly species has been documented between 1953 and 2005 within a 1000 hectare area of mixed forest and agricultural land (Franzén and Johannesson 2007). In the village Nöbbele, Småland, a 450 hectare area in a typical forest dominated agricultural landscape, 44% of the 48 butterfly species present in 1910 were extinct in 2003 (Nilsson et al. 2008). Similarly, a survey investigating changes in the butterfly and burnet moth fauna in a set of 13 pasture-dominated plots in Skåne, Blekinge and Småland between 1981 and 2002 found that an average 35% of the original 30 species found in pastures of this study (with a combined area of 328 hectare area) had gone extinct (Öckinger et al. 2006b). Considerably fewer species had colonised the three areas sur-

Table 1. Butterfly and burnet moth species that have disappeared (*Extinct*), decreased in numbers (*Decrease*), increased (*Increase*) or remained relatively unchanged (*Unchanged*) in abundance in three systematic resurveys in southern Sweden at Kullaberg (*Kullaberg*; Franzén and Johannesson 2007), Nöbbele (*Nöbbele*; Nilsson et al. 2008) and in 13 pasture areas (*Pastures*; Öckinger et al. 2006b), as well as their main habitat (*Grassland, Wetland, Forest;* cf. Eliasson et al. 2005), and the main larval food plants of each species in these areas. Burnet moths are indicated with asterisks (*). Species not present in a study are indicated with dashes (-). Only species that had decreased or increased in at least two of these three studies are included in the table. Species not reproducing in Sweden are excluded. Positions of the studies are indicated with capital letters in Figure 2.

Species	Grassland, Wetland or Forest	Kullaberg	Nöbbele	Pastures	Major larval food plants
*Adscita statices**	G	Unchanged	Decrease	Decrease	*Rumex acetosella* *Rumex acetosa*
Anthocharis cardamines	G	Unchanged	Decrease	Decrease	Brassicaceae
Aporia crataegi	G	Extinct	Extinct	Extinct	*Sorbus aucuparia* *Crataegus*
Araschnia levana	G	Increase	-	Increase	*Urtica dioica*
Argynnis adippe	G	Extinct	Extinct	Decrease	*Viola* spp.
Argynnis aglaja	G	Extinct	Unchanged	Decrease	*Viola* spp.
Boloria euphrosyne	W	Extinct	Decrease	Decrease	*Vaccinium uliginosum*
Boloria selene	G	Extinct	Unchanged	Decrease	*Viola*, especially *Viola palustris*
Coenonympha pamphilus	G	Unchanged	Decrease	Decrease	Poaceae
Colias palaeno	W	Extinct	Extinct	-	*Vaccinium uliginosum*
Cupido minimus	G	Extinct	Extinct	-	*Anthyllis vulneraria*
Erynnis tages	G	Extinct	-	Extinct	*Lotus corniculatus*
Favonius quercus	G	Unchanged	Decrease	Decrease	*Quercus*
Hesperia comma	G	Extinct	Extinct	Decrease	*Festuca ovina* *Festuca rubra* *Agrostis vinealis*
Lasiommata maera	G	Extinct	Decrease	Decrease	Poaceae
Leptidea sinapis	G	-	Extinct	Extinct	*Lathyrus linifolius*
Limenitis populi	F	Extinct	Extinct	-	*Populus tremula*
Lycaena hippothoe	G	Extinct	Extinct	Decrease	*Rumex acetosa* *Rumex acetosella*
Lycaena virgaureae	G	Extinct	Extinct	Decrease	*Rumex acetosa*
Maculinea arion	G	-	Extinct	Extinct	*Thymus* *Origanum vulgare*
Melitaea athalia	G	Extinct	Decrease	Decrease	*Melampyrum*
Melitaea cinxia	G	Extinct	-	Extinct	*Veronica spicata* *Plantago lanceolata*
Nymphalis polychloros	F	Extinct	Extinct	-	*Ulmus, Salix*
Papilio machaon	G	Extinct	Extinct	Extinct	*Peucedanum palustre* *Pimpinella saxifraga*
Plebejus optilete	W	Extinct	Decrease	Unchanged	*Andromeda polifolia* *Vaccinium oxycoccos* *Vaccinium uliginosum*

Species	Grassland, Wetland or Forest	Kullaberg	Nöbbele	Pastures	Major larval food plants
Polyommatus semiargus	G	Extinct	Extinct	Decrease	*Trifolium pratense*
Pyrgus malvae	G	Unchanged	Decrease	Decrease	*Fragaria vesca* *Potentilla*
Satyrium pruni	G	Extinct	-	Decrease	*Prunus spinosa*
Thecla betulae	G	Extinct	-	Extinct	*Prunus spinosa* *Prunus padus*
*Zygaena filipendulae**	G	Unchanged	Extinct	Decrease	*Lotus corniculatus*
*Zygaena lonicerae**	G	Extinct	Extinct	Decrease	*Trifolium medium*
*Zygaena viciae**	G	Extinct	Unchanged	Decrease	*Lathyrus linifolius* *Vicia cracca*

veyed, 4% were new at Kullaberg in 2005, 6% were new at Nöbbele in 2003 and on average 18% were new in the 2002 survey of pasture-dominated landscapes.

It is worth noticing that most historical Swedish butterfly information on trends is based on presence/absence data as relatively few quantitative analyses have been carried out over time (Eliasson et al. 2005). However, there is now a nationwide butterfly monitoring scheme in Sweden with about 25% of its 271 monitored sites at least partially covering agricultural land on a yearly basis (Pettersson et al. 2012). This new Swedish data is included in the 2012 revision of the European Butterfly Indicator for Grassland species (van Swaay et al. 2013).

In total, 130 butterflies and burnet moths have been recorded in Sweden; 117 of these are resident and another 13 species occur sporadically. While no species have become extinct from Sweden during the last four decades, 40 butterfly and burnet moth species are included in the latest Red List (Gärdenfors 2010). In the counties which we cover in this review, an average of 4.3 species has become regionally extinct, with the southernmost county Skåne suffering the greatest loss with 10 extinct species (Figure 2, Table 2). The majority of the Red Listed butterfly species in Sweden are closely associated to species-rich unfertilized grasslands (cf. Eliasson et al. 2005; Gärdenfors 2010).

Trends in European Butterfly Indicator species in the area

In Sweden, we presently have 12 of the 17 different grassland species included in the European Butterfly Indicator for Grassland species (Pettersson et al. 2012; van Swaay et al. 2013). These include Dingy Skipper (*Erynnis tages*), Large Skipper (*Ochlodes sylvanus*), Orange Tip (*Anthocharis cardamines*), Small Copper (*Lycaena phlaeas*), Little Blue (*Cupido minimus*), Large Blue (*Maculinea arion*), Mazarine Blue (*Polyommatus semiargus*; Figure 3), Common Blue (*Polyommatus icarus*), Marsh Fritillary (*Euphydryas aurinia*), Wall Brown (*Lasiommata megera*), Small Heath (*Coenonympha pamphilus*), and Meadow Brown (*Maniola jurtina*) (Pettersson et al. 2012). Several of these are characteristic of many types of grassland in southern Sweden. Five of them, Dingy Skipper, Orange

Table 2. Butterfly and burnet moth species listed in the Swedish Red List as extinct from the studied counties in southern Sweden (Gärdenfors 2010). Extinctions are indicated with the sign †.

