The invisible harm: land clearing is a significant issue of animal welfare

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Abstract
Land clearing is a significant environmental issue in Australia and an area of active legislative reform. Despite evidence of the harm that land clearing causes to individual animals, such harm is either ignored or considered only indirectly in environmental decision-making. We argue that the harm that land clearing causes to animals ought to be identified and evaluated in decision-making relating to land clearing and consider three propositions in support: (1) land clearing causes deaths that are physically painful and psychologically distressing because of their traumatic and debilitating nature; (2) pain, psychological distress, physical injuries and other pathological conditions arising from land clearing will occur over a prolonged period as animals attempt to survive in the cleared environment or in environments they are displaced to; and (3) based on current clearing rates, more than 50 million mammals, birds and reptiles are likely to be killed annually because of land clearing in Queensland and New South Wales.

The scientific consensus about the harm caused by land clearing means that decisions to allow land clearing are decisions to allow most of the animals present to be killed and, as such, frameworks for decision-making ought to include proper evaluation of the harm to be imposed.

Additional keywords:
land clearing, animal welfare, harm, wildlife, mortality, morbidity, injury, stress, environmental decision-making
Introduction

Animal welfare is an increasingly significant component of environmental decision-making involving wildlife, whether the underlying decision relates to the conservation, exploitation or control of a species (Bradshaw and Bateson 2000; Twigg and Parker 2010; McMahon et al. 2012; Hampton et al. 2014; Descovich et al. 2015; Beausoleil et al. 2016). Factors that have influenced that shift in Australia include the evolution of animal welfare statutes in the Australian states and territories; government and non-government initiatives to communicate welfare issues (e.g. RSPCA Australia 2002; Cogger et al. 2003; Johnson et al. 2007; Commonwealth of Australia 2011; McLeod and Sharp 2014); and improvements in our understanding of how wild animals respond to non-lethal interactions with anthropogenic stressors (e.g. Bejder et al. 2009; Johnstone et al. 2012a; Brearley et al. 2013; van der Hoop et al. 2016; Tablado and Jenni 2017).

One consequence of this shift has been the development of objective and transparent procedures for the identification and assessment of the harms that human activities cause to individual animals, so that those harms can be appropriately weighed against the perceived benefits of the activity (Sharp and Saunders 2011; Calver 2012; Beausoleil et al. 2016). However, the integration of such harm-benefit frameworks into environmental decision-making has been uneven and it might fairly be said that we are currently better at identifying and evaluating certain harms than others. Further, there are some human activities for which no effective procedure exists for the identification and evaluation of harms caused to individual animals. The harm caused to native wildlife by land clearing is one example.

The basic premise of this article is that the deaths, physical injuries, other pathological conditions, pain and psychological distress experienced by individual wild animals during and
after land clearing is a harm of sufficient intrinsic value that it ought to be identified and evaluated in decision-making, including in: assessments of applications for permits (or other authorisation) to clear native vegetation, assessments of planning or development proposals that will require land clearing, and strategic planning initiatives in which land clearing is contemplated (e.g. Department of the Premier and Cabinet 2015). Currently the harm that land clearing causes to the welfare of individual animals is either ignored in such decision-making or is considered only in instrumental terms, as when decision-makers focus solely upon the population-level effects of the loss of individuals that will result from a proposed clearing action.

To support this premise, we seek to demonstrate three basic propositions, namely that: (1) land clearing causes deaths that are physically painful and psychologically distressing because of their traumatic and debilitating nature; (2) animals will experience pain, psychological distress, physical injuries and other pathological conditions (i.e. morbidity) over a prolonged period as they attempt to survive in the harsh and unsuitable environment of the cleared area or in the environments they are displaced to; and (3) land clearing is likely to kill more than 50 million mammals, birds and reptiles in Queensland and New South Wales each year based on current clearing rates.

In advocating for greater consideration of the harm that land clearing causes to individual animals in environmental decision-making, we do not wish to minimise or disregard the tension that may arise between the objectives of conserving populations and species and those focused upon preventing harm to individual animals (Fulton and Ford 2001; White 2009; Paquet and Darimont 2010; Twigg and Parker 2010; Cooney et al. 2012; Jones et al. 2012; Lunney 2012a,b; Harrington et al. 2013). Rather, we seek here to set out a normative basis for why the
harm that land clearing causes to individual animals ought to be considered as a relevant and significant harm in its own right.

The article uses terminology commonly applied in wildlife pathology and in wildlife forensic investigations (see Vogelnest and Woods 2008; Ladds 2009; Cooper 2013a,b; Vogelnest and Allan 2015, as well as materials supported by the Australian Registry of Wildlife Health at http://arwh.org/common-diseases). Definitions and relevant references for some terms are given in Table 1. Although the focus here is on harm to mammals, reptiles and birds, the issues are broadly applicable to other vertebrates (e.g. frogs: Hazell 2003) and to invertebrate species (Valentine 2004), though we note relevant differences across taxa in terms of (e.g.) the perception of pain and the experience of psychological distress (Koolhaas et al. 1999; Paul-Murphy et al. 2004; Wingfield 2005).

**Land clearing in an Australia context**

The conversion of native vegetation to other land uses, or ‘land clearing’, remains a fundamental pressure on the Australian environment (Jackson et al. 2016). Evans (2016) describes ‘land clearing’ as the ‘local term for deforestation’ in her analysis of the clearing and modification of native forest in Australia for agricultural, urban and industrial development. The amount of native vegetation that is cleared annually in Australia for those purposes is significant on global terms (Bradshaw 2012; Ritchie et al. 2013; Evans 2016). Systematic monitoring of clearing rates for native vegetation is undertaken in some jurisdictions. In Queensland, for example, the total state-wide woody vegetation clearing rate was reported to be 296 000 ha/year in 2014/15 (ie an area of approximately 54 km x 54 km), of which 91% was undertaken to convert land to pasture with the remaining 9% involving clearing for cropping, forestry, mining, infrastructure or settlement (Department of Science, Information
Technology and Innovation 2016). In New South Wales, a reduction in woody vegetation of 40 500 ha was reported for 2011–12 and 105 900 ha for 2012–13, with fire and forestry accounting for most of those losses (Office of Environment and Heritage 2016). The rates of woody vegetation loss due to clearing for cropping, pasture, infrastructure, and thinning in New South Wales were reported to be about 13 000 per year for 2011-2012 and 2012-2013 (Environment Protection Authority 2015; Office of Environment and Heritage 2016). The New South Wales figures are controversial, with suggestion that they may substantially under-estimate clearing rates in that state (Hannam 2016a,b).

