1080 AND AUSTRALIAN FAUNA

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Cover: York Road Poison contains very high levels of fluoroacetate. It is a common plant in the hills east of Perth and caused the death of many stock as they were being driven towards York in the early days of settlement in Western Australia. It still causes stock losses today.

The illustration is reproduced courtesy of the Department of Conservation and Land Management and the Department of Agriculture (after Aplin (1969) J. Ag 10(6)).

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INTRODUCTION

In 1953 the poison 1080 (sodium monofluoroacetate) was first used in W.A. for the control of rabbits. It has since replaced poisons like arsenic, phosphorus and strychnine for that purpose, and has also been used in W.A. for the control of other species such as dingoes, foxes, agile wallabies and pigs.

This poison, one of the most toxic substances known, was first synthesized in Europe in the 1890's. Its toxicity to insects was recognized in the 1920's and it was patented for use as a moth-proofing agent. It is not now used as an insecticide. Further studies were carried out in the 1940's to evaluate the potential of fluoroacetate and related compounds as chemical warfare agents. During those tests, it was found to be extremely toxic to rabbits. Further work showed that it was highly toxic to a wide range of mammals and it's particular value as a rodenticide was determined in the U.S.A. in 1944. The common name of 1080 was derived from the laboratory serial number given to it at that time. Compound 1080 was first used as a vertebrate pest control substance in the U.S.A. in the late 1940's and is still widely used there.

The commercial-grade 1080 which is used by the A.P.B. is a tasteless and odourless powder which is readily soluble in water but relatively insoluble in most organic solvents, fats and oils. It has a high level of chemical stability, but decomposes at approximately 200°C .

Mammals are generally more sensitive to 1080 than are other groups of animals. It is highly toxic to most insects, birds and mammals. It is particularly toxic to canids (dogs, foxes, coyotes, etc) and felids (cats). It is an effective poison for rodents. Domestic stock and humans are also sensitive to 1080. Native wildlife in most parts of the world are also readily poisoned by it, either by eating the bait or by feeding on the carcasses of poisoned animals. The use of the poison in vertebrate pest control programs is thus often opposed and it's use is highly restricted in many countries.

MODE OF ACTION AND SYMPTOMS

Solutions of 1080 are absorbed through the gastrointestinal tract, open wounds, mucous membranes and the pulmonary epithelium but not through intact skin.

In the body, fluoroacetate is converted into fluorocitrate, which blocks the Krebs Cycle which is the major pathway for releasing energy from food. Other energy-releasing mechanisms are also blocked by the resultant disruption of normal activity within the cells. The energy supply to the cells is reduced. Cardiac and central nervous system dysfunction occurs and death may result from heart and/or nervous system failure.

The actual cause of death from fluoroacetate poisoning is not fully understood. Ionic imbalances are created in the body which may cause cardiac or central nervous system irregularities and disruption of the movement of some compounds between parts of the cells.

Herbivores generally develop cardiac symptoms, carnivores mainly show central nervous system disorders and omnivores show mixed responses.

There is a latent period between the time fluoroacetate is ingested and the time when the first symptoms of poisoning occur. The length of this period varies, depending on the size and the rate of metabolism of the animal, but is generally in the range of 30 minutes to 3 hours in mammals. This delay presumably results from the time taken for the 1080 to be absorbed and penetrate the cells, to be converted into fluorocitrate and for it to disrupt the processes of the cells. Death generally occurs within 24 hours, but may occur after that time. Sublethal doses are detoxified in the liver and kidneys or excreted, so the poison is not accumulated in the body.

Many species show signs of increased excitability when poisoned. They may run wildly, howl and convulse. Others may simply die while still feeding on bait material and not show any symptoms of distress.

There is no effective antidote for 1080. Some treatments have been suggested but they appear to mainly treat the symptoms rather than the causes and have limited value. Great care must therefore be used when handling this poison.