Species	**Skåne**	**Blekinge**	**Gotland**	**Öland**	**Kalmar**	**Kronoberg**	**Jönköping**	**Halland**	**Västergötland**	**Östergötland**
Argynnis niobe						†	†			
Coenonympha hero	†					†				
Euphydryas aurinia	†						†			†
Euphydryas maturna	†	†								
Hamearis lucina	†	†								
Limenitis camilla	†									
Lopinga achine	†									
Lycaena hippothoe			†							
Maculinea arion						†	†	†		†
Melitaea britomartis							†			†
Melitaea cinxia								†		
Melitaea diamina									†	
Parnassius apollo	†	†				†	†	†	†	
Parnassius mnemosyne	†		†	†	†					†
Polyommatus dorylas		†			†					
Pyrgus alveus	†	†		†						
Satyrium ilicis								†	†	
Zygaena osterodensis	†								†	
Total	10	5	2	2	2	4	5	4	4	4

Tip, Large Blue, Mazarine Blue, and Small Heath have all been disappearing or strongly decreasing in two or three of the detailed studies covering Kullaberg, Nöbbele, and the 13 pasture-dominated landscapes in Skåne, Blekinge and Småland (Franzén and Johannesson 2007; Nilsson et al. 2008; Öckinger et al. 2006b) causing concern for the future. Surprisingly, many species that were numerous just a few decades ago have more or less disappeared from the surveyed areas; among those Silver-spotted Skipper (*Hesperia comma*), Scarce Copper (*Lycaena virgaureae*; Figure 3), Purple-edged Copper (*Lycaena hippothoe*; Figure 3), High Brown Fritillary (*Argynnis adippe*), and Mazarine Blue.

Among species associated with forest glades and wetlands, Moorland Clouded Yellow (*Colias palaeno*), Pearl-Bordered Fritillary (*Boloria euphrosyne*) and the glade-inhabiting Wood White (*Leptidea sinapis*) have all decreased markedly (Nilsson and Franzén 2009). The Moorland Clouded Yellow and the Pearl-Bordered Fritillary both utilize Bog Bilberry (*Vaccinium uliginosum*) which is a low nitrogen specialist that may suffer from the ongoing nitrogen deposition. The three spectacular species Black-veined White (*Aporia crategi*), Poplar Admiral (*Limenitis populi*), and Swallowtail (*Papilio machaon*) have all disappeared from the areas investigated in the three detailed studies

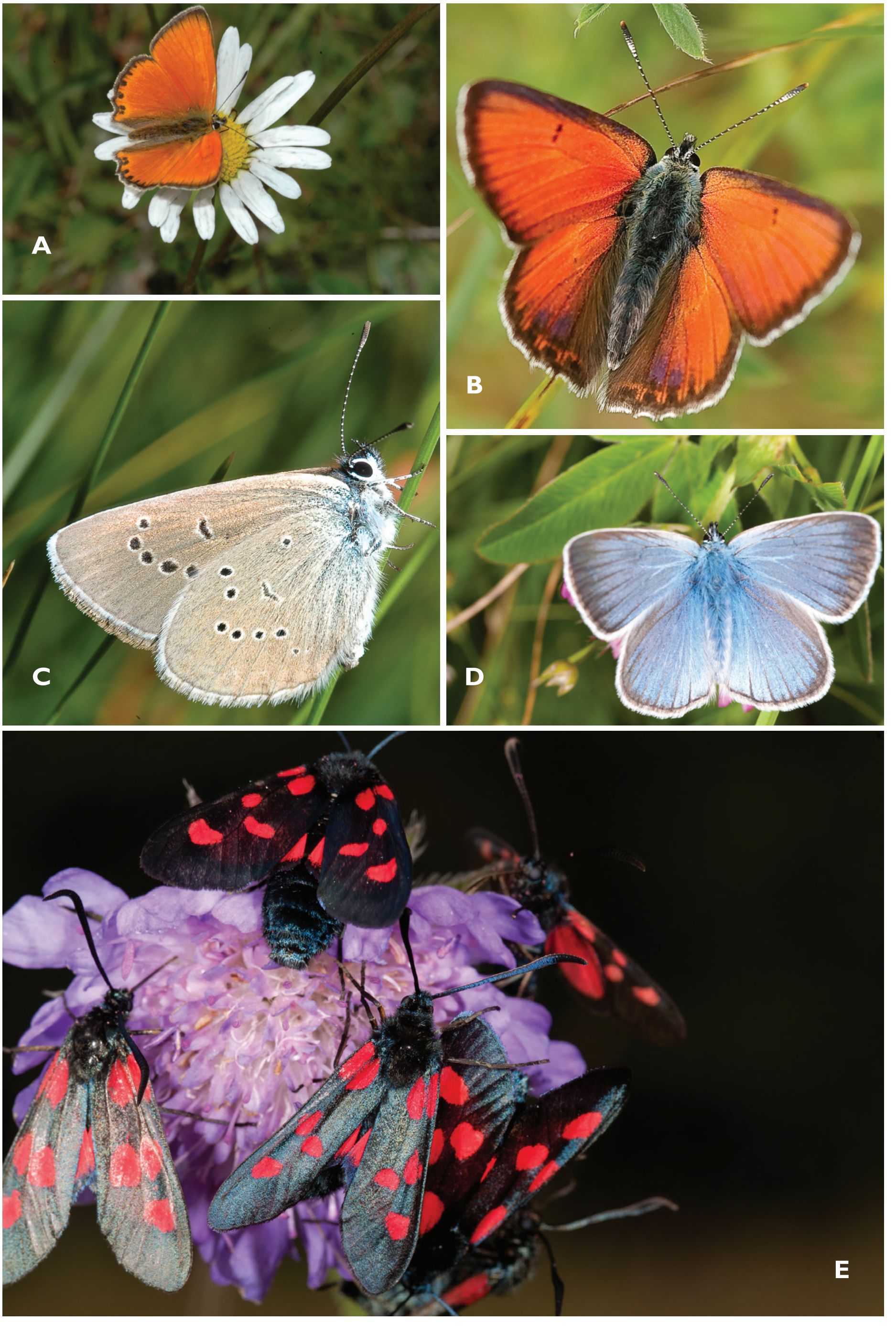


Figure 3. Butterflies and burnet moths associated with semi-natural grasslands in the area: **A** Scarce Copper (*Lycaena virgaureae*) **B** Purple-edged Copper (*Lycaena hippothoe*) **C** Mazarine Blue (*Polyommatus semiargus*) **D** Amanda's Blue (*Polyommatus amandus*) **E** New Forest Burnet (*Zygaena viciae*) and Narrow-bordered Five-spot Burnet (*Zygaena lonicerae*). *Photos: Markus Franzén.*

(Franzén and Johannesson 2007; Nilsson et al. 2008; Öckinger et al. 2006b). While these negative trends in grasslands and other habitats represent considerable losses in diversity, there are also species expanding their ranges. Two species with nitrogen-favoured larval host plants are currently highly successful and are rapidly expanding to the north through southern Sweden: the Map Butterfly (*Araschnia levana*) and the Purple Emperor (*Apatura iris*) (Betzholtz et al. 2013; Pettersson et al. 2012).