Across Australia, the national State of the Environment report for 2016 reported the following total deforestation rates for the Australian states and territories for the period 2010-2014, based on deforestation data reproduced from Evans (2016): New South Wales (297 482 ha), Northern Territory (7 232 ha), Queensland (477 555 ha), South Australia (49 534 ha), Tasmania (17 163 ha), Victoria (54 941 ha), and Western Australia (119 231 ha) (Metcalfe and Bui 2016). Illegal native vegetation clearing also remain an issue in Australia (Bricknell 2010), with ‘unexplained clearing’ accounting for a significant proportion of total woody vegetation clearing detected by satellite monitoring in New South Wales (Office of Environment and Heritage 2014).

Regulatory frameworks for land clearing in Australia

Evans (2016,) describes New South Wales, Queensland, South Australia, Victoria and Western Australia as the ‘historically high-deforestation states’ in Australia. The regulatory frameworks for land clearing in those states typically consist of a complex amalgam of statutes, statutory instruments (e.g. regulations), policies, and guidance and technical materials (see COAG Standing Council on Environment and Water 2012; Evans 2016). Three observations may be
made about the consideration that wild animal welfare receives within the regulatory frameworks for land clearing in those states.

First, the frameworks do not expressly recognise harm to the welfare of individual wild animals as a relevant category of harm. Those frameworks all identify particular harms that land clearing is said to cause, either as part of a list of statutory objects for the principal acts (e.g. section 3 of the New South Wales *Native Vegetation Act 2003* and section 3 of the Queensland *Vegetation Management Act 1999*) or as part of a list of principles said to guide decision-making about native vegetation clearance (e.g. schedule 5 of the Western Australian *Environmental Protection Act 1986*, schedule 1 of the South Australian *Native Vegetation Act 1991*, and clauses 52.16-6 and 52.17-5 of the Victoria Planning Provisions). The harms identified in those statutory objects and lists of principles include: loss of biodiversity, loss or fragmentation of habitat for native species, land degradation, salinity, deterioration of surface or underground water quality, and greenhouse gas emissions. Notably absent from the compendium of harms contained in those objects and principles is the harm that land clearing causes to the welfare of the animals using that vegetation. Similarly, considerations of animal welfare are not mentioned in *Australia’s Native Vegetation Framework*, which was intended to provide a national policy framework to guide the ecologically sustainable management of Australia’s native vegetation (COAG Standing Council on Environment and Water 2012).

Second, those regulatory frameworks do not require decision-makers to identify and evaluate the harm that a proposed clearing action may cause to the welfare of individual animals. None of the four principal acts indicated in the paragraph above nor the Victoria Planning Provisions contain any provision or clause that expressly require decision-makers to take animal welfare considerations (i.e. the causing of pain, physical injuries, other pathological conditions, and
psychological distress to individual animals) into account when making a decision in relation
to proposed clearing actions.

Three, some indirect consideration of harm to individual animals may occur if decision-makers
are required to evaluate the potential impact of a proposed clearing action on a threatened
species or to assess the value of vegetation proposed for clearing as habitat for that species. For
example, threatened species assessment guidelines issued and enforced under s 94A of the New
South Wales *Threatened Species Conservation Act 1995* provide for the evaluation of direct
and indirect impacts of proposed developments, including land clearing, on individuals and
their habitat (Department of Environment and Climate Change 2007). Nonetheless, the focus
of those impact assessment guidelines, similar to guidelines in other Australian jurisdictions
(e.g. Commonwealth of Australia 2013; Department of Environment and Heritage Protection,
undated; Environmental Protection Authority 2016), is on population-level impacts. Further,
as was observed by Thompson and Thompson (2015, page 223), ‘rarely, if ever, are impacts
on the non-threatened fauna seriously considered in the [environmental impact] assessment
process and mitigation strategies included in the approval conditions’.

For reasons of length it is not proposed here to set out any particular mechanisms by which the
harm caused to animals could be integrated into decision-making for land-clearing.
Nonetheless, it is relevant to point out that there are a range of potential statutory mechanisms,
including: the express extension of statutory prohibitions on the taking of fauna to the
circumstances of land clearing; the statutory expression of considerations or principles relating
to animal welfare that decision-makers are required to consider in assessing applications to
clear native vegetation; and statutory requirements for applicants or proponents to provide
estimates of native fauna mortality likely to occur if a proposed clearing action proceeds.
Statutory changes could be complemented by the development of policy-based mechanisms, including assessment methodologies to appropriately identify and evaluate harms from land clearing actions. A key point is that the objective of making considerations of individual animal welfare legally relevant to decision-making about land clearing does not necessarily prescribe any particular mechanism by which that might be done.

**Why the issue is relevant for wildlife researchers and managers and other environmental professionals**

An evaluation of the harm that land clearing causes to wildlife may seem unnecessary as there would appear to be little scientific controversy as to the basic proposition that clearing native vegetation kills animals living at that site (Ehmann and Cogger 1985; Glanznig 1995; Williams et al. 2001; Cogger et al. 2003; McDonald et al. 2003; Department of the Environment 2006; Johnson et al. 2007). Nonetheless, there are several reasons why it is timely to review the harm that land clearing causes in a journal read by wildlife researchers and managers and environmental consultants, as well as by other environmental administrators and professionals.