Sublethal levels of fluoroacetate can cause damage to the testes, reduced sperm production or lower levels of reproductive hormones which can decrease the fecundity of the animals. This could result in species which are not fatally poisoned being placed at risk through lower than normal reproductive rates. This could be of particular importance in those non-target species such as small dasyurids like the Red-tailed Phascogale (*Phascogale calura*) and the Dibbler (*Parantechinus apicalis*) where all the males die at the end of each breeding season. Entire populations of these species could disappear if the baiting caused males to become sterile during or before the breeding season. In animals which ingest sub-lethal levels of 1080, this can also result in temporary sterility of males. A higher level of tolerance to the poison in that species can evolve than is necessary to avoid being poisoned fatally by simply eating the poison. This has apparently occurred in the Bobtail lizard (*Tiliqua rugosa*). (See following).

NATURAL OCCURRENCE

Many years after 1080 was first synthesized, its toxic principle was found to occur naturally. In 1944 fluoroacetic acid was identified as the toxin contained in an African genus of plants (*Dicapetalum*). The first species from which it was isolated was a plant in South Africa (*Dicapetalum cymosum*, commonly known as "Gifblaar ") which had for many years been known to be poisonous to livestock. The particular poison involved was however unknown until that time. Subsequently, in 1963 and 1964, it was found to be the toxin in Gidyea, an acacia (*Acacia georginae*) which occurs in the Georgina River basin, on the Northern Territory - Queensland border. It was also detected in several species of the genus *Gastrolobium* (which is found in northern and southwestern Australia) and also in the genus *Oxylobium* in the southwest of Western Australia. Levels of 1080 in the dried leaves differ markedly between species, ranging from 50 mg/kg to 2650 mg/kg.

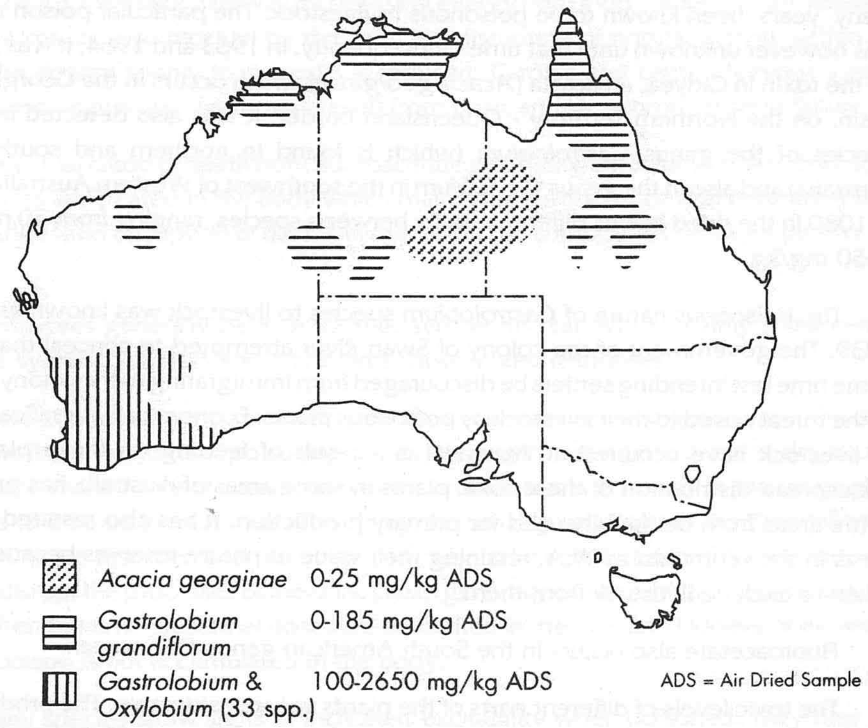
The poisonous nature of *Gastrolobium* species to livestock was known as early as 1839. The government of the colony of Swan River attempted to conceal that fact for some time lest intending settlers be discouraged from immigrating to the colony because of the threat posed to their livestock by poisonous plants. Economically significant losses of livestock have occurred in Australia as a result of feeding on these plants. The widespread distribution of these toxic plants in some areas of Australia has prevented some areas from being fully used for primary production. It has also resulted in many areas in the southwest of W.A. retaining their value as nature reserves because care is taken to exclude livestock from them.