Trends in land use and farming systems affecting the habitat types

The land use in the focal area has changed dramatically over the last decades. Before Sweden joined the European Union in the early 1990s, there was a period when large farmland areas were used as set-asides in order to reduce subsidised production of wheat and other crops. The set-asides of these areas had a major positive impact on the population sizes of several bird species (Wretenberg et al. 2007). The effect on butterflies remains little studied in Sweden but data from Finland and the UK indicate positive effects on butterflies, moths and bumblebees (Alanen et al. 2011; Merckx et al. 2009). Soon after Sweden joined the European Union, these large set-asides were taken back into production. At the same time, grazing of pastures intensified for a number of reasons. Partly, authorities encouraged the use of high grazing pressure to increase floral diversity, which had been high during historical periods of intensive grazing. Intensive grazing is also easily quantifiable as the sward is kept to a measurable height, and this may also have contributed to the implementation of sward height regulations for farmers to qualify for agricultural subsidies. The movement towards more intensive grazing also led to larger areas being grazed by sheep (Figure 4). Sheep grazing is generally more negative for butterflies and burnet moths than cattle and horse grazing (Öckinger et al. 2006a). New results suggest that careful management and timing of sheep grazing can reduce negative effects substantially (van Noordwijk et al. 2012) but these approaches have not yet been widely adopted. Altogether, changes in land use and grazing pressure beginning in the early 1990s led to a marked decline in flower availability in summer in the southern Swedish agricultural landscape (Franzén and Nilsson 2008; Nilsson and Franzén 2009). Cattle farmers and horse owners were recommended to let their animals graze intensively, and sheep selectively grazed herbs. This heavy grazing regime, often applied early in the season and homogenously within whole pastures, has had clear negative impacts on many butterflies and disastrous impacts on burnet moths (Nilsson and Franzén 2009; Öckinger et al. 2006a; Öckinger et al. 2006b).

Another trend in recent years has been to harvest hay earlier and earlier, moving the onset of hay harvest back from around Midsummer to early June, and now often to late May (Franzén and Nilsson 2008; Nilsson et al. 2008). Much of the hay harvest has now been replaced by repeated bale silage which commonly starts as early as May and then continues 2-3 times throughout the summer (Figure 4). Although much of the bale silage is based on ley harvest from former arable fields, it is also being practised

Figure 4. Three examples of sites less suited for butterflies: **A** Intensified hay cutting of ley fields has a strong negative effect on the butterfly fauna. Here is a storage place for bale silage close to a former Clouded Apollo, *Parnassius mnemosyne,* site in Blekinge **B** Succession of former semi-natural grasslands due to abandonment and **C** Intensive grazing early in the season as here by sheep can be devastating for many butterflies, their eggs, larvae and pupae as well as for nectar resources. *Photos: Markus Franzén.*

in former hay fields (Nilsson et al. 2008). Bale silage is increasing rapidly throughout Sweden and the deployment is already nearly 100% in many areas. Woodland grazing was common 50-100 years ago, but is unfortunately used much less today. This type of management is important for maintaining sparsely vegetated and semi-open woodlands with glades that constitute important butterfly habitats (Nilsson and Franzén 2009; Nilsson et al. 2008). Grazed woodlands in Sweden do not qualify for the same subsidies from EU as semi-natural pastures do, a problem which has received much attention lately but still remains unresolved (Anon. 2010). Small scale farming is not an economically attractive profession today and this has led to a dramatic decrease in the number of farmers as well as an increase in the number of livestock per farm remaining. The disappearance of small to medium-sized farms initiates vegetation succession in semi-natural grasslands and gradually transforms these grasslands into forests (Figure 4). This is especially prominent in the forest dominated regions with low productive soils, where traditional management survived until recently. On the productive plains, small to medium-sized farms were merged into larger units and converted to intensively used arable fields several decades ago.

Wetlands in the agricultural landscape have been drained in many places, and the butterflies of these areas were often seeking nectar on the surrounding meadows and pastures. Thus, because of the interactive effect of wetland draining and flower-rich pastures and meadows disappearing, species associated with wetlands have declined in the area during the last 50 years (Nilsson and Franzén 2009).

Comparisons with other regions

The present results from southern Sweden show an interesting parallel to studies elsewhere in Europe (Kuussaari et al. 2007; van Swaay et al. 2011; van Swaay et al. 2006; Wenzel et al. 2006). It seems that species that are severely decreasing in southern Sweden already have gone extinct from the UK, the Netherlands, and Denmark or are also declining rapidly there. On the other hand, expanding species in Sweden seem to be increasing also in other countries (Betzholtz et al. 2013; Fox et al. 2011). Interestingly, butterfly distribution changes and population trends in southern Sweden show striking similarities with corresponding processes in Finland (Kuussaari et al. 2007; Pöyry et al. 2009). The general trends appear to be pronounced decreases of butterfly species and a shift in species composition from species associated with flower rich grasslands and dry grasslands, such as the Large Blue (*Maculinea arion*), towards a fauna dominated by species associated with nitrogen rich habitats, which can tolerate intensive agriculture as well as successional habitats with less suitable colder microclimatic conditions, such as the Map Butterfly and the Large Skipper *Ochlodes sylvanus* (Dennis 2010; van Swaay et al. 2013).

Grassland management

Current management and the European Union Common Agricultural Policy (CAP) regulations as applied in Sweden and elsewhere (Batary et al. 2011; Kleijn et al. 2006; Kleijn and Sutherland 2003) favour intensive grazing on the remaining semi-natural grasslands, with strong negative effects on butterfly diversity (Dover et al. 2011; Franzén and Nilsson 2008; Konvicka et al. 2008; Pöyry et al. 2004). The presumed effects on plant diversity have not been unequivocally verified, compared to the relatively lower and more varied grazing pressure before 1995 in Sweden (Söderström et al. 2001; Vessby et al. 2002). Instead, domestic animals have been concentrated on a smaller area; while much semi-natural grassland on small patches and low fertility land has been abandoned. As an example, the threatened butterfly Clouded Apollo, *Parnassius mnemosyne,* disappeared from most of its few remaining sites in Blekinge when subsidies where applied to manage grasslands (Franzén and Imby 2008) and a similar decline can be expected for other species as intense and early grazing is detrimental for many butterfly species and, in particular, burnet moths (Franzén and Nilsson 2008; Franzén and Ranius 2004a, b; Figure 4). Today, abandoned grasslands are very common in less productive areas and might in a near future become transformed into forests. There is an urgent need for immediate action to preserve the most endangered types of grassland vegetation such as unfertilized, mown and lightly grazed areas, as well as to manage the abandoned grasslands before it is too late (Skorka et al. 2007).