First, regulation of the clearing of native vegetation remains an active area of legislative reform in Australia (Evans 2016). For example, in November 2016, following the release of a review of New South Wales biodiversity legislation in December 2014 (Byron et al. 2014) and a package of proposed biodiversity and land management reforms by the New South Wales Government in May 2016, the New South Wales Parliament passed the *Biodiversity Conservation Act 2016* and the *Local Land Services Amendment Act 2016*. Notably, those legislative reforms provided for the repeal of *Native Vegetation Act 2003* and the *Native Vegetation Regulation 2013* (as well as the *Threatened Species Conservation Act 1995*) and the introduction of a new statutory framework for native vegetation clearance in rural areas that
will remove many existing controls on clearing activities. In Queensland, a bill to reform the
Vegetation Management Act 1999 failed to pass the Queensland Parliament following debate
in August 2016. Those legislative reforms had been proposed as a response to increases in land
clearing rates following the repeal or weakening of key statutory restrictions on land clearing
in 2013 by the previous Queensland Government (Department of Science, Information
Technology and Innovation 2016; Metcalfe and Bui 2016).

It is therefore worth emphasising that what the scientific community states, individually and
collectively, about the harm that wild animals suffer because of land clearing can influence
political debate about appropriate regulatory frameworks for land clearing. For example, on 17
August 2016, during the Second Reading speech in the Queensland Parliament for the
Vegetation Management (Reinstatement) And Other Legislation Amendment Bill 2016, Jacklyn
Trad (then Deputy Premier for the Queensland Government) observed:

The fact is Queensland has a shameful history on the issue of broadscale tree clearing. In 1997
we were clearing over 400,000 hectares annually and, according to the Society for Conservation
Biology Oceania’s scientific declaration, it is estimated that 100 million native animals were
dying each year between the years of 1997 and 1999 (Queensland Parliament 2016).

The text of that declaration – signed by over 250 scientists and environmental professionals –
is available at http://scboceania.org/policystatements/landclearing/.

Second, it is axiomatic in conservation biology that local population declines and, ultimately,
extinctions at regional- and species-level scales, are primarily driven by the mortality,
morbidity and reduced reproductive success of individuals (e.g. Saunders et al. 1991; Ford et
al. 2001; Lindenmayer and Fischer 2006; Ford 2011). There is therefore a basic commonality
of interest between concerns about harm to individual animals and efforts focused upon
conserving populations and species (Cogger et al. 2003; Johnson et al. 2007). On that basis,
efforts to integrate consideration of the death, injury and other pathologies caused by land clearing into environmental decision-making should also support better conservation outcomes.

Third, on-going debate over the efficacy of offsets for land clearing (Gibbons and Lindenmayer 2007; Maron et al. 2015, 2016; May et al. 2016; Sonter et al. 2016) and of programs to capture and translocate animals from sites to be cleared (Germano et al. 2015; Thompson and Thompson 2015, 2016; Menkhorst et al. 2016) suggest a need for careful consideration of the precise harm that the removal of vegetation may cause to individual animals present at that site, so that such information can then assist in environmental decision-making. In particular, such information is necessary to support appropriate applications of the mitigation hierarchy, robust evaluations of potential offset measures for residual impacts, and adequate assessments of the overall significance and acceptability of impacts from land clearing.

Finally, the clearing of native vegetation for agricultural, urban and industrial development is clearly analogous to the practice of clearcutting in forestry, and thus investigation of wildlife responses to clearcutting may also yield insights for decision-makers assessing proposed land clearing actions (Semlitsch et al. 2009; Blumstein 2010). For example, studies of the behaviour and fate of individual animals after clearcutting have investigated whether observed declines in abundance reflect mortality associated with clearcutting, displacement into adjacent forest, or other processes (Tyndale-Briscoe and Smith 1969; Miller et al. 1997; Di Stefano et al. 2007; Semlitsch et al. 2008; Escobar et al. 2015).

Evaluating the harm that land clearing causes
The article deliberately uses the word ‘harm’ to describe the deaths, injuries and other pathological conditions (i.e. morbidity) that animals may suffer when vegetation is cleared for two reasons.

First, the term ‘harm’ carries with it connotations of physical injury and deliberate intent. While noting that individuals of some species may disperse to other habitats (if such habitat is available) when vegetation is cleared, the clear scientific consensus is that most, and in some cases all, of the individuals present at a site will die as a consequence of that vegetation being removed, either immediately or in a period of days to months afterwards (Cogger et al. 2003; McDonald et al. 2003; Johnson et al. 2007).

That consequence is an important basic consideration for environmental decision-making because it means that any decision to clear native vegetation (or to allow it to be cleared) is also a decision to kill most or all of the individual animals inhabiting that vegetation (or to allow them to be killed). While a person who clears land may not desire for animals to suffer, suffering is the inevitable consequence of the decision to do so. The relevant question for decision-making is not if death, injury and other pathology will occur when land is cleared, but how much of that harm will occur, how severe it will be, and whether it ought to be avoided. If such harm is nonetheless deemed necessary, then the question is how the harm to be imposed could be minimised.

Broadly speaking, as a question of animal welfare, the removal of native vegetation may harm individual animals by causing some immediate or longer-term adverse change to their physical or mental state, either directly (e.g. by causing traumatic injury through the application of mechanical force during the clearing process) or indirectly, when animals interact with harmful
physical and biological agents (e.g. inimical microclimates, absence of food, predators, aggressive conspecifics) present in the cleared environment itself or in the environment(s) the animal is displaced to. While efforts are sometimes made to distinguish between ‘direct’ and ‘indirect’ harms in environmental impact assessment (e.g. the New South Wales threatened species assessment guidelines differentiate between ‘direct impacts’ and ‘indirect impacts’; see Department of Environment and Climate Change 2007, pages 3-4), the physical of clearing native vegetation creates environments (or causes animals to encounter environments) where there is a high level of risk of exposure to harmful agents. Thus, land clearing can relevantly be said to place animals ‘in harm’s way’ both during the clearing process and afterwards.


Animal welfare means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear, and distress.

