

## POLICY PERSPECTIVE

# Digital Games and Biodiversity Conservation

Chris Sandbrook<sup>1,2</sup>, William M. Adams<sup>2</sup>, & Bruno Monteferri<sup>3</sup>

<sup>1</sup> United Nations Environment Programme World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge, CB3 0DL, UK

<sup>2</sup> Department of Geography, University of Cambridge, Downing Place, Cambridge CB2 3EN, UK

<sup>3</sup> Sociedad Peruana de Derecho Ambiental (SPDA, Peruvian Society for Environmental Law), Prolongación Arenales 437, Lima 27, Perú

### Keywords

Biodiversity; conservation; citizen science; digital games; gamification; serious games; technology.

### Correspondence

Chris Sandbrook, Department of Geography, University of Cambridge, Downing Place, Cambridge, CB2 3EN, UK.

Tel: +44-1223-766574;

fax: +44-1223-333392.

E-mail: [chris.sandbrook@unep-wcmc.org](mailto:chris.sandbrook@unep-wcmc.org)

### Received

11 February 2014

### Accepted

18 May 2014

doi: 10.1111/conl.12113

### Abstract

Digital games play an important role in the lives of millions of people worldwide. The games industry is expanding rapidly, and games are developing in sophistication and complexity. Games (and gaming approaches to other activities) are increasingly being used for serious or social purposes in a wide range of fields, including biodiversity conservation. This paper evaluates the potential of “conservation games” (digital games that promote conservation). It explores ways in which conservation might make use of digital games in the areas of (1) education and behavior change, (2) fundraising, and (3) research, monitoring, and planning. It discusses the risk that games may distract gamers from the real world and its problems or provide misleadingly simple narratives about conservation issues. We conclude that there is great potential for conservation to take more advantage of digital games, provided that conservation games are developed in collaboration with game design specialists, have specific rather than general aims, target a specific and conservation-relevant audience, and (above all) are fun to play.

## Introduction

Digital games are a significant force in contemporary society. Games, “structured activities carried out for pleasure, according to certain written or unwritten rules” (Chatfield 2010, p. 4) are found in all cultures. The structure and rules of games (such as Monopoly) render them distinct from toys (such as a Barbie doll; Alvarez & Djaouti 2010). The development of digital technology in recent decades has opened up new arenas for gaming, resulting in a spectacular growth of digital games and of the devices on which they are played (Alpert 2007). The digital games industry was worth \$42 billion in 2010, and is growing at an annual rate of 10% (Chatfield 2010). Gaming plays an important part in the lives of significant numbers of people across the world. Digital games are diverse and appeal to a wide demographic, defying the stereotype that they involve strong violence and are mostly played by adolescent males.

A growing trend in the gaming industry has been the emergence of “serious games” that make a contribution to addressing real world problems (McGonigal

2010). Games have been designed for training, education, learning, and behavior change in a range of sectors (Annetta 2010), especially in the fields of medicine (Kato 2010) and brain function (Bavelier & Davidson 2013).

Biodiversity conservation is an activity in which changing attitudes and behaviors and promoting learning about nature are established goals. Conservation often involves hard choices, and even conflict (Redpath *et al.* 2012), both of which are rich source material for digital games (Charsky 2010). For these reasons, there may be potential for the sector to benefit from digital games, and potential interest by games designers in conservation issues. In this paper, we discuss the current engagement between biodiversity conservation and digital games, and the potential of what we call “conservation games”; those intended to make a positive contribution to conservation. We begin with a short description of the contemporary gaming landscape. We then detail the opportunities and challenges that games might provide for conservation, before concluding with a set of recommendations for the conservation sector.

## The gaming landscape

Alpert (2007) describes three platforms for digital games: consoles connected to a television (e.g., Sony Playstation), personal computers, and dedicated portable gaming devices (e.g., Nintendo Game Boy). More recently new platforms have emerged, notably mobile “smart” telephones equipped with multiple sensory devices such as cameras, GPS, and accelerometers. These technologies create new opportunities for games, as do motion capture devices that can be used to enhance games consoles (e.g., Microsoft Kinect).

