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Deevey's Hare and Haruspex revisited: Why domestication dooms civilisation?

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ABSTRACT

Sixty years of work on four species of hares shows that wild populations are held by behavioural mechanisms well below the carrying capacity of their habitat. In contrast, feral populations of domesticated rabbits, and apparently all other domesticated species, expand to the food limit and starve. Some humans became domesticated (civilized) about 11,000 years ago with the advent of agriculture, lost the 'savage' characteristics that hold populations in check, and already are well over ecological carrying capacity. Continued growth is technologically possible at the expense of a natural environment, but renders humanity increasingly vulnerable to sudden extinction.

KEYWORDS

hare; rabbit; domestication; population limitation; future humanity

INTRODUCTION

Why an attempt to review and explain the relevance to humanity of sixty years' work on hares in Scotland, Africa, and New Zealand? Ecologically, the world is in a mess, and there may be more important things to do. People who are environmentally aware want immediate action; the other 90% do not care. Yet it is dangerous to interfere in natural processes without a clear idea of what is likely to follow any alteration. Good intentions are seldom enough. After all, rabbits (*Oryctolagus cuniculus*) were introduced to Australia for very good reasons. But, as Leunig (2003) poetically puts it:

'Mr Rabbit came to Australia with his wife
To raise a family and make a brand new life...
They rushed ashore and quickly dug a hole,
Then lay down side by side and lost control.'

We should learn history, 'not to know the future but to widen our horizons, to understand that our present situation is neither natural nor inevitable' (Harari, 2014). But a knowledge of ecology is vital. Then we may offer advice, even if history tells us that the public never accept it. One day they may.

Edward S Deevey (1959) in his prescient essay 'The Hare and the Haruspex: a cautionary tale', deals mainly with why the stressed lemmings migrate like refugees to their deaths, but links it to shock disease, which kills crowded snowshoe hares: 'And though the how and why of psychosomatic ailments in wild rodents are undeniably important to tame men, the problems of grey flannel suits are not my main concern. The real attraction of stress, at least for a biologist, consists simply in the way it works'.

We haruspices (people who claim to foretell the future by inspection of animal entrails) offer this explanation of the population crisis to society, although the problems of torn blue jeans are not our main concern either: we feel a greater obligation to the 2500 hares that were shot by us or on our behalf to appease the gods of statistical sample size. After all, society has refused to heed the warnings of the demographers

since Malthus (1826), who agree that over-population is, and will remain as long as we do, the underlying cause of humanity's problems, be it via climate change, environmental collapse, war, famine, alienation, or pestilence. This paper explains why civilized societies have not responded to well-founded warnings, and the reason they never will. The answer, we suggest, lies in the juxtaposition of Deevey's 'wild rodents' and 'tame men'.

1. STARTING HARE WORK

As a boy, JECF learned to separate brown hares (*Lepus europaeus*), to be hung intact by the front feet in the cellar for nine days, from rabbits, gutted and hung by the back feet. No biology was taught at school. He was reprimanded for training bees to visit his honey-filled inkwell after reading Karl von Frisch; reared orphaned birds that became imprinted as described by Konrad Lorenz; and experimented with sticklebacks (*Gasterosteus aculeatus*) in cellophane containers in the river to measure their home ranges, following Niko Tinbergen. At university, Prof V. C. Wynne-Edwards suggested mountain hares (*Lepus timidus*) for his PhD.

In those days, at least at Aberdeen under Wynne-Edwards, we had little supervision. He wrote on the back of an envelope – 'Advantages of Mtn Hare 1 Diurnal, 2 Lives above ground, 3 Lives on moors where it can be studied free from human interference, 4 Is extremely common in suitable places near Aberdeen (up to say 10 per 100 acres), 5 Has some economic value a. for food, b. as a competitor with sheep & grouse'. He showed us a study area on Roar Hill in 1957, and left for a sabbatical year in Kentucky. MMF graduated as a biology teacher, organised the hare work, and helped during holidays.