The changes that land clearing causes to the physical or mental state of an animal can be considered in terms of the underlying pathology. Thus, land clearing could be said to ‘harm’ an animal if the clearing of vegetation causes (or leads to the development of) disease in that animal. Disease is here understood in the broad sense of being a departure from or an impairment of the normal structure or function of any part, organ or system of an animal which can be caused by (a) infectious agents (e.g. viruses, bacteria) and/or (b) non-infectious agents
(e.g. physical injuries, nutritional deficiencies) (Wobeser 1981, 2006; Ladds 2009; Jakob-Hoff et al. 2014). Disease can vary in its degree of severity and may have multiple causes.

The second reason for using the word ‘harm’ is to establish a linkage between the harm caused by land clearing and the concept of harm to individual animals that underlies animal welfare legislation in Australia. Notably, several Australian animal welfare statutes include definitions for ‘harm’. For example, section 3 of the South Australian Animal Welfare Act 1985 (SA) defines ‘harm’ to mean any form of damage, pain, suffering or distress (including unconsciousness), whether arising from injury, disease or any other condition, while section 5 of the Western Australian Animal Welfare Act 2002 (WA) defines ‘harm’ to include injury, pain, and distress evidenced by severe, abnormal physiological or behavioural reactions.

The purpose in noting those statutory definitions of ‘harm’ is not to suggest that land clearing is an animal cruelty offence under existing statutory frameworks for animal welfare in Australia, although arguably there may be grounds for a prosecution in some jurisdictions in circumstances where a clearing action is unlawful – on a basis that the suffering of animals was unnecessary because there was no legitimate object (i.e. purpose) for the activity, and where evidence to demonstrate the suffering of an animal is available (Radford 2000; McEwan 2016).

Rather, we highlight the overlap in concepts of harm to demonstrate that land clearing causes harm that is of a character that would be prohibited if such harm were inflicted on an individual wild animal in other circumstances.

The concept of the harm that land clearing causes to animals should also be broad enough to include the adverse mental states (i.e. what we broadly refer to in this paper as psychological distress) that animals will experience as a consequence of experiencing pain, physical injury,
debilitating pathological conditions, and the range of abiotic and biotic stressors they will encounter in environments fundamentally inimical to their survival. A conception of harm that includes mental states is consistent with the concepts of distress and wellbeing applied in the Australian code for the care and use of animals for scientific purposes (8th edition) (National Health and Medical Research Council 2013) and with conceptions of animal welfare used in frameworks for assessing the humaneness of wildlife management actions (Mellor et al. 2009; Sharp and Saunders 2011; Beausoleil et al. 2016).

We now turn to three specific propositions we propose in support of the view that the harm which land clearing causes to individual wild animals ought to be identified and evaluated in as a relevant harm in its own right in environmental decision-making.

Proposal 1: Land clearing causes deaths that are physically painful and psychologically distressing because of their traumatic and debilitating nature

Land clearing involves the removal of some or all of the above-ground biomass of native vegetation present at a site, as well as the destruction of burrows, middens and termite mounds in or upon the substrate. The methods by which vegetation may be removed are diverse: e.g. plants may be cut, toppled, burnt, ploughed, grazed, ring-barked, poisoned, or otherwise damaged (Australian Greenhouse Office 2000; Seabrook et al. 2006). In most cases, vegetation is removed using machinery designed for earth-moving or forestry operations or, for broad-scale clearing, by dragging a chain between two tractors (Turnbull et al. 1992; Fulton and Majer 2006; Harris et al. 2010; Gleeson and Gleeson 2012; Thompson and Thompson 2015). Fallen vegetation is often pushed into piles of residue that are later removed, burnt, buried, wood-chipped, or allowed to decompose in place (Newell 1999; Department of Industry, Innovation,
The use of machinery to clear vegetation may cause traumatic injury or entrapment (i.e. physical confinement or burial within hollows, burrows or other cavities, underneath fallen stems or branches or other debris, or within soil or other matter) (Shine and Fitzgerald 1996; Rhind 1998, 2004; Cogger et al. 2003; Johnson et al. 2007; Andrews et al. 2008; Hanger and Nottidge 2009; Gleeson and Gleeson 2012; Thompson and Thompson 2015).

Possible outcomes include death arising from traumatic injury or non-drowning asphyxiation due to suffocation, as well as pain and shock. Forms of traumatic injuries that animals may experience as a result of land clearing include: compression injury, penetrating injury, laceration, degloving injury, amputation, fracture, joint luxation/subluxation, and blunt force injury to the skeleton, soft tissues, and central nervous system, and internal haemorrhage. Those injuries may be sustained through contact with vegetation (e.g. as it is felled or shifted after felling), soil, machinery, motor vehicles, or containment barriers.

Thompson and Thompson (2015) undertook a catch and relocation program for reptiles, amphibians and mammals during vegetation clearing at a coastal site in the Pilbara region of Western Australia and found that survivorship during clearing operations differed by the type of machinery used in clearing operations (e.g. dozer, excavator, loader) and by taxa. They observed that survivorship in the clearing process appeared to reflect the ‘preferred retreat site’ and movement speed of animals as well as the manner in which the vegetation was removed and the substrates disturbed.
Animals that live in tree hollows, either in living trees or in woody debris, may be injured, crushed, suffocated or entrapped when vegetation is felled and pushed into piles and substrates are disturbed (Rhind 1998, 2004; Hanger and Nottidge, 2009; Thompson and Thompson 2015). Clearing often involves the shifting of soil by machinery, which may capture, bury and crush animals present on the surface, in the soil or in termitaria (Thompson and Thompson 2015). Animals that shelter in debris piles may suffer burns or be incinerated when the piles are set alight or killed when the vegetation is transported, sawn or ground to woodchips.

