Is the fruit you eat flying-fox friendly? The effects of orchard electrocution grids on Australian flying-foxes (*Pteropus* spp., Megachiroptera)

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ABSTRACT

Orchardists have used electrified grids, which kill or injure flying-foxes, to "protect" fruit crops. In recent years legal challenges to this practice have been mounted on conservation and animal cruelty grounds. A 2001 Federal Court judgement prohibited use of one 6.4km grid because it adversely affected World Heritage values. Subsequently, Queensland stopped permitting lethal grid operation – an orchardist's appeal against this was withdrawn before going to court. Two NSW orchardists using a grid pleaded guilty to charges of cruelty/ aggravated cruelty. Orchardists' responses to these cases, and difficulties in policing the many grids which remain in working order stimulated this review. It summarises evidence that grids are ineffective in preventing damage to crops; do not selectively kill flying-fox "scouts"; will significantly hasten decline of flying-fox populations; do not kill flying-foxes "instantly" but inflict extreme pain and suffering *before* death; injure some animals, which survive in severe pain, and cause pain/ suffering to suckling young via death of mothers. Apropos the *NSW Prevention of Cruelty to Animals Act,* grids cause (1) *multiple uncontrolled acts of cruelty*: *multiple* in that many bats are affected; *uncontrolled* in that there is no control on numbers of bats affected; *acts of cruelty*, in that animals are unreasonably and unjustifiably mutilated, maimed, terrified, exposed to excessive (electrical) heat and inflicted with pain. (2) *multiple uncontrolled acts of aggravated cruelty*, in causing death or serious disablement of *multiple animals*, some being so severely injured that it is cruel to leave them alive. Since exclusion netting provides orchardists with a wholly effective, non-lethal means of protecting crops, electrocution grid operations should be prohibited, and compliance strictly policed.

Key words: flying-foxes, scouts, orchards, electrocution grids, crop protection, pain, cruelty.

Introduction

Flying foxes have eaten fruits in orchards since early European settlement and growers who establish orchards in flying fox habitats are aware of the potential for loss and damage. In the late twentieth century many fruit-growers in Queensland installed electrified wire grids to protect their crops from flying-foxes. The grids, which kill flying-foxes by electrocution, were claimed to: (1) effectively protect fruit-crops from flying-foxes; (2) kill relatively few animals by selectively killing flying-fox "scouts"; (3) kill flying-foxes "instantly" and thus, humanely (Rigden *et al*., 2000).

The Queensland Department of Primary Industries brochure *To Net or Not to Net? Flying Fox Control in Orchards Through Netting Protection* (Rigden *et al*., (2000) describes the basic structure of a grid:

> A grid of alternating live and earth wires (usually in banks of 10 or 15) held above the canopy on posts carry a high voltage current of 550 volts which kills any flying-foxes that fly into them. Flying foxes circle prior to landing and get caught on the grid. Growers using this method report that this method is an effective control method for flying-foxes but no use at all for bird control, the birds feathers act as a good insulator which prevents electrocution... A Mitigation Permit from... Queensland Parks and Wildlife Service office is required... It is believed that the grid system because it is invariably fatal is [a] more humane way of culling flying-foxes in the orchard than shooting. Often this method is used in combination with other control methods such as shooting, scaring devices or throw-over netting.

In 2001–2 a number of legal challenges to the use of electrical grids were mounted. I was involved in three court cases as expert witness. In the first (the Bosworth case), a Federal Court judgement (Booth v Bosworth [2001] FCA 1453 (17 October 2001), [which may be found at: < http://www.austlii.edu.au//cgi-bin/disp.pl/au/cases/cth/federal_ct/2001/1453.html?query=Booth%20 versus%20Bosworth>] banned the use of a 6.4 km electrocution grid in a North Queensland lychee orchard, but did not require the grid to be dismantled. The judgement was made on the basis that, "continued operation of the Grid is likely to have a significant impact on the world heritage values of the Wet Tropics World Heritage Area" [and not, as reported incorrectly in *The Australian* of 21–05–02, because the judge, "ruled the use of electrical grids over fruit crops was excessively cruel..."], and in particular that *continuing use of the grid would cause a significant decline in population numbers of spectacled flying-foxes*. Key evidence included counts of dead bats on the grid made by Carol Booth and Allen McIlwee, an estimate of the total population of Spectacled Flying-foxes *Pteropus conspicillatus* made by Olivia Whybird, and my

Pp. 380–390 in *The Biology and Conservation of Australasian Bats*, edited by Bradley Law, Peggy Eby, Daniel Lunney and Lindy Lumsden. Royal Zoological Society of NSW, Mosman, NSW, Australia. 2011.

submission on flying-fox population dynamics and "back-calculation" of the size of population put at risk by the level of culling in the orchard (see McIlwee and Martin 2002).

Before that judgement was handed down by the Federal Court, Queensland Parks and Wildlife Service (QPWS) had stopped issuing damage mitigation permits for lethal electrocution grids and the Minister for the Environment outlawed their use as a method of control. The case raised considerable media attention and QPWS was given advice from a number of sources including the Queensland Royal Society for the Prevention of Cruelty to Animals (Qld RSPCA) that grids were not consistent with the requirement (under the Qld. Nature Conservation Act 1992) for methods of crop protection to be humane.

In September 2001, QPWS asked me to be expert witness in a test-case, brought *against* them, in Rockhampton, by a fruit-grower appealing the decision not to issue damage mitigation permits for the use of a grid against Black Flying-foxes *P. alecto* and Little red Flying-foxes *P. scapulatus* (the Rockhampton case). My primary brief was to comment on likely effects of grids on population numbers, but also on any other aspect.

Shortly before this, a NSW RSPCA officer had asked me to be expert witness in a *Cruelty/ Aggravated Cruelty* case against two NSW fruit-growers who had killed *P. alecto* and Grey-headed Flying-foxes *P. poliocephalus* on an orchard grid (the RSPCA case). I was surprised, because I had long understood that the grids were illegal in NSW. The RSPCA officer said that it was difficult to get anyone to give evidence on pain. Since I had taught the physiology of pain perception at university level, had worked for years with flying-foxes and, courtesy of many flying-fox carers, was familiar with the injuries suffered by flying-foxes on electrical power-lines, I accepted the job.

