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Four Types of Activities that Affect Animals: Implications for Animal Welfare Science and Animal Ethics Philosophy

D. Fraser
University of British Columbia

A. M. MacRae
University of British Columbia

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D. Fraser and A.M. MacRae

University of British Columbia

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ABSTRACT

People affect animals through four broad types of activity: (1) people keep companion, farm, laboratory and captive wild animals, often while using them for some purpose; (2) people cause deliberate harm to animals through activities such as slaughter, pest control, hunting, and toxicology testing; (3) people cause direct but unintended harm to animals through crop production, transportation, night-time lighting, and many other human activities; and (4) people harm animals indirectly by disturbing ecological systems and the processes of nature, for example by destroying habitat, introducing foreign species, and causing pollution and climate change. Each type of activity affects vast numbers of animals and raises different scientific and ethical challenges. In Type 1 activities (keeping animals), the challenge is to improve care, sometimes by finding options that benefit both people and animals. In Type 2 activities (deliberate harm), the challenge is to avoid compounding intentional harms with additional, unintended harms, such as animal suffering. For Type 3 and 4 activities, the challenges are to understand the unintended and indirect harms that people cause, to motivate people to recognise and avoid such harms, and to find less harmful ways of achieving human goals. With Type 4 activities, this may involve recognising commonalities between animal welfare, conservation and human well-being. Animal welfare science and animal ethics philosophy have traditionally focused on Type 1 and 2 activities. These fields need to include Type 3 and 4 activities, especially as they increase with human population growth.

Introduction

Animal welfare science has focused traditionally on the intentional use of animals, especially in food production and biomedical research. Where the welfare of wild animals has been studied, the focus has often been on animals in captivity (Carlstead & Shepherdson 2000) or under direct human control through activities such as trapping (Mason & Littin 2003; Warburton *et al* 2008).

Animal ethics philosophy has traditionally had much the same focus. Influential philosophers such as Singer (1990) and Rollin (1990, 1995) concentrated on farming and biomedical research as their primary areas of concern, and Regan (1983) saw his arguments as requiring the abolition of the intentional use of animals for food, science and sport. In reality, the intentional use of animals, vast as it is, represents only a portion of the effects of human actions on animals. Activities such as crop production, forest management, resource extraction, industrial manufacturing, urban development and transportation affect animals on a huge scale, although the effects may be unintended and often go unrecognised. Some of these activities disrupt valued ecological systems or endanger rare species, and thus become a focus of conservation concern; others, such as agricultural practices that harm animals of abundant species, do not. Nevertheless, all such activities are likely to cause classic animal welfare problems such as pain, distress and ill health to sentient beings.

In this essay we propose a framework that could help to incorporate the unintended effects of human activities into the ambit of animal welfare science and animal ethics philosophy. Specifically, we propose that human activities that affect animals can be divided into different categories which raise different scientific, ethical and practical challenges. Using this framework we argue that a broadening of animal welfare science and animal ethics philosophy is needed.

Types of human activities and their effects on animals

Human activities that affect animals can be divided into four broad types, each of which involves animals in very large numbers.

Type 1 −Keeping animals

Much of the direct contact we have with animals involves some form of animal-keeping, especially raising animals for food or other purposes, plus keeping companion animals, working animals and captive wild animals. Table 1 gives some very rough estimates of the numbers involved. Census data given in the table indicate that the number of terrestrial vertebrate animals being raised for food at any given time is roughly 22 billion, the large majority being chickens. Companion animals may number roughly 1 billion at any given time and working animals 0.4 billion. Laboratory animals likely comprise somewhat less than 0.1 billion, and captive wildlife may exist at similar or lower numbers.

Type 2 −Causing deliberate harm to animals

People cause many kinds of deliberate harm to animals, for example in killing animals to produce food, in pest control, and in some scientific research and testing.

Slaughter for food involves a vast number of animals as summarised in Table 1. Some 50 billion chickens, 1.4 billion pigs, 1 billion sheep and goats, 1.2 billion rabbits and 0.3 billion cattle are slaughtered each year, together with an estimated 10–100 billion finfish produced by aquaculture.

