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EDITORIAL

Reducing agricultural loss and food waste: how will nature fare?

I. J. Gordon[1], R. Altwegg[2], D. M. Evans[3], J. G. Ewen[4], J. A. Johnson[5], N. Pettorelli[4] & J. K. Young[6]

1 Division of Tropical Environments & Societies, James Cook University, Townsville, Australia
2 Statistics in Ecology, Environment and Conservation, Department of Statistical Sciences, and African Climate and Development Initiative, University of Cape Town, Rondebosch, South Africa
3 School of Biology, Newcastle University, Newcastle upon Tyne, UK
4 Institute of Zoology, Zoological Society of London, London, UK
5 Department of Biological Sciences, Institute of Applied Sciences, University of North Texas, Denton, TX, USA
6 USDA-Wildlife Services-National Wildlife Research Center-Predator Research Facility, Department of Wildland Resources, Utah State University, Logan, UT, USA

Correspondence
Iain J. Gordon, Division of Tropical Environments & Societies, James Cook University, Townsville, Qld 4811, Australia.
Email: iain.gordon@jcu.edu.au

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'One man's rubbish is another's treasure' – Hector Urquhart in J. F. Campbell (1980) *Popular Tales of the West Highlands*.

With the global population currently over seven billion, and expected to increase to over nine billion in the next 30 years, the race is on to find ways to feed, water and clothe the citizens of the planet (United Nations, 2013). Food security is high on both national and international agendas (Gordon *et al.*, 2012), with a push to increase the production of food by up to 70% in the next 30 years (Food and Agriculture Organization, 2013), and estimates of another one billion ha of land being converted to agriculture, mainly in the tropics (Tilman *et al.*, 2001). The food security agenda may have obvious effects on wildlife species; however, some species may be affected by perverse outcomes that have not yet been assessed. Reduction in loss and waste from agricultural production and food systems (food waste) is one such issue. Here, we highlight the potential impact on species that have become reliant on food waste. These species may be seen currently as pests or vermin; however, the consequences of a reduction in food waste could not only affect them directly, but might also have significant cascading effects across food webs and impact on animal species of conservation importance.

While the push to produce more food from agricultural systems is the major narrative for the food security agenda (Guillou & Matheron, 2014), currently agricultural production provides enough food to support the global human population (Food and Agriculture Organization, 2011; Hiç *et al.*, 2016); that this food does not get to the people who need it most is, in part, caused by restrictions on how food is distributed, but also as a result of the waste that occurs throughout the supply chain (BIS, 2011). In relation to the latter, it is estimated 30–50% of the four billion tonnes of food produced each year is wasted (Gustavsson *et al.*, 2011). In many countries 20–40% of food production is lost to pests and diseases before it leaves the farm (Lundqvist, de Fraiture & Molden, 2008), and in some developed countries 30–50% is thrown away from supermarkets and in the home because it is past its 'sell-by' date or discarded after the meal (Rayner & Lang, 2012). There are national differences of course; food waste in North America and Europe is roughly 95–115 kg/capita/year compared to 6–11 kg/capita/year in South/South-East Asia and sub-Saharan Africa (Gustavsson *et al.*, 2011).

One means to meet the growing demand for food is to reduce waste (Ashchemann-Witzel, 2016); Lundqvist *et al.* (2008) ask for 'a reduction by 50 percent of losses and wastage in the entire food chain from field to fork – including agricultural and post-harvest practices'. There would be significant benefits to nature conservation if the 'waste less' rather than 'grow more' advocates were to be in the ascendancy in the drive for food security. If less food is wasted, then, effectively, agricultural production will be higher per unit area of land and per person fed resulting in less pressure to expand the area of agricultural land to meet growing food demand. This will help maintain biodiversity that would have been lost as a result of land conversion and/or agricultural intensification. However, as food waste is part of the food web, a reduction in waste may have significantly broader consequences for biodiversity and nature conservation.