In the Rockhampton case, an opposition expert raised the issue of cruelty and, while discounting the possibility that grids were "cruel" [growers insisting that they are humane in that they killed flying-foxes "instantly"] argued that fruit-growing is an agricultural enterprise, and that society tolerates a degree of cruelty in agriculture when it is beneficial. He cited mulesing of sheep as an example. Thus *the benefits* of electrocution grids might well outweigh any "borderline" cruelty (at this point I had not satisfied myself as to just how cruel the grids might be). However, if the grids were ineffective any cruelty could not be justified. So it was that I examined evidence that grids: (1) had significant detrimental effects on flying-fox populations; (2) were ineffective in protecting crops; (3) did not selectively kill flying-fox scouts; (4) did not kill flying-foxes instantly or humanely.

The Rockhampton appeal was dropped three days before going to court. Perhaps, having seen the evidence, the appellants decided they didn't want it in the public eye. A little later the accused in the RSPCA case pleaded guilty to charges of *Cruelty/ Aggravated Cruelty*. I understand that they were not fined and that no conviction was recorded. Subsequently, the NSW National Parks and Wildlife Service (NSW NPWS; currently the NSW Department of Environment and Climate Change) prosecuted these growers for the same electrocutions. Again, they pleaded guilty. The magistrate considered the offences to be "more serious than the RSPCA charges", and recorded convictions and imposed fines.

And so, one might think, reason had prevailed and such grids would never be used again. Alas no. *The Australian Newspaper* 13/04/02 carried an advertisement which read:

> Pursuant to... the *Environment Protection and Biodiversity Conservation Act*... members of the public are invited to comment on an application... to allow the electrocution of, at most, 5,500 Spectacled flying-fox by the proponent on his lychee orchard located at Kennedy, North Queensland... for the November/December 2002 harvesting season...

The advertisement was lodged under section 93 of the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (EPBC Act) in relation to EPBC Referral No 2002/571 lodged on 14 February 2002 to "take or destroy approximately 5,500 Spectacled Flying-foxes (*Pteropus conspicillatus*) in the period November to December 2002 to protect a lychee orchard at Dallachy Creek, Kennedy, Queensland." The proposal was, in effect, an attempt by the Appellant in the Bosworth case to circumvent the restrictions resulting from the Federal Court judgement.

I examined the proposal in detail and made an appropriate submission. The proponent argued the economic necessity for the grid, contended that the bats killed did not come from the World Heritage Area, misrepresented data presented in Booth v Bosworth, asserted that, "the number of females taken by the electric grids is in the vicinity of 10%" and questioned estimates of population size. My submission countered these and other points, using material like that in the present paper. Apropos cruelty, I pointed out that:

> ... while the issue of cruelty to animals is not covered specifically by the *Environment Protection and Biodiversity Conservation Act 1999*, the proposed action would almost certainly constitute multiple acts of cruelty and of aggravated cruelty against indigenous fauna of the Wet Tropics World Heritage area viz., Spectacled flying-foxes... I draw attention to the successful prosecution by the NSW RSPCA, in December 2001, under the NSW *Prevention of Cruelty to Animals Act*... of two fruit growers using flying-fox electrocution grids.

Then appeared the following letter in the *QLD Fruit and Vegetable News* February 2002 showing the depth of feeling surrounding the debate among orchardists and how scientific research (*"emotional, theoretical drivel"?*) can fall on deaf ears:

> GRID LOSS THREATENS LIVELIHOODS BEWARE. You could be the next victim of terrorism from environmental extremists with their international push to ban all damage mitigation permits for all wildlife. The interests of individuals, business enterprises or even local communities would unlikely take precedence over the national interest in matters of national environmental significance. Conservationist Carol Booth took orchardist Rohan Bosworth to court and won by using the *Environmental Protection and Biodiversity Conservation Act* 1999 (EPBC Act) and the international World Heritage Convention to... stop Rohan from using his electric grid system to protect his lychee crops from fruit bats. The court ruled his grid "has, or will have, or is likely to have, a significant impact on the

> world heritage values"... the RSPCA, as well as EPA's Director General James Purtill... classify grids as inhumane with no prior consultation with industry... Qld Parks and Wildlife Service... declared grid systems illegal and stopped the issue of damage mitigation permits for their use, despite no viable alternative methods. Even QPWS admit the current alternative methods being researched will not work in the wet tropics and yet electric grids, properly installed and maintained, are humane! As usual, public servants and politicians jumped to the tune of the environmental extremists, who are terrorising legitimate businesses... We have legally installed an electric grid... to protect our crops from flying-foxes by killing fruit bats instantly. The RSPCA compromises its integrity by sanctioning the use of 1080 and myxomatosis (two of the most horrific deaths imaginable), as well as ignoring... speared dugong dying slowly. How can the RSPCA claim electric grid systems are inhumane?... As it suddenly became illegal to turn on our humane electric grid system, our income for the next year has been stolen by World Heritage fruit bats... Queensland cannot afford to have a major contributor of jobs and export earnings... to be destroyed! All community members need to be contributors to the management of flying-fox mitigation, with a cooperative, un-biased, realistic and practical approach, with resolution based on fact... Environmental extremists talk only about exclusion netting. But exclusion netting is no different to clearing the land [sic] and environmentalists have stopped that... We are under constant scrutiny and surveillance by environmental extremists. Many growers have placed "No Trespassing" signs on their properties but does this legally protect them?... We need... practical, logical ideas... not emotional, theoretical drivel that drives the system for bureaucrats who sit on polished seats in air-conditioned offices in cities...
>
> Dick Yardley, lychee orchardist, Miriwinni, Far N.Qld".

Okay, there is the "extremist" terminology, the malapropisms, the conspiracy theories, but this bloke is hurting. He is someone we must try to get on side. If I were a grower with crops being ravaged by FFFFflying-foxes, I could easily share his feelings and attitudes. That is why I consistently argue that, ***if the community wishes flying-foxes to be conserved, then it*** *must* ***help fruit-growers***, for example, with non-means-tested netting subsidies. In this respect, I draw readers' attention to several papers by fruit growers in the symposium, *Managing the Grey-headed Flying-fox as a threatened species in NSW* (Eby and Lunney 2002) notably – Biel (2002), Comensoli (2002), Gough (2002), Rogers, (2002), Bicknell (2002) and Ullio (2002).