Fewer data are available on hunting, trapping and fishing. The capture and killing of wild fish involves nearly twice the tonnage produced by aquaculture (FAO 2009a) and includes many fish taken at very small body size. The number killed may be in the order of 1,000 billion (Mood 2010). In addition, many birds, mammals and reptiles are killed or injured incidentally as ‘by-catch’ (Lewison *et al* 2004). Hunting and trapping will account for far fewer individuals. Hunting claimed roughly 120 million birds per year in the United States during the 1960s and 1970s (Banks 1979), and more recent data by Raftovich *et al* (2009) showed that harvest levels remained roughly similar for most species. Hence, a current figure for the United States is likely in the order of 0.1 billion per year. If this very significant form of hunting

accounts for 5–10% of hunting worldwide, then the global total would be in the order of 1–2 billion per year.

Table 1. Estimates of the number of animals kept by people at a given time (census numbers) and the number killed per year.

Category of animals	Census numbers (billions)	Killed per year (billions)	Notes
Food-producing animals[1]			
Cattle	1.4	0.3	FAO (2007)
Pigs	1.0	1.4	FAO (2007)
Sheep and goats	2.0	1.0	FAO (2007)
Chickens	17.3	50.3	FAO (2007)
Rabbits		1.2	FAO (2007)
Total farmed animals	–22	–54	FAO (2007)
Finfish in aquaculture[2]		10 – 100	Mood (2010)
Companion animals[3]	1		WSPA (2009)
Working animals	0.4		Ramaswamy (1994)
Laboratory animals[4]	< 0.1	0.1	Taylor *et al* (2008)
Captive wild animals[5]			
Mammals	0.0002		ZSL (2009)
Birds	0.0003		ZSL (2009)
Reptiles, amphibians	0.0001		ZSL (2009)
Fish	0.0008		ZSL (2009)
Total captive wild animals	0.01– 0.1		

[1] Food-producing animals are expressed as census numbers (the number alive at a given time) and the number killed (slaughtered) per year. Because cattle typically live > 1 year, the number slaughtered is smaller than the census number, and *vice versa* for chickens.

[2] The estimate of 10‑100 billion was provided by Mood (2010). In addition, fish production by aquaculture was estimated at 51.7 billion kg for 2006 for all species combined FAO (2009a). If the average weight per fish is 1‑4 kg, then the number slaughtered per year would fall within Mood's estimated range.

[3] WSPA (2009) estimates 0.5 billion dogs and a similar number of cats, roughly 80% of which are strays.

[4] The number given by Taylor *et al* (2008) is 115.3 million. This is the estimated number of animals used per year. Because many of the animals used in science are rodents that live for less than one year, the number alive at any given time will presumably be less than 100 million.

[5] The numbers shown for mammals, birds, etc are the numbers of individuals reported by accredited zoos and aquaria as listed in the *International Zoo Yearbook* (ZSL 2009). We assume that the true number (including unaccredited zoos, circuses and exotic pets in homes) may be 1‑2 orders of magnitude greater, hence the proposed range of 0.01 to 0.1 billion for total captive wild animals.

Type 3 − Causing direct but unintended harm to animals

Human activities often harm animals in direct but unintended ways. Many of these activities have received so little attention that they are difficult to quantify, but a few examples suggest that they involve harm to animals on a very large scale. In the following examples, we have used data on the death and disappearance of animals as a proximate index of the level of harm involved, simply because such data are often the only information available. Presumably many of the deaths are accompanied by significant animal welfare problems including suffering, injury and ill health; moreover, the data on death and disappearance likely represent only a fraction of the total number of animals harmed.

Table 2. The number of small mammals (especially rodents) per hectare principally in farmland, cropland and old field, as reported in several studies.