Based on the examples above, on conservation practitioners experience (cf. Kleijn and Sutherland 2003; Sutherland et al. 2004) and recent literature (Dahlström et al. 2008; Dover et al. 2011; Franzén and Nilsson 2008; Konvicka et al. 2008; Nilsson et al. 2008; Öckinger et al. 2006a; Pöyry et al. 2004; van Noordwijk et al. 2012; van Swaay et al. 2012), we believe the following measures are likely to be highly valuable for the butterfly and burnet moth fauna if implemented in the remaining grasslands of Sweden and similar parts of Europe.

- Later grazing, and grazing in segmented/split parcels so that some parts of pastures can grow taller and keep nectar resources longer in summer.
- Reduced grazing pressure in spring and early summer on herb-rich sites.
- Rotational grazing with some semi-natural grassland grazed only in late summer in some years.
- Hay cutting later in summer, preferably in late July, and once per season, followed by grazing of cattle in September–October.
- Herb rich grasslands should preferably be grazed by cattle or horses rather than sheep.
- If sheep are used, grazing needs careful management and timing to minimize negative effects on nectar resources.
- Implementation of policy measures that reduce in the overall nitrogen deposition from the atmosphere.
- Burning grasslands when the vegetation is dry in early spring, before the middle of April.
- Soil disturbance measures where fertilized top soil is removed, particularly at sun-exposed, sandy sites.
- Young invading trees (bushes), expanding shrubs, invading brackens and other expanding plant species should be removed.
- Spruce and pine plantations must cease on low fertility, semi-natural grassland sites.
- Implementation of compensation action from activities with negative impacts on butterfly habitats.

Acknowledgement

Markus Franzén was supported by the STEP-project (grant 244090–STEP–CP–FP; Potts et al. 2011). Lars B. Pettersson was funded by Lund University and the Swedish Environmental Protection Agency. We thank Alrun Siebenkäs for proofreading of an earlier draft. The research presented in this paper is part of the strategic research area Biodiversity and Ecosystems in a Changing Climate, BECC.

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Nature Conservation 6: 49–65 (2014)
doi: 10.3897/natureconservation.6.6498
http://www.pensoft.net/natureconservation

RESEARCH ARTICLE

A peer-reviewed open-access journal
Nature Conservation
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Improved access to integrated biodiversity data for science, practice, and policy – the European Biodiversity Observation Network (EU BON)

Anke Hoffmann[1], Johannes Penner[1], Katrin Vohland[1], Wolfgang Cramer[2], Robert Doubleday[3], Klaus Henle[4], Urmas Kõljalg[5], Ingolf Kühn[6], William E. Kunin[7], Juan José Negro[8], Lyubomir Penev[9], Carlos Rodríguez[8], Hannu Saarenmaa[10], Dirk S. Schmeller[4], Pavel Stoev[9], William J. Sutherland[11], Éamonn Ó Tuama[12], Florian T. Wetzel[1], Christoph L. Häuser[1]

1 *Museum für Naturkunde - Leibniz Institute for Evolution and Biodiversity Science, Invalidenstrasse 43, 10115 Berlin, Germany* **2** *Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale (IMBE), Aix-Marseille Université - CNRS - IRD - UAPV, Bâtiment Villemin, Europole de l'Arbois, BP 80, F-13545 Aix-en-Provence cedex 04, France* **3** *Centre for Science and Policy, University of Cambridge, 10 Trumpington Street, Cambridge CB2 1QA, United Kingdom* **4** *UFZ – Helmholtz Centre for Environmental Research, Department of Conservation Biology, Permoserstr. 15, 04318 Leipzig, Germany* **5** *Natural History Museum and Botanical Garden, University of Tartu, 46 Vanemuise Street, 51014 Tartu, Estonia* **6** *UFZ - Helmholtz Centre for Environmental Research, Department of Community Ecology, Theodor-Lieser-Str. 4, 06120 Halle, Germany* **7** *School of Biology, University of Leeds, Leeds LS2 9JT, United Kingdom* **8** *Estación Biológica de Doñana (EBD-CSIC), Americo Vespucio s/n. 41092, Seville, Spain* **9** *Pensoft Publishers and Bulgarian Academy of Sciences, Sofia, Bulgaria* **10** *Digitarium, University of Eastern Finland, Länsikatu 15, FI-80110 Joensuu, Finland* **11** *Conservation Science Group, Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, United Kingdom* **12** *GBIF Secretariat, Universitetsparken 15, DK-2100, Copenhagen Ø, Denmark*

Corresponding authors: *Anke Hoffmann* (anke.hoffmann@mfn-berlin.de); *Christoph L. Häuser* (christoph.haeuser@mfn-berlin.de)

Academic editor: *Pierre-Yves Henry* | Received 25 October 2013 | Accepted 21 March 2014 | Published 26 March 2014

Citation: Hoffmann A, Penner J, Vohland K, Cramer W, Doubleday R, Henle K, Kõljalg U, Kühn I, Kunin WE, Negro JJ, Penev L, Rodríguez C, Saarenmaa H, Schmeller DS, Stoev P, Sutherland WJ, Ó Tuama É, Wetzel FT, Häuser CL (2014) Improved access to integrated biodiversity data for science, practice, and policy - the European Biodiversity Observation Network (EU BON). Nature Conservation 6: 49–65. doi: 10.3897/natureconservation.6.6498

Abstract

Biodiversity is threatened on a global scale and the losses are ongoing. In order to stop further losses and maintain important ecosystem services, programmes have been put into place to reduce and ideally halt these processes. A whole suite of different approaches is needed to meet these goals. One major scientific contribution is to collate, integrate and analyse the large amounts of fragmented and diverse biodiversity data to determine the current status and trends of biodiversity in order to inform the relevant decision makers. To contribute towards the achievement of these challenging tasks, the project EU BON was developed. The project is focusing mainly on the European continent but contributes at the same time to a much wider global initiative, the Group on Earth Observations Biodiversity Observation Network (GEO BON), which itself is a part of the Group of Earth Observation System of Systems (GEOSS). EU BON will build on existing infrastructures such as GBIF, LifeWatch and national biodiversity data centres in Europe and will integrate relevant biodiversity data from on-ground observations to remote sensing information, covering terrestrial, freshwater and marine habitats.