The size of arboreal animals and the capacity for flight may affect whether they are killed or seriously injured when trees are felled. A study of the effects of logging on brush-tailed phascogales (*Phascogale tapoatafa*) in the Jarrah forest in southwestern Australia assessed the fate of phascogales and two possum species (western ringtail possums *Psuedocheirus occidentalis* and brushtail possums *Trichosurus vulpecula*) when trees were felled during logging operations (Rhind 1998, 2004). Rhind (2004) reported that three radio-collared phascogales who were present in trees when they were felled survived without apparent injury but that, of 65 possums found in the hollows of felled trees over an area of about 63 ha in a 12-week period, 17% had died when the tree was felled. Tyndale-Briscoe and Smith (1969) reported that the number of sugar gliders killed at tree fall was small and that most were able to escape the effect of impact by gliding free of the tree. Newell (1999) reported that Lumholtz’s tree-kangaroos (*Dendrolagus lumholtzi*) remained in the tree or vine thicket they were using until a bulldozer approached the tree or a chainsaw had nearly toppled it, then leapt from the tree and quickly hopped away.
A draft code of practice developed for the welfare of animals affected by land clearing in Queensland includes descriptions of the deaths and injuries that animals may experience when land is cleared (Hanger and Nottidge 2009). The authors were then from the Australian Wildlife Hospital (now the Australia Zoo Wildlife Hospital) and could speak to the injuries suffered by animals because of land clearing through their own first-hand experience of them. The traumatic injuries and issues of entrapment that may arise when land is cleared were described in these terms:

Animals injured directly in the process of vegetation clearing generally suffer from major crushing, deceleration or fall related injuries. Arboreal species may suffer from trauma associated with falling from a tree and/or crushing and avulsive injuries associated with boughs falling on or beside them. Such injuries include severe internal bleeding and organ disruption, multiple bone breaks, eye and head injuries. Animals resting in hollows, similarly, may receive crushing injuries if the hollow bough disintegrates, or suffer internal organ injuries and tearing as a result of rapid deceleration (deceleration injury).

Ground dwelling animals, such as bandicoots, echidnas, snakes and lizards most commonly suffer from crushing and avulsive injuries (such as traumatic limb amputation), or may be buried alive during earthworks.

Highly mobile species such as birds and macropods may avoid direct injury by machinery, but may suffer injuries by running into fences, motor vehicle strike or other misadventure.

Injuries suffered by animals during land-clearing vary from mild to severe and fatal, but these animals are only rarely presented to wildlife hospitals or shelters. This is primarily because they are less likely to be discovered by members of the community and are more usually buried or confined in piles of debris during the process of clearing, which are then subsequently burnt or chipped (page 6).

We will deal further with the physical pain and psychological distress associated with debilitating conditions below, but it should be obvious that the types of traumatic injuries inflicted by land clearing cause tissue damage that will result in severe physical pain (see Bateson 1991; Weary et al. 2006). Animals will also experience the adverse mental states associated with the subjective experience of pain and with their cognitive assessment of their circumstances (including the experience of being smothered or physically entrapped) (Machin...
Proposition 2: Pain, psychological distress, physical injuries and other pathological conditions occur over a prolonged period as animals attempt to survive in the cleared environment or in other environments they are displaced to.

Animals that survive the clearing process and who remain at the cleared site are left to inhabit a harsh and radically altered environment that is generally inimical to their survival (Tyndale-Briscole and Smith 1969; Newell 1999; Bladon et al. 2002; Cogger et al. 2003; Fulton and Majer 2006; Johnson et al. 2007; Thompson and Thompson 2015). Likewise, animals that leave the cleared site may encounter environments that are (e.g.) unfamiliar (Powell and Mitchell 2012), unsuitable (Sato et al. 2013), or hostile (Doherty et al. 2015).

Many native species show strong attachments to small areas of habitat and have relatively low mobility and thus, if vegetation is removed from a site, most individuals will not disperse to adjacent habitat (if such habitat is available), but will remain at or near the cleared site (Newell 1999; Cogger et al. 2003; Johnson et al. 2007; Kavanagh et al. 2007; Brown et al. 2008). Containment barriers around the area where clearing occurs may prevent those animals that do manage to avoid land clearing activity from actually being able to leave the cleared area (Environment and Communications References Committee 2017, paragraph 2.22).

Even if individuals are able to leave the cleared site, they are likely to die or to suffer physical injury or other pathological conditions because of the predators and other environmental challenges (including road strikes and other anthropogenic impacts) they will encounter, both
in the environments they disperse through and in the habitat they are ultimately displaced to (Fischer and Lindenmayer 2000; Bennett 2003; Cogger et al. 2003; Johnson et al. 2007; Guy and Banks 2012; Armstrong et al. 2015; Menkhorst et al. 2016; Gonzalez-Astudillo et al. 2017). Further, a new habitat, if suitable, may already be occupied by conspecifics, which may lead to hostile interactions, competition for resources, and infectious disease transmission because of increased population density (Cogger et al. 2003; Wobeser 2006; Ladds 2009; Sainsbury and Vaughan-Higgins 2012; Pacioni et al. 2015). A new habitat may also result in contact with new species, who may act as either vectors for infectious disease or reservoirs for hitherto novel infectious diseases (Wobeser 2006). Even if dispersal is initially successful, the ultimate harm of dispersing to another habitat might not manifest until sometime later (McAlpine et al. 2017).

The clearing of vegetation from a site removes or substantially alters the habitat features present, including: the abiotic environmental conditions (e.g. temperature, humidity); the availability of resources (e.g. shelter/cover, food resources, water); and the biotic and social environment (e.g. the presence or absence and abundance of prey, predators, conspecifics, interspecific interactions with novel species including potential infectious disease vectors or reservoirs) (McIntyre and Hobbs 1999; Ford et al. 2001; McAlpine et al. 2002; Cogger et al. 2003; Kanowski et al. 2003; Wardell-Johnson et al. 2004; Pearson et al. 2005; Wobeser 2006; Johnson et al. 2007; Craig et al. 2012).

The range of harms that may occur as a consequence of those changes include but are not limited to: pain from tissue damage sustained through physical injury or other pathological conditions; predation; temperature-related injuries; stress-related pathology (e.g. adverse effects on reproduction, adversely affected immune function, suppression of growth);
secondary infection and shock/sepsis arising from injuries sustained during clearing or afterwards; maladaptation; misadventure; exertional myopathy; nutritional disease; infectious disease; dehydration; and increased likelihood of infectious disease transmission (see Table 1).