Density (animals per hectare)	Species	Type of land	Source
143 to 490	Rodents	Farmlands of the temperate zone and steppe	Jędrzejewski & Jędrzejewska (1996)
60 to 362	Common vole (*Microtus arvalis*)	Cropland in central Germany	Jacob (2003)
< 60 to 186	Montane vole (*Microtus montanus*)	Old field, Canada*	Sullivan *et al* (2003)
0 to 300	Field vole (*Microtus agrestis*)	Old field (1 ha plot), Finland	Myllmäki (1977)
28 to 37	Small mammals	Old field, sage and riparian habitats, Canada**	Sullivan & Sullivan (2006)
0 to 25	Wood mouse (*Apodemus sylvaticus*)	Arable land, England	Tew & Macdonald (1993)
12 to 60	Deer mouse (*Peromyscus maniculatus*)	Old field, Canada**	Sullivan *et al* (2004)
6 to 19	Yellow-pine chipmunk (*Tamias amoenus*)	Old field, Canada**	Sullivan *et al* (2004)

* Lower densities were also reported in orchard habitat.

** Lower densities were also reported in orchard and forest habitat.

Agricultural practices such as harvesting and soil tillage can be extremely harmful to animals. Nass *et al* (1971) monitored radio-tagged Polynesian rats (*Rattus exulans*) during the mechanical harvesting of sugar cane. Of 33 animals studied in two trials, 14 were killed by the equipment, three suffocated in their burrows under compacted soil, and another three died from predation after the covering vegetation had been removed. Tew and Macdonald (1993) followed radio-tagged wood mice (*Apodemus sylvaticus*) during grain harvesting, also with a sample of 33 animals. Of these, one was killed by the combine harvester, 17 disappeared within a week likely because of predation when the covering vegetation was removed, and two were suffocated in their burrows when the stubble was burned. Jacob (2003) studied the effects of different farming practices on populations of common voles (*Microtus arvalis*); he found that mulching, mowing and the harvesting of wheat had little immediate effect on vole survival, whereas virtually all voles disappeared immediately after ploughing, and 44% disappeared after the harvesting of beans. Disappearance in these cases was presumed to have been 'mainly due to decreased survival' (p 24) rather than emigration.

The global effect of such farming practices can be estimated only in very approximate terms. Densities of small mammals in arable land vary widely depending on rainfall, vegetation and other factors. Data in Table 2 indicate that for the most abundant species (especially *Microtus* spp), densities of several hundred animals per hectare are common in farmland, cropland and 'old field' habitat, whereas densities tend to be lower for other rodents (*Apodemus* spp, *Peromyscus* spp) and in other habitats such as orchards. Moreover, for fields that are ploughed yearly, re-colonisation (and hence the death rate from ploughing in a subsequent year) is likely to depend on the availability of less-disturbed habitat nearby. Given that the world contains about 1.4 billion hectares of arable land excluding permanent pasture and meadow (FAO 2009b), such animal densities create scope for vast harm to animals through agricultural practices, with deaths certainly in the billions, and possibly tens of billions, per year.

Vehicles and roads are another significant cause of death of animals. Forman and Alexander (1998) concluded that roughly a million vertebrates are killed per day on roads in the United States, and that roads and vehicles have now replaced hunting as the leading direct human cause of death of wild terrestrial vertebrates. Reviewing several European studies, Sainsbury *et al* (1995) proposed that the number of birds and mammals killed on roads in Europe could be in the range of 10 to 100 million annually. Extrapolating these estimates from the United States and Europe to a global level would suggest billions of deaths per year. Other aspects of transportation are also harmful to animals. Large oil spills resulting from shipping can kill hundreds of thousands of birds (eg Ford *et al* 1996), and the damage from smaller and largely unreported releases of oil at sea is probably more significant. For example, the routine discharge of machinery waste oil from ships is thought to kill over 300,000 birds off the coast of Newfoundland each year (Wiese & Robertson 2004).

Windows and other reflective and transparent surfaces are a major cause of injury and death to birds. Summarising several decades of research, Klem (2009) concluded that windows and similar surfaces likely kill a billion birds each year in the United States and billions worldwide.