A key feature of EU BON will be the delivery of relevant, fully integrated data to multiple and different stakeholders and end users ranging from local to global levels. Through development and application of new standards and protocols, EU BON will enable greater interoperability of different data layers and systems, provide access to improved analytical tools and services, and will provide better harmonised biodiversity recording and monitoring schemes from citizen science efforts to long-term research programs to mainstream future data collecting. Furthermore EU BON will support biodiversity science-policy interfaces, facilitate political decisions for sound environmental management, and help to conserve biodiversity for human well-being at different levels, ranging from communal park management to the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). Additionally, the project will strengthen European capacities and infrastructures for environmental information management and sustainable development. The following paper outlines the framework and the approach that are pursued.

Keywords

Biodiversity information, biodiversity observation/recording, monitoring, data interoperability, data management, biodiversity portal, earth observation, informatics infrastructure, bio-repository, GEOSS, GEO BON, science policy, dissemination

Background

The world's biodiversity is in a dramatic decline and in its speed is unprecedented. However, the target to "achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth", formulated in the "2010 biodiversity targets" at different Conferences of Parties (COPs) of the Convention on Biodiversity (CBD), has not been met (Secretariat of the CBD 2010, but see Carvalheiro et al. 2013). The empirical basis for assessing the scale of biodiversity loss remains weak, and a comprehensive global analysis is lacking. A main obstacle in achieving the "2010 biodiversity targets" was the lack of integration of biodiversity information into decisions in sectors other than nature conservation (Mace et al. 2010). Thus, there is a need to acquire the capacity to assess the consequences of a range of political and economic decisions in many different sectors. However, these developments and assessments are limited by our ability to predict the future of biodiversity and its interactions with the anthroposphere. Therefore a wide range of different scenarios are required in order to improve the decision making capacity of those responsible for sound adaptive management of terrestrial, freshwater and marine ecosystems, as well as the sustainable governance of our planet's natural resources. For this purpose, scenarios need a sound scientific knowledge basis that is reliable, relevant, up-to-date, readily accessible and understandable. Only then will it be possible to achieve the five strategic goals of the "Strategic Plan for Biodiversity 2011–2020" and the Aichi targets for 2020 formulated therein.

All five strategic goals and the underlying twenty targets are important. The development of EU BON is directly linked to the target that states "By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied." (target 19 under strategic goal E; see http://www.cbd.int/sp/targets/). While a large quantity of biodiversity data have already been gathered, access to it remains difficult as it is often distributed in fragmented and heterogeneous datasets. Data are scattered across countries and continents with many differences due to countries' specific traditions and societal frameworks (Amano and Sutherland 2013; Vandzinskaite et al. 2010). Furthermore, there is often a heavy bias towards easily recognisable and high profile taxa. Research methodologies and monitoring schemes are largely conducted by different independent communities who rarely share concepts, data or infrastructure (Schmeller 2008, Schmeller et al. 2009, 2012). To meet Aichi target 19, the available biodiversity data needs to be reorganised in a Big Data platform, which allows sharing and easy transfer of the vast amount of biodiversity data collected in Europe each year (Schmeller 2008).

This Aichi target was motivated by the growing demand to provide readily accessible data that can be integrated and analysed to support political decisions (cf. Hardisty et al. 2013). This demand was first addressed by the Group on Earth Observations (GEO) and resulted in the idea of establishing GEOSS (Global Earth Observation System of Systems), with a focus on providing information on nine areas of social benefits (disaster, health, energy, climate, water, weather, ecosystems, agriculture and biodiversity; http://www.earthobservations.org/geoss.shtml). The GEOSS biodiversity monitoring platform is organised through GEO BON (Group on Earth Observations – Biodiversity Observation Network; e.g. see Pereira et al. 2010, Scholes et al. 2008, 2012). Europe has high quality data as well as substantial capacities to contribute to such a platform (Schmeller 2008). Since 2005, the European Commission has invested in several large scale projects with that objective. Examples include the quest for a better understanding of the monitoring landscape in Europe (EuMon; Schmeller 2008), the development of a European Biodiversity Observation network with a focus on terrestrial habitat and ecosystem monitoring (EBONE; Halada et al. 2009) and a European contribution to GEOSS, which addressed interdisciplinary interoperability in three strategic areas (biodiversity, drought, forestry) (EuroGEOSS; Vaccari et al. 2012) and, most recently the successor of EBONE, to further build the European contribution towards a global Biodiversity Observation Network (EU BON; this paper).

The main aims of EU BON are to follow up the requirements set by GEO BON, while building on the groundwork set by the above mentioned projects, mainly following the footsteps of EBONE (see http://www.wageningenur.nl/ebone). To achieve this aim, a large collaborative network has been assembled with contributions from 30 institutions including research institutes, small companies (SMEs) and NGOs from 15 European countries, Israel, Brazil and the Philippines (see Figure 1), with the intention to subsequently involve additional associated partners around the world. The 4.5 year EU BON project period, which commenced in December 2012, is supported by the European Commission under the Seventh Framework Programme (FP7). Further details and updates can be found on the project's website at http://www.eubon.eu.

Additionally, the question arises how the above mentioned data and results are best presented to science, policy and the broader society (see discussion "Connecting policy, models and data" later in the paper. A more detailed discussion and results from a first workshop are presented separately (Vohland et al. in review).

What is needed to link science and conservation policy?

Networking for biodiversity science and conservation policy can occur at two main levels that need integration: (1) a science-based social network, comprising and linking the communities of practice engaged in collecting, managing, analysing, and using biodiversity data, and (2) a physical network of interoperating IT infrastructures and systems that store and distribute information of all kinds held by multiple organisations and partners, providing a platform for data analysis and interpretation. For resource efficiency, the establishment of EU BON is built on existing infrastructures and efforts to integrate monitoring schemes and their data across Europe and internationally, in particular the Global Biodiversity Information Facility (GBIF). In supporting GEO BON, EU BON has the specific objectives:

- Advance the technological and informatics infrastructures in close collaboration with GEO BON, by moving existing biodiversity networks towards standards-based, service-oriented approaches, enabling full interoperability through the "GEOSS Common Infrastructure".
- Increase data mobilisation and data publishing via scientific communities, citizen scientists and potential data users.
- Enhance our knowledge of biodiversity, biological resources, related habitat and environmental characteristics (e.g. measured via remote sensing), for Europe, and beyond, by integrating, harmonising and mainstreaming data and identifying current knowledge gaps.
- Improve the range and quality of methods and tools for assessment and analysis, as well as visualisation of biodiversity and ecosystem information, focussing particularly on predictive modelling, identification of drivers of change, biodiversity indicators, and supporting priority setting.
- Provide mechanisms for delivering integrated biodiversity information to EU member states, other governments, and sectoral stakeholders to support their reporting obligations under the CBD, the Nature Directives as well as other international conventions and mechanisms.