Fluoroacetate also occurs in the South American genus *Palicourea*..

The toxic levels of different parts of the plants vary considerably. The production of fluoroacetic acid, which is presumably produced for the purpose of deterring animals from feeding on the plants, requires the investment of energy and material by the plants. Therefore, it is most efficient if the toxin is concentrated in the most important parts of the plants, such as the seeds, flowers and young leaves rather than being spread thinly through the tissues of the plant, including those less likely to be eaten by an animal.

DEGRADATION OF 1080 IN SOILS

Figure 1. DISTRIBUTION OF PLANTS CONTAINING FLUOROACETATE IN AUSTRALIA



Several species of bacteria, fungi or algae have been found to degrade 1080 in moist soils in New Zealand, Japan and England, where the toxin does not occur naturally. Microorganisms from these groups also defluorinate and thus detoxify 1080 in soils in Western Australia. If microbial detoxification of 1080 did not occur in Australia, large quantities of 1080 contained in shed leaves of the toxic plants would have passed into the soil and remained there, making the southwest of W.A. a very hazardous place.

The distribution of fluoroacetate-bearing vegetation in Australia is shown in Fig. 1. Most of the toxic species and those with the highest concentrations of fluoroacetate in their tissues are found in the southwest of W.A. where 33 species have been found to contain the toxin. Toxic plants containing 1080 occur over much of the southwest of W.A. and occur in a variety of vegetation and soil types. They are not found in the deep sandy soils of the coastal plain. Their abundance in a region is quite variable but in some areas a single species can form very dense stands of plants.

Toxic species of *Gastrolobium* and *Oxylobium* do not occur in the southeast of Australia (Fig. 1). The native fauna there have consequently not evolved an elevated tolerance to 1080 as have those in the southwest. The level of tolerance to 1080 can therefore differ greatly between populations within the same species. The brushtailed possum clearly demonstrates this difference.

EVOLUTION OF TOLERANCE IN NATIVE FAUNA

It had been suspected for years that some native animals in W.A. were tolerant to these poisonous plants but no firm evidence of this was obtained until the 1970's. It was then discovered that the brushtailed possum from areas in the Darling Ranges had much higher levels of tolerance to 1080 than did possums from the eastern states of Australia or those which had been introduced into New Zealand from the eastern seaboard. High levels of tolerance have since been found to occur in many species of native animals in Western Australia. These include animals from many independent evolutionary lineages, ranging from insects through reptiles, birds and both the marsupial and the placental mammals. The elevated levels of tolerance must therefore have evolved independently on several occasions, presumably through coevolutionary associations with the toxic plants. As the poison levels of the plants increased, the least tolerant individuals of a species which fed upon them would have been fatally poisoned whereas the most tolerant would have survived and subsequently bred. Their offspring would have inherited the ability to tolerate the toxin and thus the level of tolerance of that species would have increased. The tolerances of some native Australian species, on a body weight basis, are over 1000 times those of introduced dogs or foxes. Those species with the highest tolerances have had long evolutionary associations with the toxic plants and have relied heavily on those types of plants for their food. Evolution of increased levels of tolerance to 1080 has not occurred in introduced species, apparently because of the disparity between the high 1080 levels in the plants and the low levels of tolerance of the introduced animal species. They have simply arrived too late in the game. If they eat even small quantities of the plants they will die and consequently those species are highly unlikely to ever acquire substantial levels of tolerance to 1080. The techniques used for poisoning the animals whose numbers are being controlled with 1080 ensure that an animal feeding on the poisoned bait is almost certain to eat enough to cause it to die. This ensures that increased levels of tolerance to the poison will not develop in pest species in that way.

Rabbits from areas of Western Australia where poison plants are abundant (Chidlow) and where the toxic plants occur and 1080 baiting has been done regularly for over 30 years (Mt Barker) do not have higher levels of tolerance than do those from eastern Australia. They are also similar to those of rabbits from an area in W.A. where rabbit poisoning with 1080 has not been done and where plants containing 1080 do not occur (Quobba Station). They have not acquired higher levels of tolerance of 1080 either by being baited or from coming into contact with plants containing the toxin.