Artificial lighting, especially on towers and tall buildings, is also a significant cause of harm to birds. In particular, birds become disoriented in lit areas during night-time migration, often flying continuously within a lit area until they are injured. The small number of television towers that have been monitored carefully generally show 2,000 to 3,000 bird deaths per tower per year (Banks 1979; Kemper 1996; Crawford & Engstrom 2001). The number of communication towers in the United States was estimated at 75,000 in 1999 (Crawford & Engstrom 2001), but several thousand new towers are erected annually to accommodate the expanding use of mobile telephones and digital television (Crawford & Engstrom 2001; Anderson 2003).

In summary, these few examples indicate the vast number of animals that are harmed in unintended ways by agricultural practices, transportation, buildings, and many kinds of human activity.

Type 4 − Harming animals indirectly by disturbing ecological systems and the processes of nature

The harms described in the above section are the unintended but direct consequences of human activities. A fourth category of harm to animals occurs indirectly from human actions that disturb ecological systems and the processes of nature.

The introduction of exotic species has caused major disturbance to ecological systems with incalculable effects on animals. For example, the deliberate introduction of the Indian mongoose (*Herpestes auropunctatus*) to Puerto Rico and other islands caused the disappearance of 7 to 12 species of amphibians and reptiles, and the accidental introduction of the brown tree snake (*Boiga irregularis*) to Guam caused the disappearance of 10 of the 13 native forest bird species (Pimentel *et al* 2005). Domestic cats are one of the most ubiquitous of introduced predators. May (1988), extrapolating conservatively from a small study, proposed that domestic cats might kill 100 million birds and mammals per year in Great Britain; and Coleman *et al* (1997) estimated that rural cats in the United States kill more than a billion small mammals and hundreds of millions of birds each year. Some of these deaths may be relatively quick, but undoubtedly there will be many cases of injury and of unfledged broods dying from starvation when a parent is killed. Indeed, non-fatal attack by cats is a common reason for injured birds' being submitted to wildlife rehabilitation facilities (Dubois 2003).

The release of toxic chemicals into the environment has caused both immediate and long-term harm to animals. Many toxic chemicals accumulate in the bodies of long-lived, meat-eating species. For example, raptorial and fish-eating birds underwent severe population declines in many parts of the world during the

1900s, largely because of the harmful accumulation of organochlorine pesticides in their bodies (Hickey & Anderson 1968; Elliott *et al* 2005). The use of mercury compounds in industry and agriculture has also led to devastating consequences for birds (Clarkson 1992). In the view of Colborn (1994), "the environmental load of synthetic chemicals has reached critical levels at which wildlife and human health are at risk" (p 55).

Many agricultural practices degrade soil and water, and create major harms to animals. Agricultural fertilisers carried by rivers into marine environments create hypoxic 'dead zones' in nearly 0.25 million km^2 of coastal waters where 'mass mortality' of fish and other animals may result (Diaz & Rosenberg 2008; p 926). Slash-and-burn agriculture, when used too intensively, can lead to deforestation, erosion of soils and loss of animal habitat (Brady 1996). Other harmful land-use practices include overgrazing by livestock, crop cultivation on sloped and marginal land, and the removal of protective vegetation through repeated tilling or harvesting of crop residues for fuel (Lal 1990; Pimentel *et al* 1995). As a result of such practices, close to one-third of the world's arable land has been lost to erosion, and approximately 10 million ha continue to be lost annually (Pimentel *et al* 1995), often being replaced by vast areas of forest converted to agricultural use (Tilman *et al* 2001).

Human activities have caused the spread of disease organisms that have severely affected the health of animals (eg Daszak *et al* 2000, 2001). In medieval times, the movement of Asian armies brought rinderpest to Europe and Africa and caused the death of hundreds of millions of wild and domesticated ruminants (Blancou 2003). The accidental spread of myxomatosis into the United Kingdom in 1953 is thought to have killed most of the rabbits in the country, with numbers in the millions or tens of millions (Sainsbury *et al* 1995). More recently, the importation of African rodents infected with monkey pox transmitted the disease to North American prairie dogs (*Cynomys* spp) (CDC 2003). As well, activities that increase the proximity of humans, livestock and wild species, such as the development of previously wild habitats, have been associated with emerging infectious diseases (Daszak *et al* 2000). For instance, the transmission of Nipah virus from fruit-eating bats to pigs has been attributed to habitat destruction driving bats into orchards where pigs were kept (Chua *et al* 2002).