Nevertheless, the letter and the Bosworth action sound a warning. Grids remain in place and intact in Queensland. Growers continue to assert that grids are effective and humane, and may be tempted to use them (note the reference to *"No Trespassing signs"),* and there is anecdotal evidence that some growers *have* continued to use them. Several questions must be raised. Who will police the grids – guarantee that they will not be used? How strongly will the law be enforced, offenders prosecuted? It is these concerns which led me write this paper, which is based on the expert-witness statements I presented in the court cases.

Discussion of these issues is also hampered by the lack of systematically acquired "hard" data on levels of crop damage attributable to flying foxes (this has never been a requirement for licences to cull in Queensland), and the variations in damage between years and between orchards. Thus much of orchardists' views of the problems are based on inferential and subjective evidence – as will be evident in what follows.

Likely effects of electrocution grids on flying-fox populations

Reproduction and the capacity for population increase in flying-foxes

Unlike opportunistic, highly reproductive species such as rabbits or mice, flying-foxes have a very low capacity for increase, even under ideal conditions. All Australian species are seasonal breeders, with *P. alecto* showing some plasticity in seasonality compared to the essentially unvarying seasonality of *P. poliocephalus* and *P. scapulatus* (Martin 1997; Martin and McIlwee 2002). The theoretical maximal rate of population increase is limited by the fact that, for all species, females can effectively rear only one young per year and cannot produce viable young before their second or third year of life. Twin-births occur at low frequency, but it is unknown for both to survive in the wild. Irrespective of any plasticity in seasonality, reproductive rate is limited by the duration of pregnancy (6 months), lactation (3–5 months) and a period of courtship and copulation (1–2 months). Thus 12 months are required to complete one reproductive cycle. Such a breeding strategy is only successful if flying-foxes are long-lived and suffer naturally low mortality rates.

If all female flying-foxes lived for at least 15 years, became sexually mature at age 2–3 years, and had 100% breeding success every year thereafter, the maximal rate of population increase would be 25% per year [in formal population-ecology terms, (lambda, the finite rate of increase per year) = 1.25, and r_m (the instantaneous rate of increase/ intrinsic capacity for increase) = 0.226], and the population would double every 3.1 years. The basis for these calculations are described in McIlwee and Martin (2002) and Martin and McIlwee (2002).

The effects of mortality and breeding success on flying-fox population growth and decline

In reality, flying-fox populations suffer significant mortality rates (McIlwee and Martin 2002) and annual breeding success may be 70% or less (Vardon and Tidemann 1998). With an annual mortality of 10% per year, and breeding success of 70%, a flying-fox population will increase by only 9% per year (λ = 1.09; r_m = 0.088) and double every 7.9 years. With a "litter size" of 1 (= 0.5 females/ per annum) changes in mortality rate have relatively much greater effects on rates of population change than do comparable changes in breeding success (McIlwee and Martin 2002). Thus, if the annual mortality of a population with a breeding success of 70% is increased to 20% per annum, that population will go into slow decline (λ = 0.99; r_m = –0.013) with numbers halving every 52 years. With an annual mortality of 20%, flying-fox population doubling times will vary between 34 and 154 years as breeding success varies between 90 and 80%; if breeding success falls to 70%, the population goes into slow decline with a halving time of 52 years. With a breeding success of 90%, a flying-fox population is in positive growth when mortality is 21% per year (λ = 1.01; r_m = 0.0098;

doubling time 71 years) and in negative growth when mortality is 22% (λ = 0.999; r_m = –0.001; halving time 693 years).

Thus, when some 20% of a flying-fox population die each year and 80–90% of females successfully rear young, the population size changes only slowly and, in the longer term, will fluctuate around some average value, effectively remaining at approximately the same size. It is presumed that this was the situation for Australian flying-fox populations before European settlement, and that population parameters of the order of 20% annual mortality/ 80–90% breeding success were in operation and, in the long term, were the parameters that were involved as the animals evolved to adapt to the Australian environment.

Increasing annual mortality to 25–30% leads to population decline, irrespective of females' breeding success. Thus, with 90% breeding success, annual mortalities of 25% and 30% lead to population halving in 20 and 7.5 years respectively. If breeding success rates are lower than 90%, population halving times are correspondingly shorter. Such trends are illustrated in McIlwee and Martin (2002). The mortality imposed on flying-fox populations by orchard electrocution-grids simply adds to the "natural" mortality. Thus a population in approximate steady-state, with a "natural" mortality of 20%, will be put into rapid decline by an additional 10% mortality imposed by an electrocution grid.

Clearly, the overall effect of any grid-induced mortality on a flying-fox population will be inversely proportional to the size of that population. The Bosworth case dealt specifically with a relatively well defined population of *P. conspicillatus* in the Wet Tropics World Heritage Area. The Rockhampton case dealt with a permit to electrocute *P. alecto* and *P. scapulatus*, and one opposition witness made assertions that were either incorrect or highly debatable.

Thus, it was stated that, "The reproductive biology of the Black Flying-fox is such that it has the potential to increase its population by up to 40% annually (see Vardon and Tidemann 1998; 2000)" and elsewhere, "can increase numbers at a substantial rate...". Vardon and Tidemann (2000) state that, for *P. alecto*, "the maximum reproductive potential of the species... is likely to be around 0.4 as calculated for *P. giganteus* (Dolbeer et al. 1988)", and that, "Dolbeer et al. (1988) calculated that *P. giganteus* had a maximum (or intrinsic) rate of growth of 0.40. Simply put, this means that populations of this species can theoretically increase in size by 40% each year".

Vardon and Tidemann (2000) appear to have confused the instantaneous rate of increase (r_m) with the finite rate of increase (λ), since an r_m of 0.4 would lead to a population doubling time of 1.73 years, which is a nonsense. Dolbeer *et al.*'s (1988) description of reproduction in the Maldive *P. giganteus* agrees with that of Marshall (1948) for the mainland population. While Dolbeer *et al.* (1988) do list an r_m of 0.4, it appears that their calculations, which are not detailed, involve an arithmetical error of 2. Marshall (1948) sampled *P. giganteus* monthly from the wild over three years. He described the breeding season as "sharply defined", noting that all conceptions occurred in December/ January, and parturition "in late May and perhaps early June". He stated that, "The gestation period is thus about six months, and the number of young was invariably one". This equates to the annual cycle of reproduction in Australian *Pteropus* species.