The most basic digital games are single player, two dimensional “casual” games, such as *Candy Crush*.<sup>1</sup> These games are often free or very cheap to buy, and can be played on almost any games platform. The market is expanding rapidly (Chatfield 2010): *Angry Birds* had been downloaded over 1 billion times by May 2012 (Brian 2012). More complex games (e.g., the *Sims* series, *Fifa Soccer*), are usually played on personal computers or games consoles; they are significantly more expensive to buy, and encompass multiple genres, including sports, strategy, action, role-play, and family games (Alpert 2007).

The advent of the internet has altered the digital games landscape by allowing many users to play games together online, making possible Massively Multiplayer Online Role-Playing Games (MMORPGs) with millions of users such as *World of Warcraft*. These are complex environments that can host markets for virtual goods and services that are paid for with virtual or real currency, estimated to be worth billions of dollars in the real world (Pixel-sandpolicy 2010). The multiplayer nature of these games allows them to include a rich social component, fundamentally challenging the earlier assumption that digital games are an isolating and in some sense antisocial activity (McGonigal 2010).

New developments in technology make possible mixed reality games that “are not fully contained by virtual or physical worlds” (Bonsignore *et al.* 2012, p. 2). For example, *Ingress* requires gamers to visit places in the real world with their smartphone as part of the game. Mixed reality games suit smartphones, which are not fixed to a particular location and contain sensory devices to facilitate integration of computer-generated images or sound with real-world features (Gotow *et al.* 2010).

A related development is gamification, the application of game dynamics (competition with others within certain rules, gaining points) to other activities (e.g., shopping, exercise, or dieting), thereby making them more enjoyable and rewarding (Chatfield 2010). Gamification extends familiar retailing techniques such as loyalty cards or “air miles” (Zichermann & Cunningham 2011), and can be used in both the real world (e.g., exercise apps

for mobile devices such as *Endomondo*), or the virtual world (e.g., the ability to “like” material on Facebook, creating a competitive dynamic and encouraging further engagement).

## Digital games and the conservation of biodiversity

### Conservation games

Many games offer a particular view of nature, ranging from the dystopian urban landscapes of *Fallout 3*, to the perfect imaginary meadows of *Flower*. In some cases, nature is included as background scenery to the game. In others, there is a clearer link between the game dynamics and biodiversity conservation. Games that have an implicit conservation message include those in which natural resources provide exhaustible “currencies” that are crucial to game play. For example, in *Civilization*, harvesting of resources can lead to deforestation and desertification (Golebiewski 2013). Such games are not explicitly about conservation, but may nonetheless raise awareness about relevant issues.

Games that are explicitly about conservation are becoming increasingly popular. Examples include *Zoo Tycoon*, in which the gamer manages a zoo full of different species, *MyConservationPark*, in which the gamer manages a protected area and keeps out poachers, and *Team Wild*, a 2D platform game in which the gamer plays a scientist trying to save species and habitats. Some of these games are made by commercial companies that may have no interest in conservation other than as an opportunity to make profit, and others are made by, or in partnership with, conservation organizations.

### How might games contribute to conservation?

Conservation involves a wide range of activities (Salafsky *et al.* 2002). We identify three main mechanisms by which games could play a role in conservation: education and behavior change, fundraising, and promoting research, monitoring, and planning (Table 1). Each has the potential to reach different target audiences and carries with it particular advantages and risks (Table 1).