In these and many other examples, we see human activities interfering with ecological systems and the processes of the natural world. The number of animals affected is impossible to quantify, but data on species extinctions and biodiversity provide some insight into the relative seriousness of such activities. For example, Mackenzie (1977) calculated that of the 76 species of birds that had become extinct from 1600 to the time of his analysis, 13 had succumbed to human hunting (a form of deliberate harm) whereas 63 were driven to extinction by the indirect effects of human actions, notably habitat destruction (14 species) and the introduction of non-native animals (49 species). Similarly, the Millennium Assessment Report (2005) identified five major threats to biodiversity; one of these (over-harvesting) consists of deliberate harm, whereas four (habitat change, climate change, pollution, and invasive species) involve harming animals indirectly by disturbing ecological systems and natural processes. In an attempt to predict the effects of climate change, Thomas *et al* (2004) applied climate change models to an extensive sample of taxa and regions; they predicted that by 2050, between 15 and 37% of species in their sample will be 'committed to extinction'. Such approaches suggest that the level of harm caused to animals indirectly by disturbing ecological systems and natural processes may exceed that of other types of human activity.

In addition, disturbances to ecological systems and life-sustaining natural processes can also cause significant harm to people. The release of toxic substances by agriculture and industry has caused serious health problems for both people and animals (Clarkson 1992; Dewailly *et al* 1993; Safe 1994). Deforestation through slash-and-burn agriculture can ultimately destroy the livelihood of farmers (Brady 1996). Many novel pathogens claim human as well as animal victims (Daszak *et al* 2000; Chua *et al*

2002; CDC 2003). And climate change is expected to have devastating consequences for people and animals alike (IPCC 2007).

Different types of activities, different challenges

Type 1 and 2 activities present the challenges that are typically addressed in animal ethics and animal welfare science, whereas Type 3 and 4 activities have been largely ignored. Each type raises different scientific, ethical and practical challenges.

Type 1 −Keeping animals

In many of the situations where people keep animals, actions that benefit the animals will also, to a certain degree and within certain limits, benefit the human keepers. For example, certain improvements to animal housing can increase both animal health and economic productivity (eg Tauson 1998); high-welfare environments for laboratory animals can reduce chronic stress and may lead to more valid experimental results (eg Reinhardt & Rossell 2001; Sherwin 2004); owners of working animals can achieve significant economic benefits by treating animal diseases (eg Samui & Hugh-Jones 1990); and low-stress handling of food-producing animals can lead to improved growth and reproduction (Hemsworth & Coleman 1998).

There are, of course, many important exceptions and limitations to the relationship between positive animal welfare and benefits to human keepers. First, artificial incentives can encourage people to act in ways that are harmful to animals. For example, high-value animal products are produced by restricting access to iron and forage in calves raised for 'white' veal, and by force-feeding birds to produce *foie-gras* from pathologically fat livers (Morisse *et al* 1994; SCAHAW 1998). The criteria used to judge show dogs, and commercial incentives for production animals, can encourage genetic selection for extreme traits at the expense of the health and longevity of the animals (Rauw *et al* 1998; McGreevy & Nicholas 1999; Sandøe *et al* 1999).

Second, economic constraints can discourage or prevent animal-keepers from taking actions that would benefit animals. As examples, animals may be given very limited living space because farm buildings are costly to construct and maintain; the income from production animals may be too low for farmers to afford vaccines and other products that would promote animal health; and attention to sick animals may not be economical if the cost of farm labour and veterinary assistance is high (Rollin 2004; Fraser 2008b).