The biochemical mechanism by which animals have developed elevated levels of tolerance to 1080 is not definitely known but it is thought to involve changes to the transport system in the mitochondrial membranes of cells. The enzyme glutathione, which is involved in the detoxification of many poisons, detoxifies fluoroacetate by defluorinating it and also has some protective effect on the liver. Animals with depleted liver glutathione levels have increased levels of susceptibility to toxins. Sublethal levels of 1080 reduce the level of glutathione in the liver, which may remain at a reduced level for several days or weeks. The detoxification capabilities of sensitive animals from the eastern states are as good as those of the same species from Western Australia, but are not sufficient to protect them from high doses of 1080. The unfortunate easterners are still frantically detoxifying the 1080 when it kills them. The tissues of their western counterparts are somehow protected through unknown mechanisms for long enough to enable them to completely detoxify the 1080 which they have ingested.

In addition, western populations of native animals have higher levels of tolerance to 1080 than eastern populations and thus are able to survive the same dose which will quickly kill the animals from the southeast.

Herbivores are generally more tolerant to the poison than are carnivores. *Gastrolobium* and *Oxylobium* species are shrubs and those herbivorous species with the highest levels of tolerance are the browsers which feed upon them. Those species of herbivorous animals with lower levels of tolerance are primarily grazers. These may have browsed a few bushes or accidentally eaten leaves from the toxic plants which have become mixed into their normal food material of grasses and forbs. Native carnivores in the southwest also have increased tolerances to 1080 compared to those from elsewhere which have presumably become elevated through secondary ingestion of the poison present in their prey.

In retrospect, it should have been apparent that a high level of tolerance to fluoroacetate was present in at least some animals native to Western Australia. The levels of toxin contained in some of the toxic species of *Gastrolobium* and *Oxylobium* are otherwise unreasonably high. The plants must devote material and energy to produce the toxins and it is not efficient to incur extra costs by producing higher levels than necessary to prevent or reduce grazing.

Despite the fact that birds and reptiles are generally more tolerant of 1080 than are mammals, increased tolerance in southwestern populations of both has been found. Bronzewing pigeons from the southwest are approximately half again as tolerant as those from South Australia while Rosenberg's monitor, a goanna from the south coast of W.A., is approximately 6 times more tolerant than the same species from Kangaroo Island, S.A..

Following the discovery of the high levels of tolerance of some native Australian mammals, it was predicted that some species of African and South American animals would also be shown to have elevated levels of tolerance. This has recently been confirmed in a number of native mammals in southern Africa. Thus coevolution between the fluoroacetate-bearing plants and the native fauna has happened on at least two continents. There are also indications from published work that some South American mammals also have elevated tolerances to 1080.

Grey kangaroos in the southwest of W.A. eat substantial amounts of the leaves of *Gastrolobium* and *Oxylobium*. They eat more of those which contain low levels of fluoroacetate than they do of those with high levels of the toxin.

DETERMINATION OF LEVELS OF TOLERANCE TO 1080

The term LD50 will be used frequently here. It refers to the estimated dose of poison at which 50% of a group of animals will be killed. The value is usually determined by giving small groups of animals different doses of the poison and determining the level at which they die. These tests are usually conducted on animals kept under laboratory conditions. There are a number of environmental factors which can influence the LD50. These values are not as precise as they appear to be - the results obtained in different laboratories can differ slightly from one another because of the experimental conditions and techniques which apply. A high LD50 value, however, means that the animal has a high level of tolerance to the toxin.

Methods other than LD50 determinations are used to indicate the sensitivity of a species of animal to a toxin. Among these are values for the ALD (approximate lethal dose) which is also known as the MLD (minimum lethal dose). These values are obtained using the same experimental procedures used in obtaining the LD50 but they indicate the dose at which individuals of that species begin to die. When 10% or more of the animals in a dose group die, the ALD (or MLD) has been reached and dosing ceases. Therefore far fewer individuals need to be used in testing the toxicity of a substance than are needed for an LD50 trial and the trials are also less expensive to conduct. Although ALD values are obviously lower than LD50 values, there is a strong correlation between the scale of tolerances determined by these methods.

