


POLICY PERSPECTIVES

License to Kill?—Disease Eradication Programs May Not be in Line with the Convention on Biological Diversity

Axel Hochkirch^{1,2} , Joscha Beninde¹, Marietta Fischer¹, André Krahnert¹, Cosima Lindemann¹, Daniela Matenaar^{1,3,4}, Katja Rohde¹, Norman Wagner¹, Charlotte Wesch¹, Sarah Wirtz¹, Andreas Zink⁵, Stefan Lötters¹, Thomas Schmitt^{1,6,7}, Alexander Proelss⁵, & Michael Veith¹

¹ Department of Biogeography, Trier University, 54286 Trier, Germany

² IUCN SSC Invertebrate Conservation Subcommittee, Department of Biogeography, Trier University, 54286 Trier, Germany

³ Stuttgart State Museum of Natural History, Department of Entomology, Rosenstein 1, 70191 Stuttgart, Germany

⁴ Hessisches Landesmuseum Darmstadt, Friedensplatz 1, 64283 Darmstadt, Germany

⁵ Institute for Environmental and Technology Law, Trier University, 54286 Trier, Germany

⁶ Senckenberg German Entomological Institute, 15374 Müncheberg, Germany

⁷ Entomology, Department of Zoology, Institute of Biology, Martin Luther University Halle-Wittenberg, 06099 (Halle) Saale, Germany

Keywords

Eradication; insect conservation; wetland conservation; biodiversity hotspots; conservation value.

Correspondence

Axel Hochkirch, Department of Biogeography, Trier University, 54286 Trier, Germany.
Tel: +49-651-201-4692, fax: +49-651-201-3851
E-mail: hochkirch@uni-trier.de

Received

11 October 2016

Accepted

23 April 2017

All authors are members of the interdisciplinary graduate school “Cooperation of Science and Jurisprudence in Improving Development and Use of Standards for Environmental Protection—Strategies for Risk Assessment and Management”

doi: 10.1111/conl.12370

Introduction

Halting the loss of biodiversity is a major challenge agreed upon in the Convention on Biological Diversity (CBD). However, in contrast to subsequent efforts in species conservation, other programs aim for the exact opposite—the eradication of species considered as harmful. Considering the appalling consequences of several diseases, it is completely understandable that eradication programs for several pathogens have been developed. The plans to eradicate malaria have already led to a drastic decline in malaria deaths (48% from 2000 to 2015; WHO 2016a).

Abstract

Global human population growth is associated with many problems, such as food and water provision, political conflicts, spread of diseases, and environmental destruction. The mitigation of these problems is mirrored in several global conventions and programs, some of which, however, are conflicting. Here, we discuss the conflicts between biodiversity conservation and disease eradication. Numerous health programs aim at eradicating pathogens, and many focus on the eradication of vectors, such as mosquitos or other parasites. As a case study, we focus on the “Pan African Tsetse and Trypanosomiasis Eradication Campaign,” which aims at eradicating a pathogen (*Trypanosoma*) as well as its vector, the entire group of tsetse flies (Glossinidae). As the distribution of tsetse flies largely overlaps with the African hotspots of freshwater biodiversity, we argue for a strong consideration of environmental issues when applying vector control measures, especially the aerial applications of insecticides. Furthermore, we want to stimulate discussions on the value of species and whether full eradication of a pathogen or vector is justified at all. Finally, we call for a stronger harmonization of international conventions. Proper environmental impact assessments need to be conducted before control or eradication programs are carried out to minimize negative effects on biodiversity.

Similarly, the recent spread of the Zika virus (Fauci & Morens 2016) has prompted massive efforts to control its vector, *Aedes* mosquitoes (WHO 2016b). Some eradication programs are at an advanced stage, such as the Guinea Worm Eradication Program (Enserink 2014), which has led to a decline of Guinea worm (*Dracunculus medinensis*) infections by 99.99% since 1986 (Carter Center 2016). However, these eradication programs raise manifold ethical and legal concerns. Key questions in this context are: What determines the value of species and which legal instruments provide the basis to depart from conservation and turn toward eradication?