P. alecto and *P. scapulatus* extend over a large range and it is apparent that both species remain in "large" numbers. However, there are no scientific estimates of population size that would justify a Rockhampton witness's statement that, "there are very likely to be more than a million individuals of each of the two species". In the USA, the Passenger Pigeon was present in "large numbers" only shortly before the species became extinct.

While there may be no "hard" evidence that *P. alecto* and *P.scapulatus* populations are in decline, on balance, it is likely that they are. Neither species has any greater or more rapid reproductive potential than *P. poliocephalus* and *P. conspicillatus* (Martin and McIlwee 2002; McIlwee and Martin 2002) – both of which have been declared to be vulnerable on the basis of scientific evidence of population decline. Over much of their range, *P. alecto* and *P. scapulatus* are subject to the same pressures that contribute to the decline of *P. poliocephalus* and *P. conspicillatus* populations, *viz.* habitat destruction, loss of natural food sources, disturbance and destruction of roost sites and orchard culling by shooting, poisoning and electrocution.

A Rockhampton witness argued that, since the range of *P. alecto* has extended southwards in recent decades, its overall population must be increasing. However, the home-range of flying-foxes can extend over many hundreds of kilometres, and expansion of range does not necessarily mean expansion of numbers, or be dependent on such. Thus the expansion of *P. alecto* into areas previously occupied exclusively by *P. poliocephalus* may reflect no more than occupation of sites vacated as the *P. poliocephalus* population contracts, with gradual southern movement of *P. alecto* from northern "source" populations. The spatial expansion may well reflect better exploitation of available resources by *P. alecto*, but does not require it to possess any reproductive advantage over *P. poliocephalus*.

The effects of culling depend on the size of the population being culled. In the absence of any meaningful estimate of *P. alecto* and *P. scapulatus* population sizes, one cannot define the actual effect of any given level of killing by electrocution grids. However, by using realistic estimates of likely natural mortality and breeding success, one may work "back" from known or likely cull rates to calculate the size of population that would be put into decline by such culling. For example, if a flying-fox population was close to stable, then the annual "natural" mortality would be about 20%. If the annual electrocution cull was 30,000, and 50% of those were females, that would add 10% mortality to an existing 20% mortality of a population of 150,000 females, and produce a population-halving every 5.4–7.4 years, depending on breeding success. Including males in the equation, the total population put into such decline would be 300,000. If the proportion of females in the cull was greater than 50%, or the "natural" mortality greater than 20%, the population affected would decline at an even faster rate.

Clearly, killing 75 *P. alecto*, as requested by the Appellants in the Rockhampton case, even year after year, would have negligible effect. However, the effects of this one grid cannot be taken in isolation. Consider the situation that may exist in Queensland. I understand that in 2001 there were five grids in the Rockhampton area, and a possible 150 in Queensland. While damage mitigation permits may be issued for small numbers of animals for each grid, as requested in the Rockhampton case, there is no guarantee that the numbers *actually* killed will fall within that limit and may well be many times the permitted number. For example, in the Bosworth case, the grower was granted a permit for 500 *P. conspicillatus*, yet the number killed over four nights was 1,510, and the total killed over an eight week electrocution period was calculated at 21,000 – 23,000 (McIlwee and Martin 2002).

Suppose that each grid operator receives permission to kill 100 bats (not an unreasonable number?} and 150 grids kill only their permitted quota, that totals 15,000 bats of which approximately 50% (7,500) are females. If those females constitute 10% of a population of females with a "natural" mortality of 20%, then the size of population shifted from steady-state into rapid decline would be 75,000. If the average actual kill is more than that permitted, the size of the female population put into rapid decline goes up accordingly:- 150,000, 300,000 and 600,000, if growers exceed their quota by 2-, 4- and 8-fold respectively. If the male:female ratio is 1:1 then the size of populations put into decline by orchard electrocutions are respectively 300,000, 600,000 and 1,200,000.

Implications of the mobility and large home range of flying-foxes

Flying-foxes can move many kilometres to food sources; Pierson and Rainey (1992) emphasise that, "Foraging areas are almost always separated from roosting areas. On large land masses, animals may travel 40–60km". Indeed they may do so every night. Thus, bats attacking a given orchard cannot be regarded as an isolated population. Indeed, Tidemann (2000) arguing that electrocution of *P. conspicillatus* in a lychee orchard would not have significant adverse effects, stated that,

> In any event, a localised reduction in numbers of spectacled flying-foxes is likely to be counterbalanced by individuals flying in from elsewhere... satellite tracking studies of grey-headed flying-foxes... have revealed one individual that flew 500 kilometres in less than a week. It is not known if spectacled flying-foxes have a comparable capacity for long-distance flight, but it is known that they are highly mobile animals.

If there is a good food source, flying-foxes may move from distant roost sites to ones closer to that food source. If the bats in the latter are being killed, bats from more distant areas will move in to replace those that are killed. The ecological term for such movement into a cull site is "source-sink dispersal" (Pulliam 1996); the site of culling is the "sink" into which animals move from surrounding "source" areas. To a grower killing the animals, there will be a *perception* of "millions" of animals – a never-ending supply – and the *misconception* that the bats breed like rats and mice.

Thus, any orchard culling of a perceived "local" population will not only fail to stop the problem damage, but will simply drag animals in from far afield. In describing this, the image of a pteropucidal "black hole" and its irresistible gravitational force sweeping everything into its maw is a not unreasonable metaphor. Culling produces a local vacancy, bats move into it from further afield, and are killed, so producing a local vacancy which... Thus, localised culling can effect a flying-fox population over its whole range. On these bases, I consider that continuing flying-fox culling by orchard electrocution grids is not sustainable, and is likely to cause population declines of a magnitude as to put the species at risk.

Efficacy of electrocution grids in protecting fruit crops from flying-fox damage

One must question the effectiveness of orchard electrocution grids in preventing crop losses, as opposed to their "effectiveness" in "controlling" (culling) flying-fox populations. If the grids are *not* very effective in protecting fruit crops, and if there is a wholly effective non-lethal, albeit expensive, method of protection available, then clearly, conservation and prevention of cruelty to flying-foxes outweigh use of grids.