Fortunately, Ray Hewson, an excise officer (a sinecure for people of good character, usually artists or writers, their only duty being to open and shut the distillery) was working on *L. timidus* as a hobby near Dufftown. His office had hare skins piled to the ceiling (Hewson, 1958). Ray taught us to catch hares alive in 'stopped' snares, and drink overproof whisky. We caught and ear-tagged 102 hares on Roar Hill to study their abundance, reproduction, behaviour, movements, and the time of colour change to white in winter (Flux, 1970a,b). Adam Watson (1963) was studying colour change too, and gave much useful advice. Why these seasonal changes have not adapted to shorter snow-cover, as *L. americanus* has (Mills et al. 2013) following climate change (M. Zimova, pers. comm., 2018) presents a new puzzle for us, and the hares.

Here, however, we are concerned with population density. At that time, Roar Hill had a maximum of 0.78 hares/ha. The highest density recorded for Scotland was 2/ha, normal being 0.3–0.69/ha (Watson & Hewson, 1973) until the recent catastrophic decline (Watson & Wilson, 2018). Island populations can reach 4/ha (Angerbjorn, 1986). The highest density ever recorded for brown hares (*L. europaeus*) on a Danish island with no predators was 3.4/ha (Abildgard, Anderson, & Barndorff-Nielsen, 1972), but continental populations do not exceed 2.5/ha (Barbar & Lambertucci, 2018).

2. REPRODUCTION

In 1960 we moved to New Zealand, joining the Department of Scientific Research (DSIR) to study brown hares. Rabbit Boards were worried that hares were increasing as rabbit numbers declined, and wanted research. (Actually, there was little increase, but the Boards had changed from poisoning, which killed few hares, to night-shooting, when the hares become obvious.) We began monthly collections of 30 hares shot by the Boards in each of the four areas: Waikato, Wairarapa, Canterbury, and Southland, to investigate reproduction. One interesting result was that hares start breeding in midwinter close to the shortest day, and this held in all the countries studied, including Canada where first litters died in the snow – presumably because all females were affected; subsequent litters were sufficient for replacement, and selection had nothing to work on. In contrast, rabbits breed whenever they can find enough green food (Flux, 1965, 1967a).

So what happens on the equator, where there is no shortest day? A spare (in both meanings, unused, and meagre) student grant allowed us to exist for a year at Nairobi (population then 400,000; now 4.4 m.) to find out. We shot 10 Cape hares (*Lepus capensis*) a month in three study areas in the Rift Valley, and Keith Eltringham sent samples of scrub hares (*Lepus victoriae*) from Queen Elizabeth Park in Uganda. These two species were hard to separate, even in the hand (Fig. 1). We found the easiest way was to smell them: *capensis* is musky, like *timidus* and *europaeus* and probably would hybridise as they do; but *victoriae* smells sweet, their way of avoiding interbreeding (Flux & Flux, 1983).

We were surprised to find *L. capensis* and *L. victoriae* grazing side by side in parts of the Rift Valley because normally hare species do not overlap – their niches are too similar. It seemed a result of Masai fires to clear scrub for their cattle: *L. capensis* likes open grassland, while *L. victoriae* prefers scrubland, and the patchy location of these habitats kept changing.

Although most other animals reproduced during either or both of the rainy seasons, hares bred all year round. Females could have eight litters a year, but only of one or two young ones, and the annual production fitted the hyperbolic function xy = 10 (Flux, 1981a); in other words, females of all species of hares produce 10 young ones a year (no one knows why), by adapting litter size to the length of the breeding season. Rabbit productivity, however, varies from zero to 45/female/year, depending on the food supply. Population density is not related to litter size of course (possums, *Trichosurus vulpecula,* in New Zealand forest average about 10/ha despite having only a single young one each year; and can retain these densities for at least 40 years (Efford & Cowan, 2004)), but litter size may explain why cats could not control rabbits until their numbers had been reduced by poisoning, and their lower pro-

Figure 1. Left, Lepus europaeus *(above),* L.timidus *(below) interbreed and produce fertile offspring Right,* L. victoriae *(above),* L. capensis *(below), collected 100 m apart in Kenya, do not interbreed*

ductivity balanced by a widespread distribution of cats (Flux, 1999).

3. BEHAVIOUR

We started watching mountain hares in 1957 from a hide on Roar Hill, and followed their tracks in the snow to see what they ate. Walking around with a spotlight at night just disturbed the hares, and camera traps had not yet been invented. Thirteen young hares (*timidus, europaeus,* and *capensis*) were reared over the years as house pets, singly, one pair, and one group of three, to study individual behaviour, interactions, food, growth rates, and moult (Fig. 2).