Another method used to determine the level of tolerance of species or populations to 1080 relies on measuring the increase in the level of citrate in the plasma which results from fluoroacetate poisoning. Within a species the level of plasma citrate reached following dosing is related to the size of the dose. The smallest rises in citrate levels at a given dose occur in the animals which are least susceptible to 1080. Differences in size and type of animal influence their rates of metabolism and prevent this technique being used to compare results obtained from species which are not closely related to one another.

Citrate levels are determined from blood samples collected from a small number of animals, which are then injected with 1080. Further blood samples are collected at intervals over the next 24 to 48 hours and changes in plasma citrate levels are determined. The increases above the initial level can then be compared with those of other species or populations. If data on mortality levels for one species are available, estimates of LD50 values can then be made for other closely related species. This minimises the number of animals used during trials and also the number of animals which die during trials. Such an approach (which produces approximate LD50s) is ethically more acceptable than conducting LD50 trials (during which 50% or more of the animals may die) on large samples of animals . It is also important when conducting trials on rare or endangered species of animals.

Fluoroacetate poisoning disrupts the energy supply to the cells resulting in a decrease in body temperature of poisoned animals. This can be a useful indication of whether or not a particular level of 1080 is having an adverse effect on animals whose tolerance is being assessed.

VARIATION IN TOLERANCE BETWEEN POPULATIONS

Different populations of some species of native animals have different levels of tolerance to 1080. This may occur because the different populations had different levels of exposure to plants containing 1080 during their evolutionary history. Incorrect taxonomy of the animals - that is, two or more species being incorrectly classified as constituting one species - sometimes explains apparent differences in tolerance within a species. This has been found during the work on the 1080 sensitivity of West Australian species. The tolerances of animals which were supposedally Sandy Inland Mice (*Pseudomys hermannsburgensis*) from the same population differed substantially, and several of the animals were subsequently found to belong to another species, Bolam's Inland Mouse (*Pseudomys bolami*).

The most common reason for differences in tolerances between populations, however, is different evolutionary exposure to the toxic plants. Possums from near Canberra were found to have an LD50 of 0. 68 mg /kg whereas possums from Western Australia have LD50's of over 100 mg/kg. The differences in the levels of tolerance of other species of animals which occur in both areas are less extreme than those for possums but populations from the southwest are generally more tolerant than those from the southeast. Different levels of tolerance are found between eastern and western populations of Tammar Wallabies (*Macropus eugenii*) but not for W.G.K. (*M. f.*). The tolerances of Tammars from South Australia (LD50 = 0. 3 mg/kg) and those from near Manjimup, Western Australia (LD50 = approximately 5 mg /kg) differ substantially, while that of Tammars from Garden Island is intermediate between them. The tolerance of Western Grey Kangaroos at the eastern edge of their distribution in New South Wales is the same as that for Grey Kangaroos from Western Australia (LD50 = approximately 20 mg/kg). The apparent explanation for these differences is that there are no toxic species of *Gastrolobium* or *Oxylobium* in New South Wales or South Australia and that Tammar Wallabies originated in southeastern Australia, whereas Western Grey Kangaroos originated in southwestern Australia. Both species subsequently spread into other areas, with Tammars moving westwards and acquiring higher levels of tolerance to the toxin when they encountered it in their newly encountered food plants. The tolerance of Garden Island Tammars is lower than that of Tammars from Manjimup. There are none of the toxic plants on Garden Island, which has been isolated from the mainland for at least 8000 years, whereas they are abundant in the Manjimup area. Evolution of higher levels of tolerance by Tammars from Manjimup continued while that of the Garden Island population did not. Western Grey Kangaroos, which evolved as a separate species in the southwest, apparently acquired a high level of tolerance during a period of separation from contact with an ancestral stock which also gave rise to the closely-related Eastern Grey Kangaroos, which are much more sensitive to 1080 (Table 1 in Appendix) than are Western Grey Kangaroos. The Western Grey Kangaroos then spread eastwards at some later time and retained their high level of tolerance in spite of the absence of 1080-bearing plants in the southeast of Australia.