Is there any threshold of impact a species must pass to fall under the human verdict of eradication? And, are there environmentally more friendly methods available to successfully control a vector or disease without eradicating it?

A particularly well-suited program to explore the potential effects of eradications is the “Pan African Tsetse and Trypanosomiasis Eradication Campaign” (PATTEC), because it focuses on the extirpation of a complete insect family within its native range. This program aims at “eradicating the tsetse fly and trypanosomiasis from Africa within the shortest time possible” (OAU 2001; Brun *et al.* 2010), given significant impacts on human health (Human African Trypanosomiasis [HAT]) and livestock (African Animal Trypanosomiasis [AAT]). HAT is usually fatal if untreated (Jamonneau *et al.* 2012) and has caused about 9,000 deaths in 2010 (Lozano *et al.* 2012), a number that is continuously declining due to the control measures with 2804 recorded cases in 2015. Unfortunately, the antigenic variation of the pathogen *Trypanosoma* (Morrison *et al.* 2009) renders it difficult to tackle. The eradication strategy thus differs fundamentally from many other disease mitigation programs by focusing on the eradication of the vector rather than on the pathogen itself (Esterhuizen *et al.* 2011). However, tsetse flies represent a unique insect family (Glossinidae) and genus (*Glossina*) with 33 recognized species and subspecies occurring across the complete African savannah and rainforest biomes (Gooding & Krafus 2005). Consequently, PATTEC targets a complete group of insects with a unique evolutionary history. For controlling tsetse flies, the WHO particularly recommends the Sequential Aerosol spraying Technique (SAT), which has already been applied successfully in Botswana, Namibia, and Ghana (Adam *et al.* 2013). Aerial applications of insecticides are largely untargeted and known to cause significant collateral damages on nontarget species (Hoang & Rand 2015; Walker *et al.* 2016). However, other techniques have also been applied, including the use of odor-baited targets or cattle dips that are more specific and can be used to control isolated populations (Grant 2001; Hargrove 2003) or the Sterile Insect Technique (SIT) that has been successfully applied on Zanzibar (Vreysen *et al.* 2000).

Is there an ethical or legal basis for the eradication of biological diversity?

The PATTEC program illustrates a negative extreme of anthropocentric valuation of species, as human pathogens and their vectors are generally perceived as “ecosystem disservices” (Dunn 2010), with detrimental

impact on human well-being (in this case, negative consequences for human health). However, organisms are valued by humans based upon several different criteria (Sandler 2010,2012), including instrumental values (i.e., their usefulness to human beings, e.g., economic value, medical value, option value), ecological values (i.e., their function in the ecosystem), or their ethical values (e.g., beauty, uniqueness, rarity). They can be arranged on a continuous scale of valuation, roughly speaking ranging from human pathogens and their vectors across animal and livestock pathogens, parasites, pests and plant pathogens, competitors for food or other resources (e.g., piscivorous animals), species without an instrumental value (e.g., many herbivorous insects) to species positively valued for providing “ecosystem services” (e.g., pollinators, decomposers, crop species), or species appreciated for subjective reasons, such as the charismatic flagships of conservation (e.g., large mammals). Evidently, some species may fall into more than one category, such as butterflies that may be pests as caterpillars but valued for their beauty as adults. Conservation efforts increase along this continuum of valuation, but for ethical reasons, we advocate that it must be questioned whether negative valuation of species alone provides a sufficient argument for promoting eradication efforts. An intrinsic value (or rather an inherent worth independent of a value) is an important historical and ethical background of nature conservation, which means that each species may have a right to exist, independent of its value to human being (Rolston III 1995).