In 1962, New Zealand Forest Service built a hut and hide above the tree-line in Cupola Basin, Nelson Lakes National Park, for a joint NZFS–DSIR team to study the erosion caused by deer (*Cervus elaphus*), chamois (*Rupicapra rupicapra*), and hares over five years; and we built a small hide to watch rabbits and hares interacting on the Travers flats near the Coldwater hut. Forest Service had estimated a very high population of hares in alpine areas, but this was based on pellet counts, assuming a 3-week decay rate; in Cupola Basin, the decay rate averaged 3 years, each hare was represented by 10 million pellets, and there were only 8 hares present on 1250 ha (Flux, 1967b). Certainly their contribution to erosion was negligible: even favoured plants were only hedged rather than killed, and native grasshoppers (*Brachaspis collinus*) were eating more of the vegetation than the other grazers combined (Batcheler, 1967). His unofficial project faced publication delays because it undermined Forest Service policy that deer were the culprits. Caughley (1983) lampooned such NZFS intransigence: 'policy-making is the prerogative of Government alone' (Forest Service annual report of 1956). Yet, the 1970 annual report informs us that "it seems appropriate to restate Forest Service Policy which is to control noxious animals..." A slip of the typewriter there.'

On Travers flats, the 25 resident rabbits usually dominated 10 hares trying to feed there, but rabbits declined to extinction over two years. JECF nearly joined them when three deer shooters fired ten rounds at the hide for target practice, while he was in it on 25 May 1965; they missed, but he learned to appreciate life from a hare's viewpoint. Hares retained the disputed area (possibly aided by flooding and stoats) and rabbits never came back. The remarkable strength of competition between hares and rabbits was later measured by comparing the survival of mixed populations on islands (Flux & Fullagar, 1992). Competition from hares proved to be more effective for removing rabbits from islands than cats, shooting, poisoning, or even myxomatosis, which killed 99.9% on first application (Flux, 1993) – this level of selection pressure, of course, led to extremely fast virus attenuation, and rabbit immunity. A review of rabbit/hare interactions (Flux, 2008) overlooked an important finding by a colleague in Australia: when fresh green grass grows, rabbit's home ranges get smaller, but hare ranges in the

*Figure 2 Leveret and adult hand reared pets (*L. europaeus*)*

same place do not change (Stott, 2003). This is an indication of the rabbit's greater tolerance of conspecifics compared to hares.

In the wild, hares could only be watched for short spells, and no young ones were seen; so we built a 3.5 ha enclosure on Belmont hill near Wellington and stocked it with one male and five female adult hares, individually marked with reflective ear discs. The whole pen could be seen from a hut on the opposite slope and the hares were watched all night with a low power torch run continuously. To occupy the day, we started a ten year study of artificial selection for increased clutch size in starlings (*Sturnus vulgaris*) nesting in 500 boxes in the same area (Flux & Flux, 1982); this was continued to track the effect of climate on breeding date (Tryjanowski, Flux, & Sparks, 2006).

We published a detailed account of how hares spent their time (Flux, 1981b) and resolved a long-standing belief among hunters dating from Xenophon, but not accepted by scientists like Barrett-Hamilton (1912) or Corbet & Southern (1977), that they confused their tracks before entering daylight resting places (forms). They used different tracks each day, and each individual entered its form at almost exactly the same time, which varied seasonally. Over three years, the number of hares did not change, and the few young ones produced disappeared. (One remarkable hare on being released in the pen ran straight to the fence, bit a hole in the wire netting, and escaped; after the fence was mended, it was replaced with a hare of normal IQ. Why hares do not use their extremely sharp teeth in self-defence is also puzzling; only one of several hundred hares handled bit, and it sliced to the bone.)

Our house in Belmont overlooked a 200 ha grass field, and from 1972–2016, we watched the 1–5 free-living hares (0.03/ha) and 2–20 rabbits (0.1/ha) there. At these low densities, they fed together peacefully (Fig. 3), but rabbits usually kept close to gorse (*Ulex europaeus*) patches for cover from predators, while hares outran them in the open.