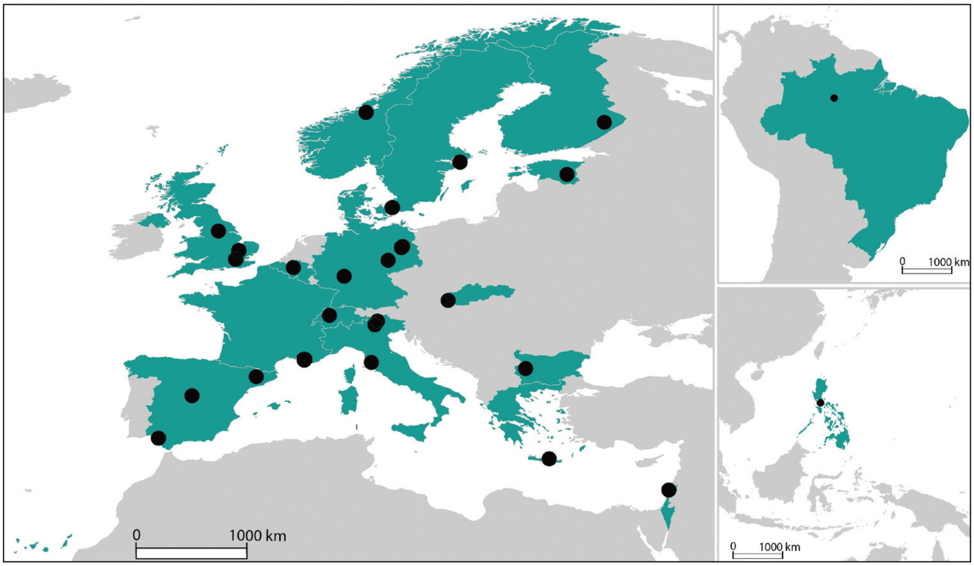

Figure 1. Geographic representation of the countries, where black dots on the map indicate the location of the EU BON partners (see http://www.eubon.eu for more details).

- Develop frameworks and strategies for future generations, management, and use of integrated biodiversity information at national and regional levels (towards full implementation of the GEO BON plan); this supports the science policy interface, in particular, for IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services) and existing national reporting obligations to European policies and international conventions.
- Design concepts to sustain future integrated environmental information systems, including active participation by citizen science as well as business and industry, thereby strengthening European capacities and infrastructures.

In addressing these objectives, EU BON directly engages with researchers, policy and other relevant stakeholders as end users of integrated biodiversity information. EU BON's main deliverables will be made available via a comprehensive "European Biodiversity Portal" designed to satisfy the data and information requirements of the different stakeholder communities, as well as through strategies allowing for a global implementation of GEO BON.

The research approach

The work programme of EU BON has been developed to advance social as well as scientific networks, and to provide at each step valuable products which serve the broader community. In a first step, a gap analysis on available data sources is being

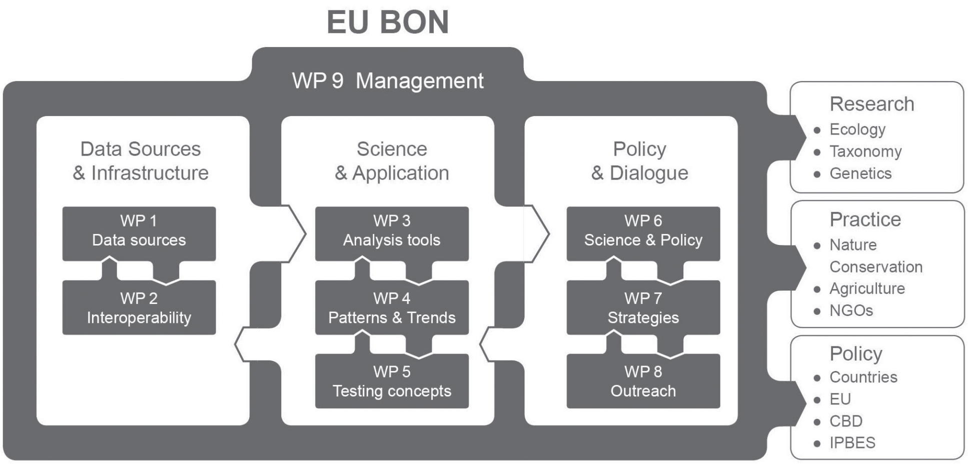

Figure 2. Structure and work flow within the EU BON project.

performed and strong efforts are being directed at mobilising fragmented or hidden but valuable biodiversity data. The interoperability between the different resources is being enhanced, and tools for interpretation, modelling and visualisation developed and applied at the global scale to identify the main drivers. A key for transformation of this concept into practical applications are the EU BON testing sites which provide additional scientific information and serve as a reality check for the EU BON tools. Last but not least, the progress and development direction of the project is being continually discussed with different stakeholder groups addressing different scales, in order to play a fundamental role in GEO BON and IPBES. The EU BON work programme has been structured along nine themes (see Figure 2).

Gap analysis and mobilisation of fragmented data sources

Biodiversity data are demanding to gather, manage, and analyse because: i) they include many different types of data; ii) the amount of data is large; iii) relevant data sources are still largely fragmented and coverage is often incomplete. Relevant data types include remote sensing data and products such as land cover, habitat information as well as land use intensity, water quality estimates and climate proxies (cf. BIO_SOS project, www.biosos.eu); taxonomic backbone data including nomenclatural information; genetic sequences and genomics data; observation and monitoring data or specific organisms or taxa; ecological data; data from bio-repositories, and species profile data (e.g. functional traits, conservation status, distribution, abundance data, invasiveness). The amount of biodiversity data is rapidly expanding not only with innovations in genome sequencing technologies but also with new tools for efficient field recording becoming available (Eymann et al. 2010) or different techniques in the realm of remote sensing. Therefore biodiversity data has to be regarded as Big Data, which requires flexible information systems (Marx 2013). For example, The European Bioinformatics Institute, one of the world's largest biology-data repositories, currently stores 20 petabytes of data (Boyle 2013). Another challenge for managing biodiversity data, particularly from meta-genomics, is the traditional classification of individuals into unique entities called species. All trait or associated biodiversity data are anchored to these species. Over time, however, one species can split into many species, and there are also cases that two or more species can be lumped together. In addition, there are also competing taxonomic concepts for many organisms, for example if one study supports single species but another study endorses two species. Solutions for this challenge are available. Kõljalg et al. (2013) for example suggest means for managing multiple species hypotheses (and associated data) that change in time and space.

The structural complexity of biodiversity data and the collection process itself are some of the reasons why important data sources are still fragmented and nearly every data type and every monitoring organisation has developed its own information system. EU BON will assess and generate a gap analysis of different data types and make recommendations as well as working examples for future integrated biodiversity mobilisation policies. The project will provide solutions for the storing and managing of selected biodiversity data types such as taxonomic backbone data, data generated by bio-repositories, species profile data, and citizen-science based data.