### Games for education and behavior change

The potential of digital games in education is widely recognized, particularly where they target people already interested in gaming (McGonigal 2010). Games create opportunities for: experiential learning, which is considered more effective than traditional didactic teacher/student teaching; repetitive play, which exposes gamers to more opportunities for learning than in traditional education;

**Table 1** The potential contributions and associated risks of using digital games for conservation

Contribution to conservation	Target audience	Hoped-for impact on audience	Advantages	Risks
1. Education and behavior change	General public	Changed personal habits (e.g., sustainable consumption, wildlife friendly gardening, reduced energy use), popular demand for change (e.g., new government policy)	Games can create strong incentives for learning and behavior change; games can reach a huge audience outside existing conservation supporters	Games may not change behavior; lack of connection between gaming audience and many conservation issues
	Specific conservation stakeholders	Changed attitudes and behaviors (e.g., more support for a park among its neighbors, reduced illegal activity)	Games can create strong incentives for learning and behavior change	Games may not change behavior; target audience may not have access to technology to play games or interest in playing them; cost of developing a game for a small, specific audience may be too high
	Decision makers <sup>a</sup>	Changed attitudes leading to more policies that promote conservation	Games can create strong incentives for learning and behavior change; games can be an effective arena for testing policy ideas	Games may not change behavior; decision makers may not be interested in playing games
	Conservation staff	Improved skills (e.g., park management, species recognition)	Games can create strong incentives for learning and behavior change; bespoke games can be developed for specific conservation skill sets	Games may oversimplify complex issues; models behind games may not be accurate (e.g., effect of management intervention may have different outcome in the game than reality)
2. Fundraising	Gamers with disposable income	Increased spending on conservation—through donations or (in)game purchases	Many gamers are relatively well off; games can reach a huge audience outside existing conservation donors	Developing commercial games is expensive and very risky in a competitive marketplace; conservation organizations may lose reputation if associated with certain types of game
3. Promoting research, monitoring, and planning	Skilled individuals (e.g., birdwatchers, scientists)	Increased contribution of specialist data to monitoring and research projects and the testing of ideas or policies	Games can create strong incentives for participation and submitting data (e.g., through league tables for number of records); games can harness expertise of gamers, saving money compared to standard research	Data submitted by gamers may be incorrect, requiring sophisticated screening and verification; game needs to be sophisticated to satisfy specialist audience
	Conservation scientists and planners	Improved models for spatial planning and resource allocation	Gamification could increase the availability of novel solutions to complex problems	Solutions suggested would have limited engagement with multistakeholder reality

Continued

**Table 1** Continued

Contribution to conservation	Target audience	Hoped-for impact on audience	Advantages	Risks
	General public	Increased contribution of nonspecialist data to research projects	Games can create strong incentives for participation and submitting data; successful games can reach a very large number of people, saving money compared to standard research	Data submitted by gamers may be incorrect, requiring sophisticated screening and verification; high chance of game failing to catch on among nonspecialist audience

<sup>a</sup>Decision makers are taken to mean influential individuals in government, business, NGOs, or other important stakeholders.

and learning experiences that are fun and enjoyable (Garris *et al.* 2002). Digital games can be used to raise awareness of a problem, improve understanding and change attitudes, as demonstrated in the field of HIV-AIDS awareness (Chib *et al.* 2010).

Digital games are widely used in formal education, particularly to support learning in schools. They have a potential role in teaching subjects relevant to conservation, from nature study with young children to biology with more advanced students. For example, *WhyReef*, a coral reef in the virtual world of Whyville.net, is targeted towards young people aged 8–16 years. Digital games have been used in professional education or training programs, for example, of surgeons (Rosser *et al.* 2007) and other medical professionals (de Wit-Zuurendonk & Oei 2011). Specialist training games have been developed in conservation, for example, *SimParc*, a game to train protected area staff in Brazil in participatory management.

Digital games can also be used in informal settings, to raise awareness of conservation issues among the general public. An example is *Congo Jones and the Loggers of Doom*, developed by the Rainforest Foundation UK. This is a 2D casual game in which the gamer helps a forest community to map their land “before the loggers arrive,” in the process learning about forest conservation issues. Players are encouraged to register for more information and other ways to help.