4. POPULATION CONTROL

The density of captive hares in our pen was high (2.1/ha) and at their upper limit for plain grassland (although we often had to bring in 30 sheep to keep the vegetation low enough to see the hares; and there were no rabbits). So, we were not expecting much increase; but this surprised our Director, John Gibb. He made a classic ten-year study of rabbits (with no hares) in a 4 ha enclosure at Kourarau, protected like ours from predators by electric fencing. There, 11 rabbits (two females) increased to 690 in three years (173/ha), and starved (Gibb, Ward, & Ward 1978). He had done his DPhil under David Lack (1954), who maintained that animal populations expand to the

*Figure 3. At low density, rabbits (*O. cuniculus*) and hares (*L. europaeus*) at Belmont feed together without interaction*

food limit; Wynne-Edwards (1962, 1986) thought overpopulation was avoided by behavioural mechanisms, some evolving through group selection. It seemed curiously fortuitous that our results followed the expectations of our supervisors, and neither of us was prepared to abandon our entrenched views.

In 1997, we spent eight days at La Selva, a tourist lodge in the Ecuador Amazon forest, and were amazed to see migrating swarms of white and yellow butterflies flying through each other in different directions, exactly as we had seen in Kenya (Flux & Flux, 1970); but these were not the same species. Other highlights were nature tours led by students doing post-graduate research under the direction of Phillip DeVries, an entomology professor from Oregon. He was curious about the Lack v Wynne-Edwards debate, and we talked long into the evenings. Eventually, he asked for a one sentence summary of the difference between rabbit and hare behaviour, and we quoted a 1905 letter from Irish hare expert, Mr Drane, saying that hares are 'very gentlemen, just as the rabbit is a very cad' (Millais, 1904–06).

On the way home, we stopped in Abu Dhabi to see Chris Drew's work on desert hares (Drew, 2000) at the multi-million dollar research centre for desert ecology, set up to boost the bustard (*Chlamydotis undulata*) numbers for falconry. We were unexpectedly asked to give a seminar to 30 staff members the following morning. Normally, we talked through slides, but the only work item we had with us was a copy of the IUCN Rabbits, Hares and Pikas action plan (Chapman & Flux, 1990).

Overnight something clicked: list the highest densities recorded for each of the 24 species of rabbit, and 29 hares, and see how many sided with Lack, and how many with Wynne-Edwards. We wrote the talk from 7 am to 8 am, only to be told the seminar was cancelled. Relief was tinged with disappointment because we had discovered something important: the European rabbit was on its own; the cads have 'lost control' and reach densities ten times higher than any of the other rabbit species, and all hares. And the reason could be the result of domestication in monasteries from about AD 600, being kept captive in hutches or warrens until they escaped and reverted to the wild from AD 1200. We gave the talk at the Euro-American Mammalogy conference in July 1998; one reviewer called it 'a wonderful paper' (AB Smith, 1998–99), but we soon found this view was not widely shared.

5. REFEREES

The manuscript was sent to three journals before it found a home (Flux, 2001).

One referee claimed 'Similar, if not identical, arguments have often been presented in the past ecological literature, so the idea is scarcely novel'. This was annoying; we had

spent 45 years reading ecological literature, following Wynne-Edwards' advice – never work on anything that has been done before. We wrote asking for any reference that we could quote, but got no reply. Four other referees just objected to Wynne-Edwards: 'readers will be of the opinion that "Wynne-Edwards plus population regulation equals group selection", so it will be helpful to de-emphasise his work.' 'The altruistic voluntary variety envisioned by Wynne-Edwards...a final nail in the coffin.' 'Wynn-Edwards (sic) ideas have been rightly rejected and largely forgotten by now.' 'The presentation is strong, focused, complete and well presented. If I had one thing to say, it would be to down-play the connection to Wynne-Edwards.' We knew of course that group selection was a taboo topic (those who still oppose it need to read D. S. Wilson (2012) and E. O. Wilson (2012)), and had made it clear in our opening paragraph that we were discussing whether vertebrates were at their food limit or safely below it: 'This problem needs to be examined independently of its mechanism of evolution'. Since it was Wynne-Edwards' idea, we were not prepared to omit his name.

Our favourite peer reviewer wrote 'The term "self-regulation" seems unnecessarily misleading. It is jargon. Whenever I see the similar term, 'self-thinning', the image of plants killing each other off or committing suicide comes to mind...I have read quite a bit of literature on regulation hypotheses, and I cannot say that I have ever come across this term. I may have, but it is not used often. Neither "self-regulation" nor "regulation" appears in the index of Wynne-Edwards's book. Did Wynne-Edwards ever characterise his ideas in this way?'