It is not feasible to discuss all of those harms here. However, the harms associated with stress-related pathologies deserve some comment as they are complex and are an area of active research for Australian species (Brearley et al. 2013; Bradshaw 2015; Narayan 2015; Hing et al. 2016; McAlpine et al. 2017). Notably, physiological stress responses to human-modified landscapes have been documented for several Australian marsupials (Brearley et al. 2012; Johnstone et al. 2012b; Davies et al. 2013; Hing et al. 2014; Narayan and Williams 2016).

An environment in which vegetation has recently been removed will present animals with multiple persistent and potentially interactive environmental stressors, both biotic (e.g. interactions with predators, food availability) and abiotic (e.g. suboptimal temperatures) (Wingfield 2005; Saunders et al. 2011; Sih et al. 2011; Schulte 2014; Hing et al. 2016; Narayan and Williams 2016; Schoepf et al. 2016). Where exposure to stressors is acute, an animal may mount a suite of behavioural and physiological responses in adaptation to the stressors (i.e. an allostatic response) and experience no lasting detriment to their health (McEwen 2005; Wobeser 2006; Schulte 2014). However, the intensity and duration of the stressors present in cleared environments are such that animals are likely to experience maladaptation and chronic stress (Moberg 2000; Gunderson et al. 2016; Narayan and Williams 2016). Further, they may sustain physical injuries which can act as an additional stressor (Ganswindt et al. 2010). In situations of maladaptation and chronic stress, the burden of maintaining adaptive responses to stressors may cause diversion of energy away from physiologic processes or have other deleterious health effects, and predispose the animal to disease (McEwen and Wingfield 2003;
McEwen 2005; Wobeser 2006; Hing et al. 2016). Notably, the immune function of an animal may be adversely affected after chronic physiological stress (Acevedo-Whitehouse and Duffus 2009; Brearley et al. 2013; Hing et al. 2016; Narayan and Williams 2016). Due to the energetic cost of mounting and maintaining an immune response, resource allocation away from such physiologic processes such as growth and reproduction may also result in minimised reproductive effort and adverse reproductive outcomes (Acevedo-Whitehouse and Duffus 2009).

Clearing-related mortality and morbidity in animals that survive the initial clearing process will typically reflect a multifactorial aetiology. For example, Gonzalez-Astudillo et al. (2017) analysed a substantial \( n = 20 \, 250 \) entries) long-term (1997-2013) dataset of koala (Phascolarctos cinereus) records at wildlife hospitals in southeast Queensland to assess causes of morbidity and mortality. The authors identified 11 aetiologies, as well several spatial-temporal clusters (or ‘hotspots’) for the occurrence of particular aetiologies or for combinations of aetiologies. Gonzalez-Astudillo et al. (2017) suggested that these aetiologies were acting together as multifactorial determinants for koala decline in the region and observed that current extensive land clearing in Queensland ‘could be leading to starvation in koalas, an issue that has surprisingly not generated much discussion’ (page 7).

How long animals survive in cleared environments may reflect a range of factors, including: the species and condition of the individuals affected; the prevailing environmental conditions (e.g. summer vs. winter) and water availability; whether vegetation debris is left for a period after clearing; the proximity of other native vegetation; and the ability of predators to access the area (Newell 1999; Cogger et al. 2003; Sih et al. 2011; Schoepf et al. 2016). A study of the effects of habitat fragmentation on eastern pygmy-possums (Cercartetus nanus) found that a
pre-clearing population of at least 15-20 individuals declined to 5-8 animals within 12 months after 30% of the study site was cleared (Bladon et al. 2002). The clearing coincided with the pygmy-possum breeding season and the recruitment of young appeared greatly reduced. Tyndale-Briscole and Smith (1969) found that, following clear-felling of a forest block, few sugar gliders dispersed into an adjacent depopulated area, indicating that most gliders died in situ without migrating out of their original home range. The authors reported that: ‘The process of clear-felling thus results in the death of over 90% of the glider population inhabiting the area, only a few animals on the boundary being able to survive in adjacent forest. The majority lose weight, lose pouch young and presumably die within 1 week of tree fall’ (page 656). Newell (1999) reported Lumholtz’s tree-kangaroos surviving for months within clear-felled forest where debris was retained (prior to its eventual burning to create pasture), but that mortality rates of affected animals appeared to increase after clear-felling, with evidence of predation by domestic dogs or dingoes and also of infectious disease.

Animals who survive the clearing of vegetation but remain at the cleared site are likely to experience pain caused by physical injuries or by debilitating pathological conditions (e.g. malnourishment progressing to starvation, with negative energy balance also predisposing them to increased risk of infectious disease secondary to stress-induced immunosuppression) related to the clearing of vegetation, for periods ranging from days to months after clearing. These animals will also experience adverse mental states that persist (either continually or intermittently) for similar periods because of their: subjective experience of such pain; perception of other physiological states associated with pathological conditions such as thirst, hunger, nausea, dizziness, debility, and fatigue (Mellor et al. 2009); experience of fear or anxiety (or other adverse emotions) relating to the presence (or anticipation) of predators or hostile interactions with conspecifics or other species (Steimer 2002; Morgan and Tromborg
Proposition 3: Land clearing causes substantial mortality

The overall conclusions reached by Cogger *et al.* (2003) and Johnson *et al.* (2007) are strikingly clear – the removal of native vegetation leads to the rapid death of all or nearly all of the birds, reptiles, and mammals present. Cogger *et al.* (2003, page 14) stated that:

One general assumption made in these calculations [of mortality from clearing], based primarily on knowledge of the ecology of a wide range of species, as well as the absence of any evidence that remaining remnant vegetation supports higher densities of a wide range of species following adjacent land clearing, is that the vast majority of animals displaced by clearing will die – either immediately or after a short space of time. Deaths result primarily from physical injury, exposure to lethal conditions of temperature or lowered microclimatic humidity, predation, or lack of food.