The CBD grants protection to all biodiversity, which it defines as “diversity within species, between species and of ecosystems” (Article 2 Paragraph 1) and does not per se value species differentially. Nevertheless, in its preamble the CBD highlights that different values are acknowledged, including the intrinsic value as well as ecological, genetic, social, economic, scientific, educational, cultural, recreational, and esthetic values. If, however, an intrinsic value was attributed to all species on earth, the eradication of a complete insect family, and even of a pathogen species, would not be justifiable. The acceptance of such an intrinsic value, which is based upon a biocentric philosophy, is even illustrated in the United Nations World Charter for Nature (1982) which states that “every form of life is unique, warranting respect regardless of its worth to man.” In contrast to this view of a general value of all biodiversity, the CBD asks contracting parties to “identify components of biological diversity important for its conservation and sustainable use” and provides guidance for prioritization in Annex I: “species and communities which are: threatened; wild relatives of domesticated or cultivated species; of medicinal, agricultural or other economic value; or social, scientific or cultural importance;

or importance for research into the conservation and sustainable use of biological diversity, such as indicator species.”

Glossina (or *Trypanosoma*) are unlikely to fall into any of these categories, although one may debate their scientific importance. With pursuit of the eradication program, it is unavoidable (and in fact the declared objective of PATTEC) that the genus becomes threatened with extinction, which in turn would make it eligible for conservation action. The CBD certainly did not anticipate such a case. Nonetheless, Article 8(h) justifies eradications, albeit only for conservation purposes, when it calls to “prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species” (see also Conference of the Parties [COP] 6 Decision VI/23). Under this premise, the eradication of *Aedes aegypti* in South America (which transmits the Zika virus) is justifiable, as this mosquito is not native here. However, the eradication of *Glossina* takes place within its native range, which means that PATTEC is not in line with the CBD.

Due to the detrimental impact on human health, the *Glossina* (and *Trypanosoma*) control certainly benefits human well-being by eliminating the detrimental impact of HAT, but not all *Glossina* eradication programs are carried out for mitigating human pathogens. In Ghana, for example, HAT is not a major health problem (Simarro *et al.* 2012) and the eradication of the tsetse fly aims at eliminating AAT, which negatively affects human livelihoods and food security through the loss of livestock (Adam *et al.* 2013). This raises the question if it is possible to define a border up to which eradications of species are justified and where it should be placed. Is eradication justified at all, only if human beings are directly affected (i.e., through disease) or also if they are indirectly affected (i.e., through food supply or for economic reasons)? Should eradication just be carried out for the pathogen or also for the vector?

Coextinction caused by eradication programs

Next to the direct impact on the target species, environmental impacts on nontarget species have to be considered. SAT is currently a recommended method to eradicate tsetse flies (WHO 2013) and the use of deltamethrin aerosols has been applied successfully in several regions (Adam *et al.* 2013). However, such pyrethroid insecticides are not specific and affect virtually all insect species in treated areas. Even negative effects on vertebrates have been reported (Sayeed *et al.* 2003; Junges *et al.* 2017). As tsetse flies are found in various habitats, including wetlands, forests, and wooded savannahs, many other

insect species are likely to become threatened by large-scale insecticide treatments. A monitoring study ensuing the tsetse fly eradication campaign in the Okavango Delta in Botswana showed that ca. 10% of arthropod species disappear after SAT treatment (Perkins & Ramberg 2004), with the degree of loss among rare species remaining uncertain. A problem with many monitoring programs accompanied to such control measures is that identification is often not taken to species level and that no long-term studies are conducted (Ramberg *et al.* 2006). These results are alarming because centers of endemism and species richness will be affected by the tsetse fly eradication, given the high overlap of the tsetse fly distribution with the African hotspots of biodiversity (Figure 1). Organisms affected by SAT will certainly include endemic species that could thereby become highly threatened, as well as organisms providing valuable ecosystem services. However, coextinctions of threatened invertebrates caused by pest control or eradication is so far not sufficiently studied.