Yes, he did; but you need to read the book, not the index. This is point 1 of 14 points raised with remarkable verbosity (we spare readers the rest). Luckily, the editor agreed with two other referees who, in seven lines each, considered it a provocative idea that might stimulate interesting correspondence.

They were wrong. Not a single published comment resulted, although Charles Krebs sent an encouraging e-mail: 'What a marvellous article in this Oikos 92;555 on the rabbit hare comparison! I enjoyed it very much; very insightful.' In the following 18 years, it has been cited 11 times, in very odd contexts, but with no discussion of the presaged population implications for civilization.

6. DOMESTICATION

Domestic animals were usually selected to be larger, faster growing, tame, and of aberrant colours (Diamond 2002). That the progenitor of the European 'wild' rabbit was a domesticated form of *O.c. algirus*, a rabbit about half its size from the west Iberian peninsula, was first suggested by Fitter (1959), and its growth rate is twice that of Iberian rabbits (Rogers, 1979). The other larger subspecies (*O. c. cuniculus*) from the east of Spain is genetically close to north European and domestic rabbits (Delibes-Mateos, Vilafuerte, Cooke, & Alves 2018), and is usually considered the origin of domestic rabbits. Whichever subspecies was ancestral, the widespread common rabbit is clearly a feral domestic. Odd colours are frequent: only 95% of thousands exported from New Zealand were plain agouti (Norbury & Reddiex, 2005). The only difference a study comparing the behaviour of Australian 'wild' rabbits with coloured domestic rabbits found was that the tame rabbits were more diurnal (Stodart & Myers, 1964). But, significantly, the behaviour of wild Portuguese rabbits does differ: LE Smith (2003) found 'group living is only common in exposed areas. The overall conclusions of this study contradict the general view of the European rabbit as being a social species...'

The main requirement for domestication is stable excess food. Humans became domesticated (civilized) when they adopted agriculture 11,000 years ago (Harari, 2014), or possibly earlier, and in several places (Robson, 2018). Previously, nearly all 'savage' tribes killed strangers on sight, an effective defence of food in their territory, that (in conjunction with infanticide, cannibalism, and elimination of the sick, weak, or aged) had stabilized human populations for thousands of years previously. Crowding was no longer a threat to resources, and 'love thy neighbour' (tameness) was promoted, as by the major religions; human life was sacred, and even euthanasia became an evil. Domestic mammals such as camels, horses, cattle, pigs, sheep, and dogs; birds like ducks, doves, quail, and pheasants; and fish like carp, were selected for the same characters, tameness, high fertility, and tolerance of high densities. Several species, like mice, rats, pigeons, and insects, attracted to stored food and monoculture crops, in effect domesticated themselves and can, in the right conditions, increase to the food limit before dying of starvation (Mutze, 1989). Most other truly wild vertebrates can be kept as pets, but have never been domesticated, and cause relatively minor trouble. Cats remain enigmatic: 'So are today's house cats truly domesticated? Well, yes, certainly they are – but perhaps only just' (Driscoll et al. 2018).

In 1944, 29 domesticated reindeer introduced on St Matthew Island increased to 6000 by 1963, a biomass of 243 kg/ha; they starved overwinter and just 42 remained in 1966 (Klein, 1968). Wild reindeer in Norway reached a peak biomass of only 2.76 kg/ha (Skoglund, 1968). On Pinta (5,940 ha, Galapagos Islands), 41,390 goats were killed after destroying the vegetation – 244 kg/ha (Campbell et al. 2004). Goats on Macaulay Island were said to have converted the forest to grassland, but the population appeared stable at 340 kg/ha when the goats were removed (Rudge, 1990). In comparison, the combined biomass of all the large ungulates in 24 African wildlife areas averaged 64.6 (4.1–199) kg/ha (Coe, Cumming, & Phillipson 1976). Rabbits in Kourarau enclosure starved at 280 kg/ha (Gibb, Ward, & Ward 1978), and on islands and places with suitable grazing, can reach 300 kg/ha (Thompson & King, 1994). This 300 kg of rabbits/ha fits well with the 3000 kg of grass/ha standing crop for non-fertilised grassland in Europe (Olff & Bakker, 1991), as predicted by the 1:10 ratio of grazer : grassland biomass expected from Elton's pyramid, so may well be a critical value for a single species to survive. In India, farmland can support a human density of one person per acre, say 125 kg/ha (Odum, 1971); so 300 kg/ha is likely to be the limit for domesticated humanity, on a vegetarian diet, just as for rabbits.