Both Cogger *et al.* (2003) and Johnson *et al.* (2007) estimated the scale of mortality from land clearing based on published population densities for birds, reptiles and mammals. These densities were then multiplied by available information on the area (in ha) of native vegetation cleared (in Queensland and New South Wales, respectively) to obtain estimates of mortality from clearing. Cogger *et al.* (2003) estimated that clearing in Queensland between 1997 and 1999 killed about 100 million native birds, mammals, and reptiles per year. Johnson *et al.* (2007) estimated that approved clearing in New South Wales between 1998 and 2005 killed more than 104 million native mammals, birds and reptiles. Both reports emphasised that the estimates were highly conservative and that actual mortality rates were likely to be substantially higher. Taylor and Dickman (2014) conducted a comparison of land clearing and mammal deaths in New South Wales from clearing before and after 2005, and suggested that a decline in clearing rates (and thus also in associated mammal deaths) post-2005 could be attributed to the more stringent clearing controls established by the New South Wales *Native Vegetation Act*
2003, which came into force in 2005. As indicated earlier, that Act is to be repealed as part of
the legislative reforms undertaken by the New South Wales Government in 2016.

The 2006 State of the Environment report for Australia included an indicator (BD-08 Estimated
loss of biodiversity resulting from land clearing) to represent the number of wild animals killed
by land clearing (Department of the Environment 2006). The indicator was expressed as a
measure of the pressure that land clearing places on biodiversity and was based on the
assumption that:

- The immediate effect of clearance of native vegetation on plant and animal species can be
  significant. When land is cleared, everything that lives in it is killed. Estimates of the number
  killed are a direct indicator for this pressure.

The information presented in support of the indicator noted the mortality estimates in Cogger
et al. (2003) and the absence of similar information on clearing-related mortalities on a
continent-wide scale. The information provided for the indicator then stated, as a way of giving
‘a very rough indicator, rather than a serious estimate’, that:

- In the absence of any similar continent-wide study, if the Queensland averages were assumed to
  apply across Australia—a national death toll from land clearing can be extrapolated. AGO
  [Australian Greenhouse Office] remote sensing data suggests that around 424 727 hectares of
  wooded land was cleared across the continent in 2004…Using the WWF averages [a reference
to information provided in Cogger et al. 2003], the animal death toll from this land clearing, in
mammals, reptiles and birds alone, would have been around 95 million animals. Across the 17
million hectares cleared since 1972, approximately 4 billion birds, reptiles and mammals would
have died.

Updated information for the indicator BD-08 did not appear in the 2011 or the 2016 State of
the Environment reports. However, a rough assessment of the current situation can be
undertaken by applying the methodology and fauna density estimates in Cogger et al. (2003)
and Johnson et al. (2007) to the current estimates of clearing rates for (a) each biogeographic
region in Queensland (Department of Science, Information Technology and Innovation 2016) and (b) the state of New South Wales as a whole (Office of Environment and Heritage 2016).

In Cogger et al. (2003) the overall annual clearing rate applied to estimate mortality in Queensland was 445,900 hectares per year, while Johnson et al. (2007) estimated mortality in New South Wales from 1998-2005 based on the amount of native vegetation approved for clearing by the state government across the whole 8-year period (639,930 ha). By comparison, the overall annual woody vegetation clearing rate for Queensland in 2014-15 was 296,000 ha/year (with forestry accounting for only 5% of that amount) (Department of Science, Information Technology and Innovation 2016), while the overall annual rate of woody vegetation loss for New South Wales in 2012-13 (for cropping, pasture, thinning and infrastructure only) was 13,000 ha. Those clearing rates would indicate, as a combined mortality estimate for the two states together, that more than 50 million mammals, birds and reptiles are killed each year in Queensland and NSW because of land clearing.

Conclusion

Free-ranging native animals suffer, of course, independent of any human action, and that suffering is both severe and substantial (Kirkwood, 1994; Nussbaum, 2006; Doherty et al. 2016). A world of more frequent and more intense wildfires also promises that animals will suffer, both during fires and in their aftermath (Chia et al. 2015), as does a world of more roads and more traffic (Lunney 2013; Rhodes et al. 2014).

However, the central fact remains that land clearing causes death, physical injury and other pathological conditions to animals in a manner that is: direct (i.e. the clearing of vegetation either causes damaging physical contact with animals or creates the cleared environment that
animals subsequently experience); demonstrable (i.e. the harms can be demonstrated through forensic or scientific investigation); and capable of being avoided or minimised with appropriate application of the mitigation hierarchy.

Thus, efforts to ignore the harm caused by land clearing must present as an act of wilful blindness which is inconsistent with objective and transparent decision-making about the benefits and harms of land clearing. Further work is needed to develop appropriate statutory and policy-based mechanisms to identify and evaluate the harms caused by proposed land clearing activities and to allow for the effective consideration of those harms in decision-making relating to land clearing.

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References


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National Health and Medical Research Council. (2013). Australian code for the care and use of animals for scientific purposes, 8th edition. (National Health and Medical Research Council: Canberra.)


### Table 1. Definitions and descriptions of pathological conditions that animals may experience in environments in which vegetation has been removed.