The keeping of animals raises a wide range of scientific, practical and ethical challenges. One scientific and practical challenge is to find better animal-care practices that also benefit animal-keepers and are therefore likely to be adopted. Another is to identify and eliminate economic and other constraints that stand in the way of better animal care. Some important ethical issues are: what form and level of care are ethically appropriate for veterinarians and owners of companion animals (Morgan & McDonald 2007)?; how should one decide whether to rehabilitate or euthanise injured wild animals (Dubois & Fraser 2003)?; and can a high level of care justify the use of animals for purposes such as labour or food production?

Type 2 −Causing deliberate harm to animals

Harm to animals is deliberate and inherent in activities such as slaughter and 'pest' control, but usually there are ways of conducting these activities that result in better or worse outcomes for the animals.

In the hunting of wildlife and the slaughter of food animals, although death is caused intentionally, animal suffering is a common but often unnecessary by-product. Red deer (*Cervus elaphus*), for instance, can be killed by expert shooters with much less distress than is caused by hunting with dogs and horses

(Bradshaw & Bateson 2000). Animals destined for slaughter can be rendered unconscious so that they do not suffer from the physical damage that leads to death; and even where slaughter is done on conscious animals, methods that cause very little pain are available (Cohn-Sherbok 2006). In the capture of fish, pain and distress can be reduced by a range of options such as killing the fish by percussive or electrical means rather than suffocation (Mood 2010), and by various changes to angling practices (Cooke & Sneddon 2007).

In controlling pest or dangerous animals, people commonly seek either to limit animal populations or to restrict animal movement, but not to cause suffering nor, in certain cases, the death of the animals. In some circumstances, non-lethal methods can be used to deter dangerous wildlife (Hristienko & McDonald 2007), and surgical neutering can be used instead of the mass killing of over-abundant dogs and cats (Molento *et al* 2005). Where animals are to be killed, certain trapping methods and certain poisons can cause relatively quick death whereas others cause prolonged suffering (Sainsbury *et al* 1995; Mason & Littin 2003; Warburton *et al* 2008).

Harmful procedures are inherent in much animal-based research, for example in toxicology testing and genetic manipulation of animals to create disease models. Here again, however, unnecessary suffering can often be prevented by the use of analgesics and humane endpoints (Stokes 2000).

The ethical issues raised by Type 2 activities have been a major focus of animal ethics philosophy, with active debate on such practices as hunting, animal experimentation, and killing animals for food (eg Sandøe & Christiansen 2008). The traditional ethical challenge has been to decide when, if ever, deliberate harm is justified, for example by benefits to the animals themselves (as in killing animals to end suffering), or by benefits to people (as in controlling animal disease vectors). The scientific and practical challenges include finding ways to achieve desired outcomes, such as managing pests or obtaining animal-based food, without causing the additional, unintended harm of animal suffering.

Type 3 −Causing unintended harm to animals

In some specific cases, Type 3 activities have attracted ethical concern and scientific attention. For example, the many bird deaths caused by windows and night-time lighting have attracted research (eg Klem 2009), and some municipalities have taken steps to reduce the problem (City of Toronto Green Development Standard 2007). Concern also arises over spectacular events such as major oil-spills (Ford *et al* 1996).

In a great many cases, however, Type 3 activities have attracted remarkably little attention or concern. As noted above, although the ongoing dumping of machine oil from ships probably kills more birds than occasional spectacular oil spills, it receives little attention; and whereas hunting has attracted great attention among animal ethicists (eg Kheel 1996; Gunn 2001), driving cars — which almost certainly kills and injures vertebrate animals in greater numbers — has received almost none.

Type 3 activities raise important challenges for both animal ethics philosophy and animal welfare science. In many cases, the first challenge is to create basic recognition of the problem so that it can be taken into account in scientific research and moral decision-making.

In some cases, simple recognition of a problem can suggest a solution. For example, once it is recognised that cutting hay can cause injury and death to ground-nesting birds, the problem can be mitigated by delaying the cut until young birds have fledged (Nocera *et al* 2005).