And we will reach those densities soon, on all the available land that can be cultivated, simply because, as Deevey puts it, we are 'tame men'.

7. DISCUSSION

Ecology has few rules, but they are important. Gause (1934) showed experimentally that two species cannot occupy the same niche, so habitat diversity matters. This, and two basic rules developed by Preston (1948, 1962), underlie our conservation predicament. First, at any location, the number of individuals of the species present, of plants or animals, form a log-normal distribution (a few are very common, and there is a long tail of rarities). Second, the number of species is related to the area available on a logarithmic scale: at one tenth the original area, only half the number of species can survive. Hence, setting aside a tenth of the country as a national park dooms half the species originally present to extinction, and those lost are the rarities. Note that this takes time: Lomborg (2001) questions the validity of this rule because the list of mammals in the Atlantic forest remnants in Brazil has not decreased – it will, because small populations are unstable, and 28 bird species have already become locally extinct (Ribon, Simon, & De Mattos 2003).

Conservationists seem unaware that only by artificial management can more exist; then we are making the planet a zoo. As an example, New Zealand had space for only 8–12 species of moa, and 30 forest birds. The 28 described species of moa have now been reclassified to 10–11; and the forest birds lost have been replaced by an equal number of open country species as forest cover declined from about 80% to 25% (Flux, 1989). The mechanism appears to be competition, as illustrated by hares and rabbits: islands need to exceed 1000 ha for both species to co-exist (Flux, 1993). A similar pattern is evident in Zealandia, a 225 ha predator-fenced reserve in Wellington city: of the 10 new bird species introduced, bellbirds (*Anthornis melanura*) have been unable to compete with tui (*Prosthemadera novaeseelandiae*), and tomtits (*Petroica macrocephala*) with robins (*Petroica longipes*); and the newcomers have caused steep declines in at least seven species previously abundant (Miskelly, 2018).

In addition, as Elton (1958) pointed out, invasions of alien species reduce biodiversity. Think of Preston's log-normal distributions that evolved in isolation to fill similar niches on various continents and islands; when these are mixed, up to half the species will eventually disappear even if the available habitat is not reduced. People transport thousands of plants and animals every year. The effect of predators is usually obvious, but competitors can be as bad. There is no room in such artificial communities for four species of white and yellow butterflies to fly together.

8. CONCLUSION

Unlike rabbits, humans are unlikely to die out quietly of stress and starvation. The haves will fight with the have-nots within groups; and all groups (based on colour, language, or religion) will fight each other to survive. Those in countries devastated by climate change, rising sea-levels, disease, and nuclear warfare will invade areas where conditions are still tolerable. Elon Musk may be right that only by settling on Mars will humans avoid extinction on an Earth they will have destroyed – Stephen Hawking agrees (Hawking, 2018). But if humans are capable of living on Mars, they could survive on an ecologically devastated Earth: at least until some unforeseen technical error proves fatal.

There is nothing new in forewarning doom. Malthus (1826) was perhaps the first recent scholar to present a well-argued case. Interestingly, he compared food supply to a tortoise unsuccessfully trying to catch the hare of increasing population: 'Finding, therefore, that from the laws of nature, we could not proportion the food to the population, our next attempt should naturally be, to proportion the population to the food. If we can persuade the hare to go to sleep, the tortoise may have some chance of overtaking her.' Unfortunately, hares sleep for only 2–4 minutes in 24 hours (Drane, 1895; Flux, 1981b), so the tortoise's chances are slim.

Experts in animal behaviour look at humans and see much to worry about.

Desmond Morris (1967): 'Optimism is expressed by some who feel ...we shall re-model our behaviour patterns and live like giant ants...that if we have to become battery chicken-apes, we can do it; that our intelligence can dominate all our basic biological urges. I submit that this is rubbish. Our raw animal nature will never permit it.' We agree, having compared the rates of evolution and culture change (Flux & Flux, 2015).