Integration and interoperability of data

EU BON will develop recommendations for data integration and interoperability. Starting from the previous work done on-ground by GEO BON (Ó Tuama et al. 2010), GBIF (Hobern et al. 2013) and for remotely sensed data by BIO_SOS, MS.MONINA (www.ms-monina.eu/), and the EAGLE working group (Blonda et al. 2013) it will address the heterogeneity of data types, projects and networks by designing the information architecture for EU BON. Furthermore, the project reviews state-of-the-art needs for improvement of current data standards and will make recommendations for their use. Tools for data sharing will be developed and an information hub, the European Biodiversity Portal (EBP), backed by a registry and metadata catalogue, will be developed for unified and easy access to data, services and analyses provided by the network. The EBP will serve as a gateway to the different data layers and individual data sets. It will be designed to facilitate access to relevant information and analyses for various stakeholders and decision makers on different political and spatial levels. The EU BON architecture will need to be linked closely to the existing European infrastructures such as LifeWatch (Hernández-Ernst et al. 2009), GBIF, LTER and related networks in other parts of the world. Therefore, an international informatics task force has been invited to advise the EU BON project. The key question of how a user-friendly interface for those myriads of data sources and services that exist in Europe and across the globe can be combined with the GEOSS Common Infrastructure will need to be explored in detail. Selected priority use cases from the wider GEO BON community will guide this work. To reach all the different potential users, a helpdesk will be established and a comprehensive training programme developed. It will include in addition to the usual functions, an applications and documentation repository.

Improving tools and methods for data analysis and interface

One important barrier to global biodiversity assessment is the shortage of appropriate analytical tools, and poor accessibility for non-specialist users of those tools that have been developed. Tools and methods for analysing biodiversity monitoring data will be improved and an interface developed to assure the best possible presentation of biodiversity data. EU BON will implement new and existing tools and methods in accessible software packages to make them more widely available to non-specialist users. Remote sensing data provide an important source of habitat information that may improve biodiversity assessment and modelling, yet such data are typically used in isolation, allowing only very coarse categorisation. The EU BON project will help to develop and promulgate recent advancements in interpretation and classification methods (e.g. learning and random forest algorithms, multi-scale methods; cf. Bradter et al. 2011). The project will also help to improve access to novel techniques for downscaling species' distributional information (Azaele et al. 2012) and upscaling biodiversity data, two key challenges in the application of biodiversity datasets in conservation planning. We also work on developing enhanced species distribution models, also called environmental niche models, to better incorporate information on spatial patterning (Keil et al. 2013). We also help in the development of tools to mine biodiversity data directly from the published literature, thus making it easier and faster to access new species records.

Linking biodiversity trends to natural and anthropogenic drivers

A key prerequisite for sustainable management and conservation of biodiversity is a good understanding of how natural and anthropogenic drivers determine spatial and temporal trends of biodiversity. Drivers as well as biodiversity patterns and trends strongly depend on the scale of the analysis even for the same dataset (e.g. Keil et al. 2012, Kühn and Klotz 2007, Tzanopoulos et al. 2013), providing major challenges for understanding the effects of drivers on biodiversity. Through the rapidly advancement of remote sensing capabilities, as well as new analytical techniques to interpret and transform digital data, a wealth of pertinent information has become available that is not yet fully used and integrated with on-ground data (e.g. Rocchini et al. 2011, Blonda et al. 2013, Nagendra et al. 2013).

The outcomes of traditional species distribution models yield substantial uncertainty originating from various ecological processes and ignorance of the diversity of life-history patterns. In EU BON, we aim at implementing methods to quantify uncertainties propagated as a result of using different sources and modules of models. An important recent advance is the development of dynamic simulation modelling approaches explicitly including ecological processes (e.g. Bocedi et al. 2012). Furthermore, new approaches exist to incorporate species interactions into species distribution models (Kissling et al. 2012, Schurr et al. 2012, Wisz et al. 2013). EU BON builds on these advances to make projections of possible future trends in both populations and distributions for real species in real landscapes. Even with improved models, predictions still depend on the availability of monitoring data which is spatially highly heterogeneous. Despite considerable advances in the theory and practice of optimal spatial sampling (e.g. Braunisch and Suchant 2010, Lin et al. 2008), trade-offs between optimal spatial and optimal temporal sampling are not yet completely resolved. The advances for habitat monitoring achieved by the EBONE project (Brus et al. 2011, Metzger et al. 2013) will be taken up and EU BON will tackle these challenges with new statistical and virtual ecological approaches (Railsback and Grimm 2012).

Testing and validation of concepts, tools, and services

The data integration and analytical work undertaken in EU BON are applied to real, on ground situations, as it is important to validate the new tools and the results gained and apply to actual, smaller-scale levels. So far, three European test sites for the envisioned results are part of EU BON: Doñana Biological Reserve (Spain), LTER Rhine-Main Observatory (Germany) and Amvrakikos Wetlands National Park (Greece). Planned additional sites are the Mercantour National Park (France) and those managed by the Sierra Nevada Observatory (Spain), the Israel National Ecosystem Assessment Program (Israel) and the Fundaçao Amazonica de Defesa da Biosfera/Instituto Nacional de Pesquisas da Amazonia (Brazil). These sites also provide direct links to the wide range of stakeholders involved in, and using biodiversity information, such as agriculture, forestry, and tourism. Based on the experiences with the test sites, a strategy for long-term monitoring and observatory data harmonisation will be developed including a business plan for obtaining and managing the necessary financial and other resources.

As a Biodiversity Observation Network (BON) needs to inform policy, a successful development will need to understand the expectations and needs of policymakers. Therefore, four work packages of the project engage in science policy dialogue (mainly IPBES), the implementation of EU BON in the global biodiversity observation network (GEO BON), general outreach and the dissemination of results, and the management of the project including its linking to other EU initiatives and projects, such as LifeWatch.

Connecting policy, models and data

Currently, for biodiversity there is typically a mismatch between the knowledge requirements of policy makers and the information available to them (Sutherland et al. 2011).

There seems to be also a data quality problem in common reports (ETC 2008). This can lead to both less efficient policy-making and to reduced political support for science if the outcomes are not perceived as useful. There are a host of reasons for this mismatch, including a lack of horizon scanning to identify future issues, a failure to identify critical issues for monitoring and research, and a gap between the manner in which biodiversity information is presented and how it is required. It is obviously important that any biodiversity programme considers how it could be used and how it can be most efficient in aiding practice and policy making.

Identifying the use of research and policy issues and their attempted resolution will show what has been effective in the past. The information needs of the policy makers require to be identified and connected to the required monitoring activities (see Vohland et al. in review). Anticipating the possible policy responses to actions in a changing world, including developments such as artificial life, nanotechnology and geo-engineering is challenging. It is an ambitious but important objective to achieve the integration of all stages in the process, including monitoring, research, modelling, dissemination and policy development. We see this as providing monitoring help to improve the rigour of assessments such as IPBES and CBD (Sutherland 2013).