In other cases, research is needed to understand the causal mechanisms in order to find options for mitigation. For example, research showed that many vehicle accidents involving moose (*Alces alces*) in

central Canada occur because the animals are attracted to roadside water containing highway de-icing salt (Fraser & Thomas 1982); this information then led to preventive measures such as draining or sign-posting places where salty water accumulates. Similarly, once research had shown that the recent massive die-off of vultures (*Gyps* spp) in the Indian subcontinent was caused by residues of the drug diclofenac in livestock carcases (Oaks *et al* 2004), it was possible to recommend an alternative drug for veterinary use (Pain *et al* 2008). The recognition that many night-flying birds are disoriented by the lighting of communication towers prompted the mitigative action of using flashing lights rather than steady lights, and the bird mortality rate was greatly reduced (Gehring *et al* 2009).

Some Type 3 activities constitute conservation problems, especially if whole populations or species are threatened. In such cases, there is an obvious opportunity for animal welfare scientists and conservation biologists to work toward shared goals. However, other cases, such as the destruction of common rodents by agricultural practices, are of little interest to conservationists, even though the animal welfare implications may be severe. The challenge for animal ethicists is to incorporate unintentional harms into ethical decision-making (Fraser 1999; Davis 2003; Lamey 2007). The practical and scientific challenges are to identify the scope and severity of such harms, and to find ways to achieve human objectives while causing as little unintentional harm as possible.

Type 4 − Harming animals indirectly by disturbing ecological systems and the processes of nature

Type 4 activities — pollution, climate change, introduction of foreign species, etc — are often major concerns for conservation and/or human health and well-being. Problems of animal welfare seem likely to exist in most such cases. The release of toxic chemicals, the introduction of new diseases, and the destruction of habitat all seem likely to cause such classic animal welfare problems as fear, pain and illness to individuals, as well as the population-level effects that are of concern to conservationists. Similarly, when the introduction of exotic species causes major declines in native species, it seems likely that individuals will suffer as a result. Even more subtle effects on populations may have implications for animal welfare. For example, when fragmentation of habitat leads to the loss of top predators (eg, cougars [*Felis concolor*], coyotes [*Canis latrans*]), the resulting increase in 'meso-predators' (eg, foxes, cats, raccoons [*Procyon lotor*]) causes populations of small prey to decline (Crooks & Soulé 1999); this seems likely to also cause fear and distress among prey species subjected to such abnormal levels of danger. Likewise for predators, Paquet and Darimont (2010) propose that many of the remnant populations of large carnivores in North America now live in 'wilderness ghettos' where survival is possible but where the animals have poor quality of life because of human disturbance, habitat fragmentation and other challenges.

Type 4 activities raise formidable scientific, practical and ethical challenges. Scientifically, the animal welfare effects of soil erosion or coastal dead zones may be impossible to quantify, but by applying a science-based understanding of animal welfare it may be possible to create plausible scenarios of how such disturbances are likely to affect animals; these scenarios may then be taken into account in predicting impacts and developing mitigation strategies. A practical challenge will be to identify interventions that are positive for animal welfare as well as for conservation and human well-being. A challenge for animal ethicists is to include harms to animal welfare alongside existing concerns regarding conservation and human interests.

Discussion

Animal ethics philosophers have often treated the keeping of animals (Type 1 activities) and deliberate harm to animals (Type 2 activities) as a single category commonly called 'animal use'. This is reasonable when the goal is to decide whether a particular use of animals is ethically acceptable. Thus, for example,

Singer (1990) discussed both the raising and the killing of farm animals when he considered whether animals ought to be used to produce food. Collapsing animal-keeping and deliberate harm into a single category is also reasonable in cases where rearing methods are so harmful, and care is so minimal, that the entire process can plausibly be seen as a form of harm.

However, treating animal-keeping and deliberate harm as separate issues can be useful in finding practical ways to improve animal welfare. Since improved care often benefits both the animals and their keepers, a general strategy for improvement is to find options that are mutually beneficial and hence are likely to be adopted in practice (Fraser *et al* 2009). In contrast, cases of deliberate harm call for the strategy of finding ways to cause the intended harms (such as death) without also causing unintended harms (such as suffering).