Hence, concerns arise that the fight against ecosystem disservices severely affects biodiversity and compromises ecosystem services due to negative effects on both targeted and untargeted biodiversity. Even if there was societal consensus on the eradication of *Trypanosoma* (which we fully acknowledge given its detrimental impact), the methods applied must be as environmentally friendly as possible. In this context, it is striking that the WHO malaria eradication strategy differs fundamentally from the trypanosomiasis eradication program, possibly as a consequence of the negative experience made with the large-scale DDT treatments in the 1960s. Insecticide-treated mosquito nets and indoor residual spraying are the dominating vector control measures for malaria, whereas larvicide application is recommended only under very specific circumstances and following environmental impact assessments (WHO 2012). Furthermore, the malaria eradication has a much stronger focus on the pathogen itself (Maxmen 2013). At a first glance, some less harmful alternatives appear to be available also for tsetse fly control, such as the SIT, which was successfully applied in Zanzibar (Vreysen *et al.* 2000). As female tsetse flies only mate once during their lifetime, the release of millions of sterile males led to a complete elimination within two years. However, SIT is less effective than insecticide-based methods (Vale & Torr 2005). Furthermore, it is costly and only effective if the tsetse fly population is already very small (Hargrove 2003). Hence, SAT or other methods are usually applied before SIT is carried out. A novel approach that may help to prevent the extirpation of the vector is the use of gene drive systems that may be used to block the transmission of the pathogen by the insect (Sinkins & Gould 2006) and is explored, for