The potential role of digital games in conservation education has been recognized for at least 10 years (Brewer 2003). They may be useful in promoting conservation education and behavior change among a range of large and novel audiences (Table 1) and using immersive experiences; clear advantages over other traditional approaches to conservation education based on the simple dissemination of scientific results (Bride 2006). However, the relationship among education, attitudes, and behavior

change is highly complex (St John *et al.* 2010), and there is a need for specific research into the capacity for games to influence conservation behavior.

### Games for fundraising

Many digital gamers are relatively wealthy and not existing donors to conservation. Conservation organizations might, therefore, raise funds by developing and selling new commercial games. Whilst this approach could in theory generate huge returns, it is limited by the specialized skills needed to design an attractive game, the marketing reach to find players, and development costs (anything between US\$1M and US\$60M, Kotaku 2014). The games market is mature and hugely competitive, making the likelihood of success for such games very limited.

An alternative approach is to collaborate with a commercial game company to raise funds from within an existing game, usually one played online. Income derives from the gameplay itself, either in the form of an invitation to make a charitable donation, or to purchase some virtual item useful within the game such as clothing for an avatar or crops to plant in a virtual farm. For example, over 25,000 gamers playing *Sims Social* have purchased a virtual WWF Panda for a \$1.75 donation, generating over \$40,000 for the charity (The Sims 2014). This approach could make a significant contribution to conservation fundraising in future. However, there might be reputational risk from association with games that feature violence or other negative activities, or if the good name of conservation is used to generate funds for unclear purposes. For example, *MyConservationPark*, a Facebook game, claims to support conservation, but gives no details of what proportion of in-game purchases are donated, or to which organizations.

### **Games for conservation research, monitoring, and planning**

The use of games is relatively well established in conservation research and monitoring. Games can be used to support conservation research by creating incentives for gamers to collect data, or by using games to identify potential solutions to real world problems. Both approaches are applications of the concept of “citizen science” as a tool for conservation research which can, when successful, deliver large volumes of high quality data at a fraction of the cost of traditional research (Dickinson *et al.* 2012). Game dynamics can be used to encourage citizens to collect and submit data relevant to conservation, such as spatially explicit records of species occurrences. Examples include *eBird*, a global bird checklist program using gamification to stimulate birders to record data useful in research, or *iSpot*, a mobile phone app in the UK that rates users on the accuracy of their identifications compared to others, thereby motivating them to contribute more records. The quality of data from citizen science is much discussed (e.g., Danielsen *et al.* 2005); clearly games using this approach must be well designed to ensure data quality.

Games can potentially help identify solutions to conservation problems through crowd-sourcing ideas. For example, in *Fraxinus*, a Facebook game, gamers score points and compete to identify patterns in the genetic code of the *Chalara* fungus that threatens ash trees in the United Kingdom and elsewhere, helping researchers develop resistant strains (Pautasso *et al.* 2013). Alternatively, games can be used to test new policy ideas. Thus in *Fate of the World*, players have to devise policy approaches to combat climate change over the next 200 years. The game is based on scientific climate change models, so solutions developed by gamers might have real world applications. Games can provide a controlled and safe simulated environment that allows gamers to try different possibilities and roles and make mistakes without fear of real-world consequences. Games could have potential in conservation planning, to identify strategies to allocate scarce conservation funds cost-effectively across multiple objectives and stakeholders. However, the value of such approaches depends on games capturing and portraying relevant issues accurately, and there is a risk that a strategy that works well in a game could be deleterious in the real world.

### **How might games detract from conservation?**

Digital games are not without risks from a conservation perspective. First, digital games of any variety might distract players from the real world and its problems, like

other technologies that mediate, augment, or simulate nature (Kahn 2011). Escapism is a core appeal of gaming: many digital games fulfill human needs that the real world is unable to satisfy (McGonigal 2010). Immersive game worlds might lull the player into a false sense of security about the state of the planet, or provide a hyper-real and cognitively satisfying alternative to real nature that reduces concern about conservation (e.g., *Flower*). Digital games may affect higher order cognitive functions including selective attention, problem solving, inhibition, and multitasking (Atchley *et al.* 2012), playing a part in some kind of “nature deficit disorder” (Louv 2005).