A number of species utilize the crops and animals we farm, for example in the fields, the by-products of harvesting food, for example bycatch from fisheries, or when food waste is sent to landfill. The ecology, evolution and life histories of these species have been shaped by this human generated food subsidy (Oro *et al.*, 2013). A question that animal conservation scientists should be asking is – will a reduction in food waste, to meet the increasing demands for food, have a positive or negative impact on biodiversity and which species will be winners and losers? Here, we highlight the issue and suggest a research agenda for conservation scientists to provide a systems level, evidence base to support policy decisions. While our focus is on how food waste impacts animal biology and conservation, this is not to take away from the significant benefits that may accrue to ecosystems from reductions in food waste, through, for example, reductions in the use of land for agriculture and the polluting effects (on soil, water, air) of the waste itself. We focus our attention on bird species for examples of animals that will be impacted by the reduction in waste agenda. Other animal species are also likely to be affected but birds provide us with insightful examples to highlight the issues and focus research questions.

So which species are likely to be negatively affected by a reduction in food waste? There are those species which will be directly affected by the reduction in waste across the agricultural/food supply chain. First, agricultural pests are likely to be the main species to feel the brunt of the move to reduce losses before crops and livestock are harvested. There are over 70 000 pest species around the world, including a diverse range of taxa from gastropods to insects to vertebrate species, such as birds, that have a significant economic impact through consumption of harvestable products (Linz *et al.*, 2011). Campaigns to reduce waste are already implemented through directly targeting control methods for the pest populations themselves. For example, the red-billed quelea *Quelea quelea* is a major granivorous pest of agricultural crops in sub-Saharan Africa, which can occur at plague proportions and lead to local famines in regions of Africa (Allan, 1996). To alleviate the problem, aerial spraying using Queletox (fenthion) and bombing are deployed across Africa with significant effects on bird populations, not just quelea (McWilliam & Cheke, 2004).

A second obvious set of candidate species for direct effects are those that rely on potential human food that is lost or discarded during the harvesting process, for example discards in marine fisheries or the residue that is left after harvesting crops. A number of species of birds use the grain spilled in the harvest during stopovers along their migration routes (e.g. Galle, Linz & Bleier, 2004). These species are likely to be directly affected by reductions in crop losses due to, for example, more efficient harvesting machinery. Scavengers are included within this group, many of which use dead livestock as significant food sources (Peterson *et al.*, 2010). In Europe, for example, legislation in the wake of bovine spongiform encephalitis forced farmers to bury or burn dead animals that would normally be left lying in fields. This led to a reduction in vulture populations to the degree that a number of species are now at risk of extinction (Donàzar *et al.*, 2009). This could be a portent of things to come as improving livestock husbandry practices reduce the amount of carrion available for scavengers, or the use of veterinary chemicals to improve livestock health and survival could have negative impacts on scavenging species, particularly in developing countries (Cuthbert *et al.*, 2014). Across the oceans, many bird populations benefit from the waste that is discarded as bycatch from wild fisheries (Hudson & Furness, 1988; Yorio & Caille, 1999). In a recent analysis of the closure of the Canadian gillnet fishery, Regular *et al.* (2013) show that surface feeding seabirds (*Larus* sp. and *Rissa tridacyla*) which are not significantly vulnerable to bycatch in gillnets, have seen a major decline in population size since 1992 (see also Oro *et al.*, 2004), possibly because of a reduction in the discards of bycatch.

A third group of species are likely to be impacted through a reduction in the amount of food waste sent to landfill. Landfills constitute important food sources for a large number of bird species worldwide, particularly for opportunistic and scavenging species (Pomeroy, 1975; Belant, 1997). An increase in landfill sites has been implicated in the growth of a number of gull populations in both the northern and southern hemisphere (Spaans & Blokpoel, 1991; Payo-Payo *et al.*, 2015). For example, the western gull *Larus occidentalis* populations in western North America has increased significantly over recent years, primarily because of food supplementation from landfill (Osterback *et al.*, 2015). The increased populations are thought to have resulted in significant impacts on threatened steelhead *Oncorhynchus mykiss* populations (Osterback *et al.*, 2015). A reduction in food from landfill may cause a dietary change in affected species with potential impacts on other more vulnerable species in the ecosystem (Duhem *et al.*, 2003). However, reliance on refuse can have negative effects on life histories of individuals in certain species (Annett & Pierotti, 1999) and removal of waste could benefit these populations in the long run.