<table>
<thead>
<tr>
<th>Pathological condition</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Deceleration injury</td>
<td>Blunt impact trauma incurred when the body in motion is forcibly stopped, however due to inertia the body cavity contents continue in the line of motion. The brain in particularly vulnerable.</td>
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<tr>
<td>Dehydration</td>
<td>Excessive loss of water from the body, occurring in several ways (e.g. inadequate intake of food, diarrhoea, vomiting). It can result in inadequate tissue perfusion and electrolyte imbalances and, ultimately, death (i.e. hypovolaemic shock).</td>
</tr>
<tr>
<td>Disease</td>
<td>Wobeser (2006) defines disease as ‘any impairment that interferes with or modifies the performance of normal functions, including responses to environmental factors such as nutrition, toxicants, and climate; infectious agents; inherent or congenital defects; or a combination of these factors’. Therefore, disease is a heterogeneous term, capturing any dysfunction or perturbation in normal physiologic homeostasis and there is a spectrum, ranging from mild and clinically insignificant, through to severe and life threatening.</td>
</tr>
<tr>
<td><strong>Disease transmission</strong> (increased likelihood of)</td>
<td>The loss of vegetation and possible dispersal to a new habitat may alter intra- and inter-specific contact rates and vector (e.g. ticks, mosquitoes) and host densities, thus increasing the likelihood of vector-borne or direct transmission of infectious disease.²,³,⁴</td>
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<td><strong>Exertional (capture) myopathy (rhabdomyolysis)</strong></td>
<td>A degenerative disease characterised by muscle damage, usually following extreme exertion, struggle and/or stress and potentially exacerbated by high ambient temperature, nutritional deficiencies and electrolyte depletion (dehydration).¹,⁵,⁶,⁷ It may occur when animals are pursued, entangled/entrapped, or are panicked and fleeing. Although seen in a range of species including birds, it is most commonly diagnosed in macropods.⁵</td>
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<tr>
<td><strong>Immune function (adversely affected)</strong></td>
<td>Immune function refers to an animal’s capacity to mount an immune response to a pathogenic (i.e. capable of causing disease) challenge. Conditions relating to land clearing such as chronic stress, inadequate energy intake, exposure to temperature extremes, and secondary infections of wounds sustained during clearing can adversely affect immune function (stress-induced immunosuppression), thereby making animals more susceptible to infectious disease and opportunistic pathogens (e.g. pneumonia, parasites).⁸,⁹</td>
</tr>
<tr>
<td><strong>Maladaptation</strong></td>
<td>Maladaptation is a circumstance of chronic stress in which an animal fails to adapt to its environment because of (e.g.) unfamiliarity with it, lack of necessary resources or of conspecifics to associate with, or adverse interactions with other animals.⁵,¹⁰ Immune function and other normal function may be compromised.</td>
</tr>
</tbody>
</table>
Misadventure

Death that is caused by the animal interacting with its physical environment in some way. During clearing or during attempted dispersal, death could occur through (e.g.) vehicle strike, drowning or entanglement in fencing.5,11

Morbidity

The state of being diseased. It may also refer to the incidence or prevalence of a disease.

Mortality

The state of being dead. It may also refer to the incidence or prevalence of death.

Nutritional disease

Nutritional disease most often refers to a general nutritional deficiency (e.g. inadequate intake of proteins or calories, vitamin deficiency) and less commonly to disease due to nutritional excess or to some other nutritional disorder.5 Inadequate or negative energy balance will result in resource partitioning, and potentially dampening of key systems/processes such as immune function, reproduction, and growth.4

Pain

An unpleasant sensory and psychological experience associated with actual or potential tissue damage.12,13 Animals may experience pain if they sustain physical injuries or are experiencing tissue damage because of some other pathological condition. Pain comprises heterogeneous categories (e.g. deep pain, visceral pain, cutaneous pain), which vary significantly in their quality, duration, and function and, further, gradation exists, ranging from low level and relatively tolerable (at least in the short-term) through to unbearable.
Pathologic conditions/pathologies

A state indicative of or caused by disease, rather than that which occurs physiologically as a result of homeostasis. Therefore, a pathogen is any agent (infectious or not) that is capable of causing disease (e.g. infectious agents such as viruses, bacteria and parasites and non-infectious agents such as toxins, adverse environmental conditions, and nutritional deficiencies or excesses).

Predation

Death due to attack by a native or non-native predator, or by a domestic animal.

Reproduction (adverse effects on)

The reproduction of animals may be affected by a reduction in fertility or reproductive output, or in survivorship of offspring, because of (e.g.) the death of offspring at foot or in utero or a failure to reproduce because of diminished body condition and diversion of resources (energy), the absence of a conspecific to mate with, or the lack of a suitable hollow or other nest site.4,9

Reservoir

An animate (e.g. any animal or plant) or inanimate (e.g. soil, water) nidus/host of an infectious pathogen in which it normally lives. The pathogen primarily depends on the reservoir for its survival, and must also be able to multiply within it, typically without causing significant clinical disease within animate reservoirs. Significant clinical disease may eventuate in a susceptible host following transmission.

Shock

A physiological response to diverse causes such as trauma resulting in haemorrhage and hypovolaemia or other challenge, involving inadequate blood flow to tissues, cardiovascular collapse, and cellular hypoperfusion and hypoxia that can be life threatening.1,14
Stress and stressors

The optimal state of equilibrium (homeostasis) is constantly challenged by intrinsic and extrinsic forces, which are known as stressors (which may be multiple and may interact). Duration and frequency of stress is central to its significance. In general, a short-term response is an adaptive ‘emergency’ allostatic response that promotes survival until the stressor(s) subside(s) as well as a return to homeostasis, and is functional (i.e. physiological). However, prolonged and or frequent stress causes allostatic overload and can be maladaptive (i.e. pathological), potentially resulting in a variety of dysfunctions (i.e. disease), including adverse effects on immune and reproductive function.4,15

Stress-related pathology

Animals may experience maladaptation and chronic stress because of sustained exposure or anticipation of biotic (e.g. predators, hostile conspecifics) or abiotic (e.g. suboptimal environmental conditions) stressors, which may have adverse effects on physiologic functions and thereby on body condition, growth, immune function and reproduction.2,4,5,16

Temperature-related injuries

Injuries due to hyperthermia or hypothermia due to excessive or extreme heat or cold arising because of lack of shelter or cover and changes in microclimates.5,6 Burns may occur if debris is burned.

Traumatic injury

Injury caused by a sudden, violent force resulting in the compression, stretching, avulsion, torsion, fracturing or penetration of tissue, as well as haemorrhage.14
Vector  Any living creature that transmits disease from one host to another. Typically the term applies to arthropods (e.g. mosquitoes, ticks, biting flies).