Second, conservation games may mislead if their modeled or synthesized environments oversimplify or misrepresent real-world problems. Thus, for example, a game may suggest that resources are inexhaustible (there are always more fish in the sea), that lives can be restored, that worlds will reboot in pristine form. Conservation is complicated, and the simple narratives that are most easily told by games may not always be helpful. For example, the introductory video to *MyConservationPark* tells the story of a natural world threatened by the growing human population, which then translates in gameplay to evil poachers who must be defeated. This simple narrative could mislead gamers into blaming all conservation problems on poor people in faraway places. Similar challenges have been identified for the use of simplistic marketing messages in conservation (Smith *et al.* 2010), and conservationists will need to consider whether they should engage with games companies to discourage them from the inaccurate portrayal of conservation issues. Playing conservation games might mislead the gamer into feeling that they have done something helpful for conservation—a form of “slacktivism.” Purchasing a virtual animal for a virtual zoo, or jumping around a virtual forest to protect it from illegal loggers may be entertaining, but hardly addresses the challenges of extinction or deforestation. In some cases, conservation games might succeed in raising awareness, but at the same time reduce understanding of an issue. This has been shown to occur among those watching Hollywood movies relating to climate change (Balmford *et al.* 2004).

### **Conclusions**

Digital games and the virtual worlds they bring into being have become significant factors in the way humans understand and respond to global problems (Chatfield 2010; McGonigal 2010). Gaming has the potential to influence ideas about nature and about conservation action in both positive and negative ways. The gaming



industry is global, large, and rapidly growing. It engages increasing numbers of people, and it is entirely dependent on devices that demand rare earths and large amounts of carbon-rich energy. For all these reasons, it is important that conservation organizations understand the world of gaming, and the thriving industry that drives it. However, in our experience, most conservationists know very little about digital gaming. To support future engagement between conservation and digital games and minimize the risk that this becomes another ineffective conservation fad (Redford *et al.* 2013), we offer the following recommendations.

First, game creation is highly specialized, and needs specific expertise. Any conservation game intended for the mass market is likely to demand close working with specialist commercial companies. This will require proactive efforts by conservation organizations: while the development of serious game to save the world might seem an obvious choice for conservation, they are marginal to the purposes of commercial games companies. Second, conservation games will usually need to be tightly focused in their aims. It is notable that successful serious games (for example, in healthcare) tend to have one goal. It is probably not realistic to use a single game to inform the general public about a conservation problem (e.g., overharvesting of ocean fish), to motivate them to address it (by changing their shopping and dining habits), to provide them with the knowledge needed to make these decisions (by explaining which fish are too rare to eat), and to lobby for a policy change. Third, conservation games need to target a specific audience with great care, based on the intended outcome for conservation, the relevance of the audience to achieving the outcome, and the gaming preferences of the audience (Table 1). A game designed to enthuse children about the importance of pollination is unlikely to have the same effect on decision makers in the ministry of agriculture: the underpinning science might be the same, but the message, game environment, and game architecture might not. Similarly, a game about illegal hunting in a developing country is unlikely to result in a relevant change of behavior if played by a child in a developed country. There is a need for further research in this area to establish to what extent digital games really can contribute to conservation in the ways we identify.

Perhaps above all, games have to be fun. Feeling guilty is not fun, and conservation stories are often about loss and destruction. In recent years, there has been growing interest in the idea that conservation should be communicated using more positive stories (Balmford 2012). It is a challenge for conservation to identify narratives and storylines that are not depressing, complex, earnest, or boring. In this task, conservation games and game dy-

namics, if used appropriately, may have an important role to play in making conservation more engaging and fun.