Evidence that electrocution grids are relatively ineffective in protecting fruit

The affidavit from the respondent in the Bosworth case states,

> Since 1986 I have... maintained electric fences... There are now... 14 erected electric fences... and consist of 20 verticle [sic] wires from 4.4 metres to 9 metres in height. The total length of fences is 6.4km... The fences are operated during the harvesting season only. In the current year... from 2 November 2000 until the end of the harvest... This amounts to less than eight weeks operation... about my average use... On average the orchard yields approximately 250 tonne... per year. The actual yield... fluctuates between nil and 450 tonne... To date [12 December 2000] we have harvested between 75% and 80%... The financial break even point... this year will be... the sale of approximately 100 tonne of fruit... I am expecting a harvest of only 70 – 75 tonne... **The low harvest... is mostly due to... flying-fox raids. I estimate the loss of fruit this year attributable to the flying-fox raids to be in the vicinity of 100 to 120 tonne**" [my emphases].

So, despite use of grids from November 2 onwards, there were crop losses of "100–120 tonne" attributed to flying-foxes. This loss indicates that, despite use of the grids, large numbers of flying-foxes continued to enter the orchard and feed even though the grids were on and killing many bats. This was corroborated by counts of freshly dead bats made in this orchard. Four once-nightly counts of newly-killed bats (made over a two week period) were: 409, 499, 305 and 297, giving a mean ± standard deviation of 378 ± 96 bats per night, and 95% confidence limits of 226–530 (ie., 95% probability that the mean lies within these limits). It is noteworthy that the grid had operated for some weeks before the first counts were made and a large number of bats were still being killed two weeks after the first counts were made, indicating that the grid had had ***no measurable deterrent effect*** on the spectacled flying-fox population attracted to this orchard. Furthermore, these numbers counteract the theory that "selective" killing of hypothetical "scouts" reduces flying-fox incursions into the orchard. Full details of the counts and of the way in which they were made are to be found online in paragraphs 21–29 of Booth v Bosworth [2001] FCA 1453 (17 October 2001).

It is apparent from the Appellants' evidence in the Rockhampton case that significant crop losses regularly occurred despite use of grids. For example, they describe,

> The damage suffered by the Appellants to their crops each year from flying-fox invasions", and refer to, "having identified in their permit application a monetary loss of up to $10,000 and in previous applications losses of up to $40,000".

These statements indicate that large numbers of bats were involved, and make one query the likely effectiveness of killing 75 *P alecto* (the requested number) over a period of 92 days – less than one presumed-scout per night.

Having on many occasions observed flying-foxes approaching food trees in suburbs close to the Indooroopilly (Brisbane, QLD) flying-fox camp, and noting the precision with which individuals approach chosen food trees, I am not surprised that electrocution grids are ineffective. Indeed, to anyone familiar with the aerial and sensory abilities of flying-foxes it is the geometry and spacing of electrocution grid-lines that is the most damning aspect regarding their supposed protective efficiency. How many of us may have envisaged grids as ***enclosing*** an orchard like exclusion netting. They do not. The 6.4km North Queensland electrocution grid comprises 14 vertical arrays of parallel horizontal wires ***spaced ~100 metres apart!***

The Rockhampton Appellants operated a ***single*** 9.3-metre-high electrocution grid-line, of the type described above,

> ... approximately 200 metres long **in a straight line through the middle of** ... a lychee orchard with the dimensions of approximately 300 metres long and 80 metres wide.". They stated that, "Since 1994 we have spent approximately $9,100 on protective netting to drape over the lychee trees... The nets offer reasonable protection from attacks by small numbers of flying-foxes, but are unsatisfactory for an attack by a large number of flying-foxes. The reasons for this is that the lychee fruit hang on the exterior of the canopy of the tree and as the net sits immediately over the tree, flying-foxes **and rainbow lorikeets** can simply land on the tree and attack/eat the fruit through the net" [my emphases].

One must ask, given the behaviour of flying-foxes in relation to trees under nets, how a ***single*** grid line in the middle of an orchard could protect the surrounding trees or deter flying-foxes from them or how grid-lines spaced 100 metres apart protect the trees in between? Is the primary purpose of the grids to protect the crops or simply to cull flying-foxes***?***

What contribution do birds make to damage attributed to flying-foxes?

In the Bosworth case, the respondent stated that, "The low harvest ... is mostly due to ... flying-fox raids" implying that other significant loss-making factors were involved. Were there significant losses from birds? The respondent had also applied for a permit to kill Rainbow Lorikeets, as had the Appellants in the Rockhampton case. Despite its title, *To Net or Not to Net? Flying Fox Control in Orchards Through Netting Protection* (Rigden *et al*. 2000) repeatedly refers to crop losses caused by birds, frequently as "Bird and flying-fox...". On page 11 it states that, "Damage by birds often exceeds that from flying-foxes". On page 34, referring to a North Queensland Lychee orchard, it states that, "Prior to netting 70% losses to parrots were incurred". The publication also describes the complete effectiveness of properly erected exclusion netting in preventing bird and flying-fox damage, as against the partial effectiveness of electrocution grids and the ineffectiveness of drape netting – all statements being based on data and opinions from fruit-growers!

After reviewing this material, I do not see how lychee growers, given the nature of their crop and size of the trees, discriminate between damage caused by birds and that caused by flying-foxes – or how they quantify each type of damage. I conclude that grids are not effective in preventing crop losses from flying-foxes and that significant crop loss is caused by birds. It also seems likely that damage caused by birds is attributed to flying-foxes. Exclusion netting is accepted as 100% effective in preventing crop losses from both birds and flying-foxes.

Do electrocution grids preferentially kill flying-fox "scouts"?

It is often asserted that grids protect fruit because they selectively kill "the scouts" – a hypothetical category of animals that allegedly guide the main body of "ordinary" bats to the orchard, and without which, said ordinary bats would not find the orchard. Culling of scouts is believed to have the benefit of reducing the total cull. Thus, p.46 of Rigden *et al*. (2000), relating to a North Queensland rambutan grower reads,

> The grids are switched on as soon as the fruit starts to colour up about 8 weeks before picking, this policy ensures that any scouts entering the orchard are culled. Culling the scouts ensures that other flying-foxes are not led to the orchard, thus the total cull of flying-foxes is reduced. If grids are switched on too late 50% losses can occur, when the system is used to its optimum effect losses are reduced to 2%.