As noted above, neither animal welfare science nor animal ethics philosophy has devoted much attention to Type 3 and 4 activities. Yet by any criterion of animal welfare—health, suffering, ability to live a natural life — the unintended effects of human activities must be viewed as affecting animal welfare to an enormous extent. Moreover, such issues would be seen as morally problematic by most theories of animal ethics. For example, destroying the food and shelter of billions of mammals by ploughing fields would almost certainly be of concern within utilitarian theory (Singer 1990), and by some criteria might constitute a violation of animal rights.

Why have such activities received so little attention? Unintended harms to animals have been recognised at least since the poet Robert Burns (1786) recorded his regret at destroying the nest of a mouse when ploughing a field. The tendency to ignore these harms, by both animal welfare scientists and animal ethics philosophers, is likely due to a combination of historical and philosophical reasons.

Historically, animal welfare research was undertaken to address ethical concerns about the use of animals; and in the late 20th century when the science was beginning, much of the popular concern was focused on food production (Harrison 1964) and animal-based research (Ruesch 1978). Therefore, it is not surprising that these became the initial topics of research. Until there is public concern about unintentional harms to animals, the amount of research on the topic is likely to remain limited.

In the case of philosophy, ethicists have traditionally tended to attach greater weight to intentional acts than unintentional ones. Thus, killing another person deliberately (murder) is seen as a greater crime than killing accidentally (negligence), and philosophers have sometimes invoked similar logic to down-play the ethical significance of harms caused indirectly to animals (Lamey 2007). In some contexts this view reflects a certain logic: a murderer may plausibly be seen as a dangerous person who requires more intervention than a person who is merely careless. However, if many of the harms that people cause to animals are unintentional, and if these harms are likely to continue unnoted and unabated unless we make deliberate efforts to curb them, then it is difficult to argue that unintentional harms deserve less attention. In fact, unintentional harms deserve special attention because preventing these harms will require recognition and sensitisation in addition to practical solutions.

To take Type 3 and 4 activities into the ambit of animal welfare science will require an expansion of the data that scientists consider. Information drawn from ecology will be needed, for example to identify how pollution, transportation and other activities affect the health and survival of animals. In many situations there will be an obvious synergy with conservation biology, particularly in cases where an animal welfare problem also constitutes a problem of conservation. Even where no conservation problem exists (as in the destruction of abundant rodents by agricultural practices) the methods used by conservation biologists may be needed to identify and address the animal welfare problems (Fraser 2010).

Similarly, for philosophers to incorporate Type 3 and 4 activities into animal ethics, their focus would need to broaden from immediate, direct and deliberate actions, such as slaughter and hunting, to include the long-term, unintentional and indirect effects on animals of activities such as transportation, forestry and urban development. A key issue will be to make ethical decisions about actions such as driving cars and using paper that may seem innocuous when done by individuals but cause vast harm to animals when done by billions of people.

In the English-speaking world, ethical concern over animals during the 1700s and 1800s was focused largely on preventing acts of cruelty as part of a broader programme of moral improvement (Fraser 2008a). In the 1900s, the focus expanded to include institutionalised forms of animal use, especially in food production and science. In the 2000s, when an unprecedented human population will lead to unprecedented levels of construction, land use, transportation, manufacturing, travel and other activities that harm animals, ethical concern over animals must expand again to include the unintended and indirect harms which may well be or become among the most significant types of harm caused to other species.

Animal welfare implications and conclusion

Different types of human activities — keeping animals, causing deliberate harm to animals, causing unintended harm to animals, and harming animals indirectly by disturbing ecological systems and the processes of nature — raise different challenges for animal ethics and animal welfare science. Managing the resulting harms, or even recognising and understanding them, will require that we adopt different strategies for different types of activities, and that we broaden the focus of animal welfare science and animal ethics philosophy.

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