## Acknowledgments

We would like to thank those who attended a workshop in Cambridge in November 2011 (Gayle Burgess, Lucy Erickson, Toby Gardner, Steven Harris, Caroline Howes, Shaun Hurrell, Rachel Jacobs, Lucas Joppa, Tadhg Kelly, Nigel Leader-Williams, Ade Long, Richard Meston, Jude Ower, Genaro Rebolledo Mendez, John Ribbins, Ian Roberts, Christel Scheske, Jonathan Smith, Scott Sturrock, Chris Swain, Maureen Thomas, and Matt Watkins). This project was funded by the Cambridge Conservation Initiative Strategic Initiative Workshop Fund.

## Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

**Table S1:** Details of game titles mentioned in the text

## References

- Alpert, F. (2007). Entertainment software: suddenly huge, little understood. *Asia Pac. J. Market. Logist.*, **19**, 87–100.
- Alvarez, J. & Djaouti, D. (2010) *Serious games: an introduction*. Questions Théoriques, Paris.
- Annetta, L.A. (2010) "The 'T's' have it: a framework for serious educational game design." *Rev. Gen. Psychol.*, **14**, 105–112.
- Atchley, R.A., Strayer, D.L. & Atchley, P. (2012) Creativity in the wild: improving creative reasoning through immersion in natural settings. *PLoS ONE*, **7**. doi:10.1371/journal.pone.0051474.
- Balmford, A. (2012) *Wild Hope: On the Front Lines of Conservation Success*. University of Chicago Press, Chicago.
- Balmford, A., Manica, A., Airey, L., Birkin, L., Olver, A. & Schleicher, J. (2004). Hollywood, climate change, and the public. *Science*, **305**, 1713.
- Bavelier, D. & Davidson, R.J. (2013) Brain training: games to do you good. *Nature*, **494**, 425–426.
- Bonsignore, E., Hansen, D.L., Toups, Z.O., Nacke, L.E., Salter, A. & Lutters, W. (2012). Mixed reality games. Available from: <http://mixedrealitygames.selfcloud.net/wp-content/uploads/2012/02/cscw2012WorkshopMixedRealityGames.pdf>. Accessed February 6, 2014.
- Brewer, C. (2003) Computers in the classroom: how information technology can improve conservation education. *Conserv. Biol.*, **17**, 657–660.