To my knowledge, there is no scientific evidence for a specific category of scouts. Unfortunately, a perennial problem in evaluating efficacy of anti-flying-fox fruit-protection systems is the year-to-year variability in the pressure on flying-foxes to attack fruit crops. See, for example, the papers by fruit growers in Eby and Lunney (2002) cited previously. It is accepted that "bad" flying-fox years for growers are associated with failure of the animals' natural food resources. Thus a grower may switch a grid on early in a "good" year, when relatively few flying-foxes are driven into orchards, and late in a "bad" year, and attribute the apparent success of early switch-on to selective killing of scouts.

While flying-foxes lack the sophisticated sonar used by micro-bats to navigate and catch prey, they have large eyes and good night vision, excellent hearing and sense of smell. They are highly intelligent, inquisitive creatures capable of accurate long-distance navigation and of remembering specific locations. Radio-tracking research (Eby 1991 and 1996) has demonstrated that individual flying-foxes can return precisely to specific locations, after long periods of time, and over long distances. In other words, flying-foxes have an excellent spatial sense and spatial memory – maps-in-the-mind, as it were. Eby's research gives no support to the theory that specific "scouts" lead other bats into orchards. On the contrary it indicates that all flying-foxes are individually capable of locating their own food sources. Other radio-tracking studies described at this Symposium demonstrated how individuals from the Sydney Botanic Gardens colony would each fly to its own specific tree over several nights (N. Burton, unpublished data, Univ. Sydney). This is entirely consistent with my own numerous observations of animals flying out from the Indooroopilly colony – widely dispersed across the sky, the flight lines radiating out in all directions, with animals at widely differing heights – the highest apparently purposefully continuing off into the distance, the lower ones, slower, peeling off, circling and descending with great precision into local trees to feed. Frequently an individual would appear in the one patch of blossom each night at roughly the same time. Clearly, individual flying-foxes will vary in their navigational and food-finding abilities and presumably older and more experience animals will be more competent, and inexperienced animals may well follow them. Thus these data and observations do not exclude the possibility of *some* knowledge sharing, or of *some* leadership, but indicate that orchard attacks are not *dependent* on the hypothetical "scouts", as many fruit-growers seem to believe. I conclude that, from the available evidence, including the counts of electrocuted flying-foxes cited above, the hypothesis of "scouts" is not supported, and that any method of killing flying-foxes in or around orchards, whether by shooting or electrocution – will not be an effective deterrent (dead bats don't learn!) and will also be indiscriminate in killing old and young, male and female, pregnant and nursing females alike.

Do electrocution grids kill flying-foxes "instantly" and humanely?

In what follows, I use the term "electrocution" (literally "the putting to death by means of a powerful electric current") to describe a situation where a substantial electric current flows through the body tissues of a flying-fox as a result of the animal's contact with an electrified-cable or wire. In considering whether electrocution of flying-foxes by orchard grids constitutes cruelty or aggravated cruelty, I review: the biology and reproductive biology of flying-foxes; the nature and perception of pain; the physiological effects of electrocution and its non-acceptability to the *American Veterinary Medical Association Panel on Euthanasia* (AVMAP) as a method of euthanasia of small mammals; the manner of electrocution of flying-foxes on domestic power lines; injuries and survival of flying-foxes electrocuted on domestic power lines; observations on the electrocution of flying-foxes on a purpose-built electrocution grid in a North Queensland lychee orchard; deaths of neonatal and infant flying-foxes resulting from electrocution of mothers.

Some aspects of the biology and anatomy of flying-foxes

The wing-membrane of the flying-fox is a thin double-sided layer of skin which stretches from the side of the body to the arm and "hand", the extended fingers of which support the outermost extension of the wing-membrane. The wing span of adult *P. poliocephalus, P. alecto* and *P. conspicillatus*; (adult body weights ~ 1 kg) is over a metre, that of *P. scapulatus* (adult body weight ~ 700g) something under.

The wing membrane serves for control of body temperature as well as flight, and is richly supplied with blood-vessels, muscles, sense organs, motor and sensory nerves. In flight, the angle of attack, extension and curvature of the wing is under fine neuro-motor control, and there is a generous representation of the forelimb in the sensory and motor cortex of the brain, in the same way as there is of the hand in humans (Calford *et al*. 1985; Wise *et al*. 1986). Flying-foxes possess a large thumb which effectively serves as a "hand" when the wing is folded away, being used for reaching, grasping, grooming, aggression and locomotion. Posteriorly, the wing membrane extends to the hind limb. This too has a generous representation in the sensory and motor cortex of the brain (Calford *et al*. 1985; Wise *et al*. 1986), again reflecting its operation in a variety of functions including grasping, grooming and locomotion. When a flying-fox "lands" in a tree it purposefully hooks on by its hind-claws, folds its wings, then reaches out with a thumb claw. When a flying-fox collides with an electrified cable or wire it tends to reflexively grasp with hind and thumb claws. Thus, many "electrocution" injuries to flying-foxes, arising from collision with electrified cable or wires, involve the limbs and intervening wing-membrane.

In captivity, flying-foxes are responsive to, and interact well, with humans. They exhibit a remarkably adaptive behaviour, and substantial capacity for learning – recognition and remembering. They are gregarious creatures with complex patterns of social behaviour. Because their brain visual pathway resembles that otherwise only found in primates, Pettigrew *et al.* (1985) suggested that flying-foxes were primates, and evolved separately from the micro-bats. This theory remains controversial. Nevertheless, the complexity of flying-fox behaviour is comparable to that of many primates and, other than primates, no mammalian group has the range of vocalisations exhibited by flying-foxes. I mention these behavioural aspects to emphasise the likely capacity of these animals to feel pain, much as we do.

On the nature and perception of pain

Pain is the word given to the conscious sensation experienced by humans when body tissues are stimulated by a noxious factor, ie. damaged in some way. Damage can be caused by external factors – mechanical, chemical, thermal, electrical, or by internal factors – ischaemia, inflammation, pressure, distension. All readers of this paper will have experienced pain in some form or other: the intense lingering pain of a sharp blow to the shin; the sharp pain of a cut or needle-prick; the intense pain of an abdominal "stitch"; the different intense pain of extremely cold fingers; the agonising pain of intense muscle cramp; the agonising pain which accompanies every breath in pleurisy; the nauseating disorienting pain of a bad headache; the pain of a twisted joint, of a broken limb; the dull, emotionally upsetting, continuing ache of bone pain; the continuing unrelenting pain of arthritis; the shocking pain of an electric current; the intense, continuing, and upsetting pain of even quite small burns or scalds.