Karl von Frisch (1949): 'Slowly, we come to understand that Man cannot afford to forget that he himself is but one link in Nature' and 'Incredibly careless about the welfare of future generations, he plays with fire before he has learned to control it.'

Konrad Lorenz wrote in 1935: 'The day will come when two warring factions will be faced with the possibility of each wiping the other out completely...when the whole of mankind is divided into two such opposing camps...We may well be apprehensive.' (Lorenz, 1961).

Niko Tinbergen (1985) wrote (his italics):

'I do *not* say that we *are* doomed. But what I must say, and say most emphatically, is that, *if we do not change* our lifestyle and reverse the trends I have listed (population, food, resources, pollution, warfare), *Homo sapiens*, and with him many forms of life on Earth, will soon, at best experience an unprecedented population crash or at worst, and in my opinion more likely, become extinct.' Note that Tinbergen refers to 'our lifestyle'; the traditional hunter-gatherer tribes are not at risk of overpopulation, but face loss of habitat, like all other 'forms of life' on Earth.

These three authors earned a Nobel prize in 1973. Curiously, Alfred Nobel (1892) had more optimistic hopes for humanity: 'When two army corps may mutually annihilate each other in a second, probably all civilised nations will recoil with horror and disband their troops'. But this view followed the erroneous publication of his obituary by a French newspaper in 1888: 'Nobel, who became rich by finding ways to kill more people faster than ever before, died yesterday', which is said to have persuaded him to leave posterity a better legacy.

We suggest Nobel's hopes are in vain. Humanity is not prepared to heed any warning. Ripple et al. (2017) say, 'Twenty-five years ago, the Union of Concerned Scientists and more than 1700 independent scientists, including the majority of living Nobel laureates in the sciences, penned the 1992 "World Scientists' Warning to Humanity"... humans were on a collision course with the natural world. They expressed concern about current, impending, or potential damage on planet Earth involving ozone depletion, freshwater availability, marine life depletion, ocean dead zones, forest loss, biodiversity destruction, climate change, and continued human population growth'. Ripple's 'World Scientists' Warning to Humanity: A Second Notice' is signed by 15,364 scientists from 184 countries. It will have no effect either. As Chapron, Levrel, Meinard, and Courchamp (2018) replied, tongue in cheek but, alas, all too accurately: 'We, the billions of people believing in human exceptionalism, categorically reject this agenda...No amount of facts showing that planet Earth is in a dire state will have us change our mindset, thank you very much. We do not care about planet Earth. We care about our next devices and their latest cool features. We want more stuff.'

Can they have it? Yes, there is ample energy; science and technology can fix the food supply (Springmann et al., 2018); and scientists are already working on carbon extraction from the atmosphere, aerosols to stop global warming, and living in biosphere enclosures (Nelson, 2018). Genetic engineering will avoid diseases and prevent aging; cyborgs can join humans to electronic devices; and artificial intelligence will exceed our abilities. After discussing this, Harari (2014) concludes: 'We are more powerful than ever before, but have very little idea what to do with all that power. Worse still, humans seem to be more irresponsible than ever... wreaking havoc on our fellow animals and on the surrounding ecosystem, seeking little more than our own comfort and amusement, yet never finding satisfaction. Is there anything more dangerous than dissatisfied and irresponsible gods who don't know what they want?' Perhaps this makes the extinction of our civilised human race not just inevitable but desirable.

9. EPILOGUE

Chimeras are an emerging escape-route for humanity. Our brain cells can be grown in rodents and form functioning brains; and although 'these do not have human capabilities such as self-awareness, the possibility is becoming less remote' (Pearlman, 2018). Cockroaches and rats (Fig. 4) have long been expected to take over after a nuclear holocaust, and it would be poetic justice to have humanity survive in the form of intelligent rats. If any normal humans survived, they would be 'fellow mortals' as the Scottish poet Burns called mice, and less inclined to consider themselves superior. In separate niches, we should be able to coexist with ourselves. A future as cockroaches and rats was foretold in 'Archy and Mehitabel' (Marquis, 1931): 'my soul went into the body of a cockroach it has given me a new outlook on life...this rat is like me he has a human soul in him he used to be a poet...' (Archy, the cockroach, types without capitals or punctuation; it forces concentration on his brilliant philosophy of life. Mehitabel, the enigmatic cat, was formerly Cleopatra.)