Implementation of GEO BON: strategies and solutions at European and global levels

As EU BON is intended to be a major contribution to GEO BON, it is necessary to closely link the EU BON work with the GEO BON agenda and also to provide an outlook and refine the GEO BON goals, especially at the policy science interface. Within EU BON we will formulate recommendations for all aspects covered in EU BON on national, regional and global levels with a special focus on monitoring schemes and biodiversity information structures. Outputs of EU BON are also expected to contribute to the work of IPBES, on reducing or even halting the global loss of biodiversity through provision of sound information on the current status as well as future trends of biodiversity. IPBES was established following a gap analysis of the Environmental Programme of the United Nations (UNEP) (UNEP 2010) and the last Conference of the Parties (COP 11) of the Convention of Biological Diversity (CBD). EU BON therefore engages on a more global level in science policy dialogue and by that also contributes to the fulfilment of the European obligations following the CBD and IPBES. EU BON also evaluates possible paths for a European or global BON business plan to assure persistence of large-scale biodiversity observation networks and infrastructures.

Dissemination and outreach

The goals and objectives of EU BON are ambitious and can only be achieved with outstanding engagement in both dissemination and outreach. Project partners are expected to put considerable efforts into communicating the outcomes of their scientific work. As funding comes from EU taxpayers, letting the public know how this money is spent is an obvious obligation of every FP7 project (European Commission 2012a). However, most of the publicly-funded research results that exist in the form of data are still not made available for others, which makes the investment highly inefficient (European Commission 2012b). With the aim of ensuring that communication and dissemination are properly developed, implemented and managed throughout the project lifetime, EU BON is developing a comprehensive communication strategy, so that the EU BON brand will be widely recognised and its results and achievements reach a broad audience across different stakeholder levels, including policy, administration, conservation managers, scientists, journalists and the general public. This "Communication and Dissemination Strategy" will be of foremost importance for the success of the project.

Furthermore, we will work on a comprehensive data publishing, citation and usage strategy, including IPR and license issues. Special efforts will also be put into a novel peer review strategy for publishing research data. As a basic dissemination principle, EU BON has adopted open access and multi-targeted popularisation of outputs, to comply with the decision of the Council of Europe recognising "the strategic importance for Europe's scientific development of open access to scientific information" and the European Commission's communication and recommendation to the member states that they should aim at improving the access to scientific information produced in Europe. "The open access to scientific research data enhances data quality, reduces the need for duplication of research, speeds up scientific progress and helps to combat scientific fraud." (European Commission 2012c).

The core output will be the development of a fully integrated data publishing and dissemination toolbox helping data providers to find the best way to publish differently structured biodiversity data. It will also integrate workflows between data journals and the leading aggregators and repositories, such as GEO BON, the Biodiversity Information System for Europe (BISE) run by the European Environment Agency (EEA), GBIF, Scratchpads, the International Nucleotide Sequence Databases Consortium (GenBank, ENA, DDBJ) and others.

Summary and vision for the future

The main impact from EU BON will be through increased interoperability and mobilisation of data and systems through adoption of new standards and technologies, towards the development of strategies for future harmonisation and mainstreaming of biodiversity recording and monitoring, and strengthened European capacities and infrastructures by providing a comprehensive "European Biodiversity Portal" for all stakeholder communities. In addition, public awareness of biodiversity, one of the prominent targets of the CBD Strategic Plan for Biodiversity 2011–2020, as well as of many national biodiversity plans, will be increased. The implementation and further enhancement of analytical methods and visualisation and interpretation tools will provide completely new insights on biodiversity and will strengthen the usefulness of the available information which then can be used for sound political decisions to help safeguard biodiversity in the future. In this way, GEO BON will emerge as the integrating network of networks, as foreseen in the GEO BON Concept Document (http://www.earthobservations.org/geobon.shtml). There will be increased intention to see that various networks and projects pursue the same aim and to share and use biodiversity data freely across borders and regions.

Recently, GEO BON set the goal to achieve an operational system by 2015, the year when GEOSS's 10-year implementation plan comes to an end. The Essential Biodiversity Variables (EBV) as proposed by GEO BON (Pereira et al. 2013) will help to focus what is meant by "operational". The use case that EU BON and GEO BON will jointly work on is making EBVs operational by streamlining and automating the data flows from the many disparate biodiversity observation systems towards EBVs, and further to useful indicators (Figure 3). Our vision for the EU BON Portal is that it will act as a window to facilitate looking into all these observation systems, how data flows are working and possibly showing how the "Shared Environmental Information System" (SEIS) of the EU (cf. Hřebíček and Pillmann 2009) works for biodiversity.

In conclusion, EU BON will use its potential to change the interrelation between citizens, science and policy for biodiversity. Decision makers at different levels will be able to make use of biodiversity information adapted to their specific requirements. Disparate and unconnected databases will be integrated to allow monitoring and evaluation of measures at different spatial and temporal scales. This requires strong efforts

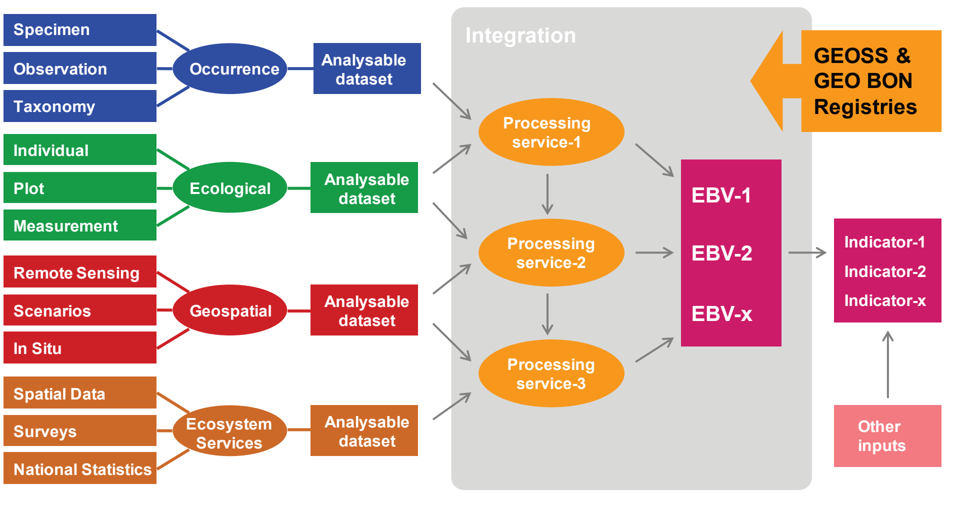

Figure 3. EU BON will be implementing the GEO BON vision of automated, streamlined data flow, end-to-end, from observations to Essential Biodiversity Variables (EBV), using a plug-and-play service-oriented approach, coordinated through the GEO BON registry system and linked to the GEOSS Common Infrastructure, and transparent to users through portals.

not only in regard to technical harmonisation between databases, models and visualisation tools, but also in the dialogue with the associated social networks, spanning a variety of scientific as well as civil science organisations.

Acknowledgements

The EU BON project is funded by the European Commission (EC) under the 7th Framework Programme (contract no. 308454). This publication reflects the views of the authors, and the EC cannot be held responsible for any use which may be made of the information contained therein. The authors gratefully further acknowledge the support from their respective institutions, and many individual colleagues involved in the project and its preparations.

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