- Brian, M. (2012). Rovio's angry birds titles hit 1 billion cumulative downloads. Available from: <http://thenextweb.com/mobile/2012/05/09/rovios-angry-birds-titles-hit-1-billion-cumulative-downloads/>. Accessed February 6, 2014.
- Bride, I. (2006). The conundrum of conservation education and the conservation mission. *Conserv. Biol.*, **20**, 1337-1339.
- Chatfield, T. (2010). *Fun inc: why games are the twenty-first century's most serious business*. Virgin Books, London.
- Charsky, D. (2010). From edutainment to serious games: a change in the use of game characteristics. *Game. Cult.*, **5**, 177-198.
- Chib, A.I., Lwin, M.O., Lee, Z., Ng, V.W. & Wong, P.H.P. (2010). Learning AIDS in Singapore: examining the effectiveness of HIV/AIDS efficacy messages for adolescents using ICT. *KM@EL*, **2**, 169-187.
- Danielsen, F., Burgess, N.D. & Balmford, A. (2005). Monitoring matters: examining the potential of locally-based approaches. *Biodivers. Conserv.*, **14**, 2507-2542.
- de Wit-Zuurendonk, L.D. & Oei, S.G. (2011). Serious gaming in women's health care. *Bjog-Int. J. Obstet. Gy.* **118**, 17-21.
- Dickinson, J.L., Shirk, J., Bonter, D., et al. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Front. Ecol. Environ.*, **10**, 291-297.
- Garris, R., Ahlers, R. & Driskell, J.E. (2002). Games, motivation, and learning: a research and practice model. *Simulat. Gaming*, **33**, 441-467.
- Golebiewski, D. (2013). *Exploring International Relations in Civilization IV: The World Within Your Hand's Reach*. SSRN Scholarly Paper, ID 2291735. Rochester, NY: Social Science Research Network. Available from: <http://papers.ssrn.com/abstract=2291735>. Accessed August 27, 2013.
- Gotow, J.B., Zienkiewicz, K., White, J., & Schmidt, D.C. (2010). Addressing challenges with augmented reality applications on smartphones. Pages 129-143 in: *Mobile wireless middleware, operating systems and applications* Y. Cai, T. Magedanz, M. Li, J. Xia, C. Giannelli, editors. Springer, New York City.
- Kahn, P.H. (2011). *Technological nature: adaptation and the future of human life*. MIT Press, Massachusetts, USA.
- Kato, P.M. (2010). Video games in health care: closing the gap. *Rev. Gen. Psych.*, **14**, 113-121.
- Kotaku (2014). How much does it cost to make a big video game? Available from: <http://kotaku.com/how-much-does-it-cost-to-make-a-big-video-game-1501413649>. Accessed April 2, 2014.
- Louv, R. (2005). *Last child in the woods: saving our children from nature-deficit disorder*. Algonquin Books, North Carolina.
- McGonigal, J. (2010). *Reality is broken: how can videogames save the world*. Penguin Press, New York, NY, USA.
- Pautasso, M., Aas, G., Quelo, V. & Holdenrieder, O. (2013). European ash (*Fraxinus Excelsior*) dieback – a conservation biology challenge. *Biol. Conserv.*, **158**, 37-49.
- Pixelsandpolicy (2010). How much is the virtual economy worth? Try \$5 billion. Available from: [http://www.pixelsandpolicy.com/pixels\\_and\\_policy/2010/01/virtual-economy-value.html](http://www.pixelsandpolicy.com/pixels_and_policy/2010/01/virtual-economy-value.html). Accessed April 30, 2014.
- Redford, K.H., Padoch, C. & Sunderland, T. (2013). Fads, funding and forgetting in three decades of conservation. *Conserv. Biol.*, **27**, 437-438.
- Redpath, S.M., Young, J., Evely, A., et al. (2012). Understanding and managing conservation conflicts. *Trends Ecol. Evol.*, **28**, 100-109.
- Rosser, J.C., Lynch, P.J., Cuddihy, L., Gentile, D.A., Klonsky, J. & Merrell, R. (2007). The impact of video games on training surgeons in the 21st century. *Arch. Surg.-Chicago*, **142**, 181-186.
- Salafsky, N., Margoluis, R., Redford, K.H. & Robinson, J.G. (2002). Improving the practice of conservation: a conceptual framework and research agenda for conservation science. *Conserv. Biol.*, **16**, 1469-1479.
- Smith, R.J., Veríssimo, D. & MacMillan, D.C. (2010). Marketing and conservation: how to lose friends and influence people. Pages 215-232 in *Trade-offs in conservation: deciding what to save*. N. Leader-Williams, W.M. Adams & R.J. Smith, editors. Wiley-Blackwell, Oxford.
- St John, F.A.V., Edwards-Jones, G. & Jones, J.P.G. (2010). Conservation and *human behaviour*: lessons from social psychology. *Wildlife Res.*, **37**, 658-667.
- The Sims (2014). The Sims social WWF Facebook page. Available from: <https://www.facebook.com/TheSimsSocial/app/194080173963949>. Accessed February 6, 2014.
- Zichermann, G. & Cunningham, C. (2011). *Gamification by design: implementing game mechanics in web and mobile apps*. O'Reilly Media, Inc., Sebastopol, USA.

## Endnote

1. All games mentioned in the text are listed in Table S1 with details of their publisher and website. In this paper, we do not attempt to identify or review all games relevant to conservation.