Fourth, a number of species will be indirectly affected by measures to control pests. As described earlier, many species of birds cause significant economic damage to crops. Farmers across the globe use pesticides that affect non-target species. For example, the use of the pesticide to control quelea has ancillary environmental effects (McWilliam & Cheke, 2004). While banned in many developed countries, DDT is still heavily used in the tropics to control pests (e.g. Abdullah *et al.*, 2015) with knock-on effects on both bird species and other non-target populations (Yohannes *et al.*, 2014). Similarly, the common use of neonicotinoid insecticides in Europe is associated with declines in insectivorous bird populations, possibly as a consequence of reductions in native invertebrate numbers (Hallmann *et al.*, 2014).

Despite the cases mentioned above, the likelihood is that the waste reduction approach to food security will benefit many more species than it harms. It is predicted that meeting the food needs of nine billion people will require over 120 M ha of land being converted to cropland in developing countries (Food and Agriculture Organization, 2012); reducing waste by even 10% would significantly reduce the pressure for land conversion (West *et al.*, 2014). Apart from species benefiting from less land being converted to agriculture, other species are likely to benefit directly and indirectly through, for example, a reduction in negative trophic interactions (e.g. predation and competition). First, a number of species that use harvest residues and landfill are negatively affected by toxins and disease associated with that feeding habit. In addition to the example of gulls at landfill sites (see above), sandhill cranes feed on groundnuts left over after harvest and suffer from mycotoxin poisoning (Windingstad *et al.*, 1989). Reducing wastage during harvesting would protect these species from such detrimental effects. Second, many of the species that are negatively impacted by a reduction in waste may also benefit from associated improvements in food harvesting. For example, significant numbers of seabirds are injured and killed as they attempt to scavenge for discards associated with fishing activity (Maree *et al.*, 2014). Reducing discards will reduce the likelihood of death while scavenging. Third, the reduction in waste will have indirect food web effects through reductions in the populations of species that are augmented by food waste. This will reduce the predation from food waste scavengers, for example Bald eagles in Chesapeake Bay (Turrin, Watts & Mojica, 2015), and competition for food from generalist species that use the same food sources as obligates. This ecosystem-level response could result in a broad benefit to species and ecosystem services; however, the linkage between reducing food waste, possible reductions in certain species and the food webs in which they are a key component is still missing. Finally, there is increasing evidence of the benefits of biodiversity as a means of controlling pests and diseases of agriculture (Johnson, Kellerman & Stercho, 2010) that is providing an ecosystem service to agriculture. Instead of using agrochemicals to control pests and diseases, biocontrol methods using native species could benefit local biodiversity (Chaplin-Kramer *et al.*, 2011; Gras *et al.*, 2016).

Whether human society will achieve a reduction in food waste to meet its food security needs is yet to be seen. However, there are moves afoot in developed countries to reduce waste (e.g. supermarkets sending ‘past sell by date’ food to charities instead of landfill) and even to use food waste for energy production, that is anaerobic digestion and biomass. The consequences of this will be far reaching for both animal populations and the ecosystems in which they exist. To meet the future needs and support better conservation outcomes, scientists working on the biology of animal species (particularly those involved in research on conservation) would do well to make predictions, and test hypotheses, about how the food waste agenda is likely to impact the biodiversity of the planet. Fundamental food web studies would be a good place to start (Bohan *et al.*, 2013). More specifically, conservation scientists will be called upon to answer questions about which species rely on or use food waste, where that reliance or use occurs in the food chain, what impact reductions in food waste might have on those species and what the food web consequences might be of reductions in food waste across the supply chain. Ecosystem-level food web models will allow predictions to be made as to how species and ecosystems will respond to the removal of waste across the agricultural/food supply chain. Waste has been ignored for too long. The food security agenda will bring it to the front of mind (Ashchemann-Witzel, 2016), and conservation scientists need to respond quickly if we are not to be left feeding from the scraps under the table.

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