One day, too late, the doomsayers and haruspices will be proved correct. The real conflict is between the increasing numbers who want stuff, and those who want a planet worth living on. Perhaps we should have been more concerned with grey flannel suits and torn blue jeans: have you noticed the increase in stress-induced psychosomatic ailments presaged by Deevey? (cf. Josephson & Josephson, 1962). Apparently, the cure to all the world's ecological troubles was recognised and written on papyrus four thousand years ago: 'Oh that man could cease to be, that women should no longer conceive and give birth. Then, at length, the world would find peace' (Erman, 1927). As Hamlet said, 'a consummation devoutly to be wished.'

But without humans, the beauty of the world will go unexplained and unrecorded. As scientists, we feel a curious sense of regret; so the last word goes to Michael Lunig:

'A most depressing thing occurs
But no one minds and no one cares;
Which means you've ended up with two
Depressing things depressing you.'

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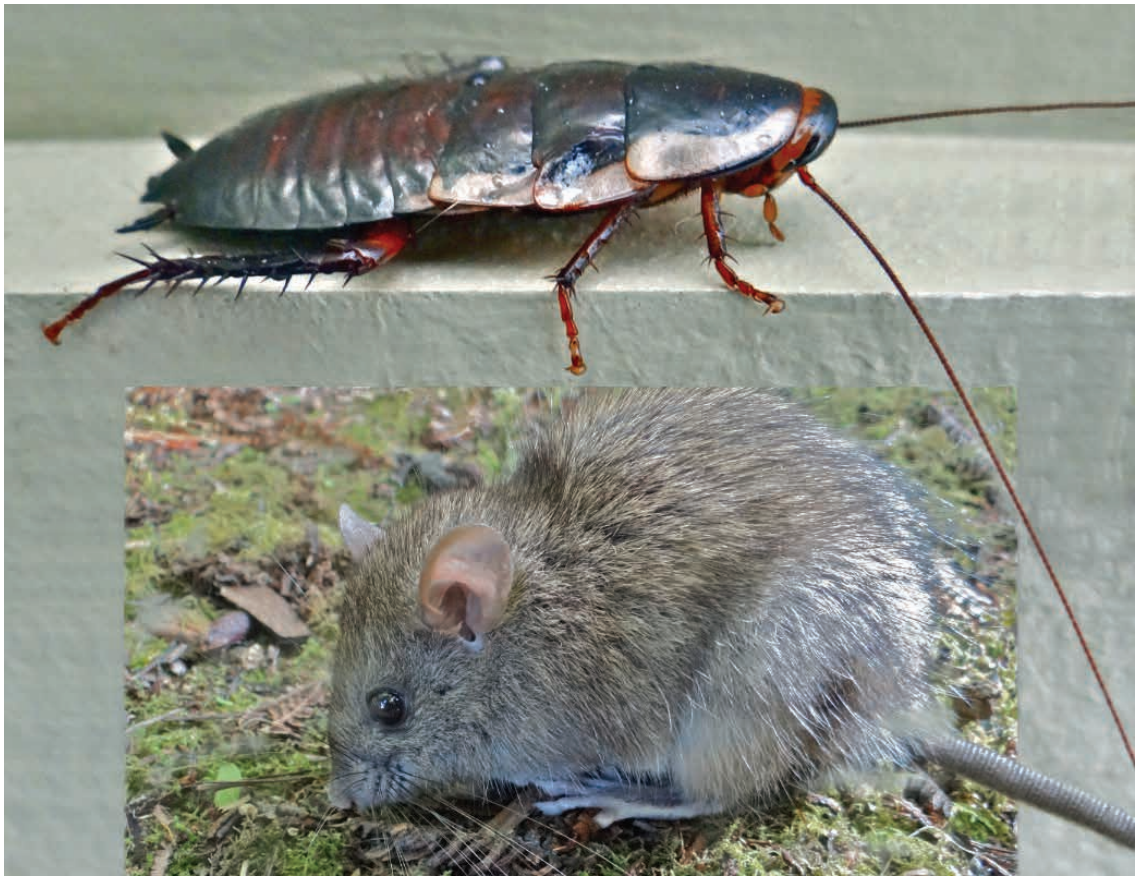

*Figure 4. Cockroach (*Drymaplaneta simivitta*) and rat (*Rattus rattus*): Future forms of humanity?*

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