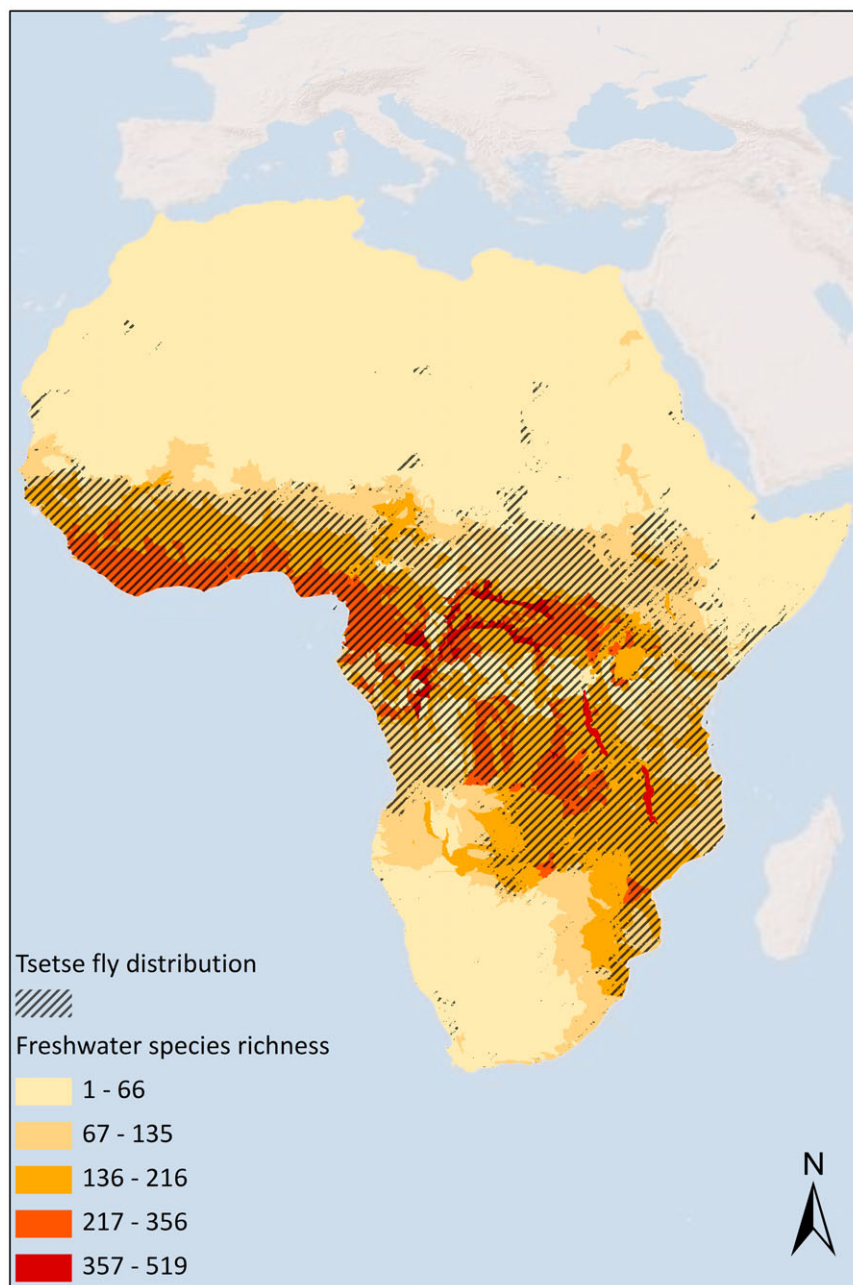


Figure 1 Overlap of the distribution of tsetse flies and freshwater species richness.

The latter is based upon the IUCN Pan-African freshwater assessment (total species numbers for dragonflies, freshwater fishes, and freshwater crabs and crayfishes; IUCN 2014). Information on the distribution of *Glossina* in Africa originates from the PAAT Information System (FAO 2014). The map was created in ArcMap 10 (ESRI).

example, in the “target malaria” program (Banks 2016). This method could further decrease environmental impact by minimizing effects on other organisms, but it still raises the question whether the pathogen itself might possess an intrinsic right to exist as well. Furthermore, the potential side effects of gene drive are so far only

little understood (Piaggio *et al.* 2017). For this reason, the IUCN general assembly has recently adopted a petition to assess the implications of gene drives and related techniques (IUCN 2016a) and the conference of the parties to the CBD in Cancun have established an ad hoc technical expert group on this issue (decision XIII/17). Recent

evidence shows that insect populations can evolve resistance against gene drives (Unckless *et al.* 2017) and thus this method might indeed be only feasible for a very short time in small populations, similar to SIT.

How can we harmonize international conventions?

The conflict between biodiversity conservation on the one hand and the combat against ecosystem disservices on the other requires environmentally balanced solutions. These should preferably be included in and reconciled with the CBD and international treaties of the WHO. Current international legislation does not call for a standardized procedure of tackling such conflicts of interests, which thus have the potential to compromise internationally agreed upon goals, such as Aichi Biodiversity Target 12, to halt biodiversity loss by 2020 (CBD 2011). Article 14(a) of the CBD calls for environmental impact assessments of projects “that are likely to have significant adverse effects on biological diversity with a view to avoiding or minimizing such effects” and Aichi Biodiversity Target 3 calls for the elimination of incentives and subsidies harmful to biodiversity and minimizing or avoiding negative impacts (CBD 2011). Therefore, it will be important to ensure that proper environmental impact assessments are carried out during the planning phase of disease eradications programs (at the global scale) as well as before disease or pest control measures are conducted (at the local scale). At the local scale, this means that adequate inventories (i.e., to species level) need to be established and sensitive species or areas as well as priority species for conservation need to be identified before any control measures are carried out. While this may not be feasible for the complete fauna, it should at least be done for some major bioindicator groups (including invertebrates). The risk to coextirpate a species needs to be assessed based upon its vulnerability (the IUCN Red List criteria provide useful guidance to assess extinction risk). Furthermore, monitoring must also consider the long-term effects of control measures. As a first step, inventories may be repeated in areas that have already been studied before and soon after SAT treatment. For global eradication programs, it will be important to identify Key Biodiversity Areas (IUCN 2016b) in which particular care and a comprehensive monitoring must be undertaken.

Finally, a fundamental and broad discussion on the valuation of nature as a whole is needed. In this context, we must ask: Do we only want to preserve our closest relatives and those species which provide ecosystem services, or do we want to preserve biodiversity regardless of its

value to humankind? If we agree on the latter, we need to acknowledge that conflicts between disease mitigation and biodiversity conservation exist. A simplified view that biodiversity conservation generally benefits disease mitigation (Johnson *et al.* 2013) will not help to solve this conflict. As a consequence, a thorough strategy to harmonize the CBD and the Aichi Biodiversity Targets with global health programs is urgently needed and must be addressed in a combined effort of science, philosophy, and jurisprudence, for example, during the COP to the CBD.