In speaking of a "good" death, we have in our minds' eye a death without pain. None of us wish for the prolonged, unrelenting deep pain suffered by some cancer patients, pain that despite palliative care and modern analgesics (pain-killers) can cause patients to call on God to end their misery. I make this point in relation to what I describe below – namely, flying-foxes carrying gross electrical-burn injuries to wings and limbs, even electro-cauterised amputations, resulting from their contact with electrified wires, and surviving for hours, even days, without any palliative treatment.

Here are words that we humans associate with pain: discomforting, distressing, suffering, hurt, anguish, agony, torment, excruciating, torture, hell, and so forth. In relation to the cruelty of electrocution and electrocutive burns, one may note that: humans envisage(d) the ultimate fate of wrong-doers to be the eternal fires of hell; witches and heretics were put to death by fire; mediaeval torture frequently involved fire; modern torture often (allegedly) involves burns and electric shocks. I emphasise this because so many injuries suffered by flying-foxes are burns, albeit produced electrically.

The physiology of pain perception

In the normal individual, the sense of pain has adaptive value, in that it warns that tissue damage is occurring. In being conscious of the pain, the individual recognises the circumstance of the damage, and learns to avoid those circumstances. In describing pain in physiological terms, the 1993 *Report of the American Veterinary Medical Association Panel on Euthanasia* (AVMAP; Andrews, *et al*., 1993) emphasises that an animal must be conscious to experience pain, and lists the typical responses of an animal to pain.

> For pain to be experienced, the cerebral cortex and subcortical structures must be functional. An unconscious animal cannot experience pain because the cerebral cortex is not functioning. If the cerebral cortex is non-functional because of hypoxia, depression by drugs, electric shock, or concussion, pain is not experienced...
>
> Behavioral and physiologic responses to noxious stimuli include distress vocalization, struggling, attempts to escape, defensive or redirected aggression, salivation, urination, defecation, evacuation of anal sacs, pupillary dilatation, tachycardia, sweating, and reflex skeletal muscle contractions causing shivering, tremors, or other muscular spasms....

In other words, application of a painful stimulus to a conscious individual elicits a suite of responses, ranging from immediate (unconscious spinal) reflex-withdrawal of the body-part from the source of the stimulus, to central-nervous-system-mediated and autonomic-nervous-system-mediated effects on hormone secretion, blood pressure, heart rate etc., and behaviour – distress calls, fearful behaviour, urination, release of certain odours or pheromones and so forth.

Humans routinely euthanase injured animals to "put them out of their misery" and many humans believe intuitively that "animals feel pain like us". However, it is unlikely that it will ever be possible to "prove" that non-human mammals perceive pain in ***exactly*** the same qualitative way as humans, or to the same level of intensity. Nevertheless, a large body of objectively verifiable knowledge supports the view that all mammals perceive pain in essentially the same way. Thus, the chemical and cellular (neuronal) basis of pain generation and perception is essentially the same in all mammals, and specific noxious stimuli elicit the same suite of measurable physiologic and behavioural responses in a wide variety of species. It also seems that for "pain" to be of adaptive value it is essential that it be a ***consciously*** perceived sensation. Only thus can an individual animal recognise and remember the circumstances of the pain, and take the appropriate action to avoid them in the future. Thus, the accepted scientific view is that ***all*** mammals perceive pain in essentially the same way and to the same degree as humans. The National Health and Medical Research Council's guidelines for experiments on animals are predicated on this view, as is the AVMAP report on animal euthanasia, and, for example, the *NSW Prevention of Cruelty to Animals Act.*

Physiological effects of electrocution; its non-acceptability as a method of euthanasia

In evaluating methods of euthanasia, the AVMAP used several criteria including: ability to induce loss of consciousness, and death, without causing pain, distress, anxiety, or apprehension; time required to induce unconsciousness. In relation to electrocution, the AVMAP states that:

> Electrocution, using alternating current, as a form of euthanasia... induces death by cardiac fibrillation, which causes cerebral hypoxia... **However, animals do not lose consciousness for 10 to 30 seconds or more after onset of cardiac fibrillation**...
>
> It is imperative that animals be unconscious before being electrocuted. Therefore, euthanasia by electrocution must be a two-step procedure. First, an animal must be rendered unconscious by any acceptable means, including electrical stunning. If electrical stunning is used, the electrical current must pass through the brain... Electrocution... may not result in death in small animals (< 5 kg) because ventricular fibrillation and circulatory collapse do not always persist after cessation of current flow...
>
> Electrical stunning and euthanasia by electrocution require special skills and equipment that will assure passage of sufficient current through the brain to induce unconsciousness followed by electrically induced cardiac fibrillation... Techniques that apply electric current from head to tail or head to foot are unacceptable...
>
> Experiments... have shown the necessity of directing the electrical current through the brain in order to induce rapid loss of consciousness... when electricity passes only between fore- and hindlimbs or neck and feet, it causes the heart to fibrillate but does not induce sudden unconsciousness... For electrical stunning... an apparatus that applies electrodes to opposite sides of the head, or in another way directs electrical current immediately through the brain, is necessary to induce rapid unconsciousness.

The AVMAP does not explicitly mention the pain caused by passage of an electric current through the body, or raise the issue of burns to body tissues, where an electric current enters or leaves the body. Presumably this is because the apparatus used for electrocutive euthanasia distributes the current over wide areas at the entry and exit points, so obviating tissue damage.

In contrast, the current flow at the points of contact between the living tissues of a flying-fox and the 1.6 mm diameter wire typically used in orchard electrocution grids is of an intensity that may be likened to that at the tip of an electric-arc welding rod. Certainly the wounds found on flying-foxes electrocuted on the substantially-larger-diameter 240v and 415v domestic electric power-supply cables are consistent with this, comprising as they do deep burns, even to the bone, on the fore-arms, thumbs and hind-limbs (sometimes the hind-claws are fused together); large areas of wing-membrane burnt away with much of that remaining crisped, brittle and crumbling. Some animals with such wounds are found near power-lines – still alive. They are always euthanased as soon as possible.