Acknowledgments

The authors were funded by the German Science Foundation (DFG, GRK 1319). We thank Mike Hoffman (IUCN Red List Committee) for providing the necessary data for compiling Figure 1. Furthermore, we are grateful for the input by J.W. Hargrove as well as anonymous reviewers of the manuscript.

References

- Adam, Y., Cecchi, G., Kgori, P.M., *et al.* (2013). The sequential aerosol technique: a major component in an integrated strategy of intervention against riverine tsetse in Ghana. *PLoS. Negl. Trop. Dis.*, **7**, e2135.
- Banks, J. (2016). Target Malaria has a killer in its sights. *IEEE Pulse*, **7**, 30-33.
- Brun, R., Blum, J., Chappuis, F. & Burri, C. (2010). Human African trypanosomiasis. *Lancet*, **375**, 148-159.
- Carter Center (2016). Guinea worm eradication program. Atlanta. https://www.cartercenter.org/health/guinea_worm/ (visited Sep. 26, 2016).
- CBD (2011). Aichi biodiversity targets. <http://www.cbd.int/sp/targets/> (visited Nov. 19, 2013).
- Dunn, R.R. (2010). Global mapping of ecosystem disservices: the unspoken reality that nature sometimes kills us. *Biotropica*, **42**, 555-557.
- Enserink, M. (2014). Guinea Worm eradication at risk in South Sudanese War. *Science*, **343**, 236.
- Esterhuizen, J., Rayaisse, J.B., Tirados, I., *et al.* (2011). Improving the cost-effectiveness of visual devices for the control of riverine tsetse flies, the major vectors of human African trypanosomiasis. *PLoS. Negl. Trop. Dis.*, **5**, e1257.
- FAO (2014). PAATMAPS. <http://www.fao.org/ag/againfo/programmes/en/paat/maps.html> (visited Dec. 12, 2013).
- Fauci, A.S. & Morens, D.M. (2016). Zika virus in the Americas - yet another arbovirus threat. *New. Engl. J. Med.*, **374**, 601-604.
- Gooding, R.H. & Krafur, E.S. (2005). Tsetse genetics: contributions to biology, systematics, and control of tsetse flies. *Annu. Rev. Entomol.*, **50**, 101-123.

- Grant, I.F. (2001). Insecticides for tsetse and trypanosomiasis control: is the environmental risk acceptable. *Trends Parasitol.*, **17**, 10-15.
- Hargrove, J. (2003). *Tsetse eradication; sufficiency, necessity and desirability*. DFID Animal Health Programme, Edinburgh, UK.
- Hoang, T.C. & Rand, G.M. (2015). Mosquito control insecticides: a probabilistic ecological risk assessment on drift exposures of naled, dichlorvos (naled metabolite) and permethrin to adult butterflies. *Sci. Total Environ.*, **502**, 252-265.
- IUCN (2014). Pan-Africa freshwater assessment. <http://www.Iucnredlist.Org/initiatives/freshwater/description/data-download> (visited Mar. 31, 2014).
- IUCN (2016a). Development of IUCN policy on biodiversity conservation and synthetic biology. <https://portals.iucn.org/congress/motion/095> (visited Jan. 23, 2017).
- IUCN (2016b). *A global standard for the identification of key biodiversity areas*. IUCN, Gland, Switzerland.
- Jamonneau, V., Ilboudo, H., Kaboré, J., *et al.* (2012). Untreated human infections by *Trypanosoma brucei gambiense* are not 100% fatal. *PLoS. Negl. Trop. Dis.*, **6**, e1691.
- Johnson, P.T.J., Preston, D.L., Hoverman, J.T. & Richgels, K.L.D. (2013). Biodiversity decreases disease through predictable changes in host community competence. *Nature*, **494**, 230-233.
- Junges, C.M., Maglianese, M.I., Lajmanovich, P.M., Peltzer, P.M. & Attadeo, A.M. (2017). Acute toxicity and etho-toxicity of three insecticides used for mosquito control on amphibian tadpoles. *Water Air Soil Poll.*, **228**, 143.
- Lozano, R., Naghavi, M., Foreman, K., *et al.* (2012). Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*, **380**, 2095-2128.
- Maxmen, A. (2013). A race against resistance. *Nature*, **503**, 186-188.
- Morrison, L.J., Marcello, L. & McCulloch, R. (2009). Antigenic variation in the African trypanosome: molecular mechanisms and phenotypic complexity. *Cell Microbiol.*, **11**, 1724-1734.
- OAU (2001). *Pan African tsetse and trypanosomiasis eradication campaign (PATTEC)*. Page 30. OAU (Organisation of African Unity), Addis Ababa, Ethiopia.
- Perkins, J.S. & Ramberg, L. (2004). *Environmental recovery monitoring of tsetse fly spraying impacts in the Okavango Delta – 2003*. Final Report. Harry Oppenheimer Okavango Research Centre, Maun, Botswana.
- Piaggio, A.J., Segelbacher, G., Seddon, P.J., *et al.* (2017). Is it time for synthetic biodiversity conservation? *Trends Ecol. Evol.*, **32**, 97-107.
- Ramberg, L., Hancock, P., Lindholm, M., *et al.* (2006). Species diversity of the Okavango Delta, Botswana. *Aquat. Sci.*, **68**, 310-337.
- Rolston, III H. (1995). Duties to endangered species. *Bioscience*, **35**, 718-726.
- Sandler, R. (2010). The value of species and the ethical foundations of assisted colonization. *Conserv. Biol.*, **24**, 424-431.
- Sandler, R.L. (2012). *The ethics of species - an introduction*. Cambridge University Press, Cambridge.
- Sayeed, I., Parvez, S., Pandey, S., Bin-Hafeez, B., Haque, R. & Raisuddin, S. (2003). Oxidative stress biomarkers of exposure to deltamethrin in freshwater fish, *Channa punctatus* Bloch. *Ecotox. Environ. Safe.*, **56**, 295-301.
- Simarro, P.P., Cecchi, G., Franco, J.R., *et al.* (2012). Estimating and mapping the population at risk of sleeping sickness. *PLoS. Negl. Trop. Dis.*, **6**, e1859.
- Sinkins, S.P. & Gould, F. (2006). Gene drive systems for insect disease vectors. *Nat. Rev. Genet.*, **7**, 427-435.
- Unckless, R.L., Clark, A.G. & Messer, P.W. (2017). Evolution of resistance against CRISPR/Cas9 gene drive. *Genetics*, **205**, 827-841.
- Vale, G.A. & Torr, S.J. (2005). User-friendly models of the costs and efficacy of tsetse control: application to sterilizing and insecticidal techniques. *Med. Vet. Entomol.*, **19**, 293-305.
- Vreysen, M.J.B., Saleh, K.M., Ali, M.Y., *et al.* (2000). *Glossina austeni* (Diptera: Glossinidae) eradicated on the island of Unguja, Zanzibar, using the sterile insect technique. *J. Econ. Entomol.*, **93**, 123-135.
- Walker, P.W., Story, P.G. & Hose, G.C. (2016). Comparative effects of pesticides, fenitrothion and fipronil, applied as ultra-low volume formulations for locust control, on non-target invertebrate assemblages in Mitchell grass plains of south-west Queensland, Australia. *Crop Prot.*, **89**, 38-46.
- WHO (2012). World malaria report. Geneva, Switzerland. http://www.who.int/malaria/publications/world_malaria_report_2012/en/ (visited Nov. 19, 2013).
- WHO (2013). *Human African trypanosomiasis - vector control*. Geneva, Switzerland. http://www.who.int/trypanosomiasis_african/vector_control/en/ (visited Nov. 18, 2013).
- WHO (2016a). Number of malaria deaths. <http://www.who.int/gho/malaria/epidemic/deaths/en/> (visited Sep. 26, 2016).
- WHO (2016b). Vector control operations framework for Zika virus. WHO, Geneva, Switzerland, Pages 1-10. WHO/ZIKV/VC/16.4.