The likely manner of electrocution of flying-foxes on orchard electrocution grids

Rigden *et al*. (2000) describe electrocution-grids as

> ... a grid of alternating live and earth wires... carry a high voltage current of 550 volts which kills any flying-foxes that fly into them", and states that, "the grid system because it is invariably fatal is more humane way of culling flying-foxes in the orchard than shooting".

In what follows it will be evident that such grids are not "instantly fatal", nor are they "invariably fatal", and that a significant proportion of adult animals will survive the electrical trauma for some time, albeit severely injured and in pain. A large proportion of neonatal young suckling on lactating females that are electrocuted will also survive, albeit with electrical burns to the mouth and throat. How ***do*** growers deal with surviving adults and neonates when "clearing the grids" each morning?

It is apparent that the AVMAP does not consider electrocution acceptable unless an animal is already unconscious, and that electro-stunning requires the current to be directed immediately through the brain. The size and shape of flying-foxes, the manner in which they fly, and the arrangement of the conducting wires in orchard electrocution grids makes it impossible to fulfil the conditions specified by the AVMAP. Typically, a purpose-built electrocution grid comprises a vertical series of 15–20 parallel wires running horizontally and spaced 25–30 cm apart (Rigden et al., 2000). The wing-span of an adult flying-fox is about 1 metre; the skull, at its broadest is about 5 cm across. It is thus physically impossible for a flying-fox colliding with the wires of a grid to be stunned by the electric current in a manner equivalent to that specified by the AVMAP, namely via, "an apparatus that applies electrodes to opposite sides of the head... directs electrical current immediately through the brain".

Consider the various geometries of collision: a flying-fox may be flying with wings in a horizontal plane, parallel to the line of wires, or at an angle to them; in either case the animal may be flying horizontally, descending or ascending. These different geometries will not make a vast difference to the most likely double contacts required to produce current flow through the animal. In the following, "***to***" delineates the primary path of the current flow:

- wing to wing (the wings' fingers, thumbs or membranes may be involved);
- hind-limb (claws or attached wing membrane may be involved) to wing on the same side (as above)
- hind-limb (as above) to wing on the opposite side (as above)
- hind-limb (as above) to head or neck; wing (as above) to head or neck.

All of the above correspond to the ***unacceptable*** routes listed by the *AVMAP*. Given the anatomy of the flying-fox wing, and particularly the broad band of wing-membrane that connects hind-limb to fore-limb structures, it is unlikely that any of the contacts listed above would cause cardiac fibrillation. Moreover, since adult flying-foxes weigh about 1kg, it is likely that "ventricular fibrillation and circulatory collapse" would not "persist after cessation of current flow".

Given the weight and shape of flying-foxes, physical contact between their tissues and the grid is likely to be physically weak and electrical contact easily broken. Thus, an animal could receive repeated transient, but painfully burning, shocks for relatively long periods – no individual shock being capable of inducing cardiac fibrillation, let alone cerebral anoxia and unconsciousness. Many flying-foxes, making the electrical contacts listed above, will be conscious and in severe pain, and either struggling, or undergoing reflex, or electrically-induced spastic movements for some time before they die. Such movement and spasms may throw them from the wires, severely injured and in pain, but alive. A video-recording accepted as evidence in the Federal Court case shows a moribund, but living bat, on the ground under the grid. This animal had clearly been there for some considerable time – almost certainly more than a day, and was feebly moving its head, ears and thumb claw. The same video-recording shows an adult bat flapping and screaming on the grid for 8 seconds before breaking free and flying to the ground.

Neonatal flying-foxes: deaths and injuries resulting from electrocution of mothers

For the first few weeks of life, neonatal flying-foxes are carried by the mother. They grip firmly to the mother's abdominal skin by well-developed horny hind-claws, and to one or other of the axillary nipples by strongly recurved milk teeth (Martin 1998). In this position they are unlikely to receive a major electric current flow resulting in cardiac fibrillation and death. It is also likely that, as neonates, they are more resistant to anoxia than adults. Be that as it may, flying-fox carers have observed that, while a significant but relatively small proportion of adult flying-foxes survive "electrocution", in the sense of remaining alive for hours or days afterwards, the majority of suckling young found on dead, electrocuted mothers (on or below power lines) ***are*** alive. Furthermore, most are relatively unhurt and survive and prosper in care. Others are found with mild-to-severe electrical burns to the mouth and throat, and may survive, given appropriate treatment. A minority are found alive but with severe internal and external electrocutive injuries and are euthanased as soon as possible. Since the birth season of *P. poliocephalus, P. alecto* and *P. conspicillatus* overlaps the harvest season for many fruit crops in eastern Australia (McIlwee and Martin 2002), it is likely that 50% or more of bats killed on orchard grids are lactating females with young attached, or left in a creche. In the event of electrocution of females with young attached, many of the latter may survive, albeit with the injuries described above, to die slowly of trauma and starvation, and in considerable pain. Orphaned young in the creche will simply die by starvation.

Conclusions regarding the humaneness or otherwise of flying-fox electrocution grids

I conclude that: orchard electrocution grids do not kill flying-foxes rapidly, instantly or painlessly; that many animals suffer gross electrical-burn injuries from the grids, yet survive for hours or days.

There is no doubt in my mind that use of the grids contravenes the *NSW Prevention of Cruelty to Animals Act* (Act 200 of 1979 as amended) in that operation of a grid results in ***multiple uncontrolled acts of cruelty***: ***multiple*** in that many bats may be affected; ***uncontrolled*** in the sense that there is no control on the number of bats which may be affected; ***acts of cruelty***, in that as a consequence, animals are unreasonably and unjustifiably mutilated, maimed, terrified, exposed to excessive (electrical) heat and inflicted with pain. Similarly, that operation of a grid results in ***multiple uncontrolled acts of aggravated cruelty***, in that its operation will result in the death or serious disablement of multiple animals, some being so severely injured or in such a condition that it is cruel to keep them alive.

Recommendations

In view of the ineffectiveness of electrocution grids in protecting fruit crops and the cruelty involved in their usage, I recommend that all such grids be dismantled immediately and that compliance with dismantling be strictly enforced. But I reiterate that, ***if the community wishes flying-foxes to be conserved, then it*** *must* ***help fruit-growers*** with non-means-tested grants and subsidies for humane, non-lethal methods of protecting fruit crops.

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