The levels of tolerance to 1080 in different populations of several species from the southwest vary somewhat depending on the degree of their exposure to the toxin during the course of their evolution. The levels of tolerance to 1080 in Quokka (*Setonix brachyurus*) populations within Western Australia differ. Those from mainland sites near

Dwellingup and Pemberton and from Bald Island, which is off the coast near Albany and which has fluoroacetate bearing plants growing on it, have high levels of tolerance with LD50's of approximately 40 mg/kg. Some quokkas from Rottnest Island have similar high levels of tolerance while others are much more sensitive to the toxin. This variation in responses to 1080 is probably caused by interbreeding in the past by members of a highly tolerant and a sensitive population. As the toxic plants do not occur on deep sandy soils, such as those on the coastal plain of the southwest, but are abundant on the heavier soils of the Jarrah forests, animals which live in the forest are thus in contact with the toxin and evolve a tolerance to it while those on the sandplain do not. If tolerant animals move into an area where there are no toxic plants they retain their elevated tolerance to 1080, but no longer need it to survive. However, if animals with very low tolerance move from the sandplains into areas where the toxic plants occur and feed on highly toxic plants, they will die.

The Bush Rat (*Rattus fuscipes*) is an example of an animal showing both of these conditions. Populations from eastern Australia are sensitive to 1080 (LD50 of approximately 1 mg/kg in New South Wales and South Australia) and those from Western Australia are highly variable, with LD50's ranging from approximately 1 to 80 mg/kg. Rats from the most southerly and easterly of the islands in the Recherche Archipelago have the very low levels of tolerance similar to those of the South Australian rats. No toxic species of *Gastrolobium* or *Oxylobium* occur on those islands. Bush Rats from mainland localities near Albany and Manjimup have LD50's of approximately 30 mg/kg. They live in areas with heavy soils and have some contact with toxic plants and presumably feed on them. Those from islands near Albany which lack toxic plants also have high levels of tolerance. Bush rats from Greenhead, which live on deep sandy soils where there are are no fluoroacetate - bearing plants have a lower level of tolerance (LD50 about 25 mg/kg) than those from the mainland near Albany. There are some members of the Greenhead population which have low levels of tolerance and some which are highly tolerant. Bush rats with the highest known levels of tolerance (80 mg/kg) are from Mondrain Island where the highly toxic species *Gastrolobium bilobum* occurs. The densities of rodents on islands are often very high as they have nowhere to disperse to when their numbers increase. They may thus experience food shortages more often than do those on the mainland and be forced to feed more frequently on unpalatable or toxic plants, thus increasing the selection pressure placed upon them. They consequently may develop higher levels of tolerance to toxins. Genetic isolation from other, non-resistant, populations then ensures that the levels of tolerance are maintained. Further increases in tolerance are also likey, leading to the ability to actually use the toxic plants/seeds as a food source.

Explanations for differences in the tolerance to 1080 of populations of other native Western Australian species such as the rodents *Pseudomys hermannsburgensis, Zyzomys argurus, Notomys mitchelli* and the dasyurid marsupial *Sminthopsis ooldea* also relate to the extent of their current and previous exposure to these toxic plants.

The Bobtail lizards (*Tiliqua rugosa*) in some areas in the southwest of Western Australia have evolved very high levels of tolerance to 1080. They exceed the levels which would be necessary to prevent a lizard whose entire daily food intake was from the most toxic species of *Gastrolobium* or *Oxylobium* it could encounter from being fatally poisoned. When male Bobtail lizards were dosed with amounts of 1080 well below that which would kill them, the amounts of reproductive hormones they produced were much lower than normal and they would probably have been incapable for 1 to 2 weeks of breeding successfully. The evolution of the high levels of tolerance to 1080 in those populations was probably a means of avoiding a possible reduction in fertility, rather than being directly killed. Male rats given sublethal levels of 1080 become temporarily sterile and 1080 may thus have detrimental effects on other animals which do not take in enough of it to actually kill them. The extent to which animals are tolerant of the poison can be influenced by limitations on their reproductive capacity, but the significance of this to non-target species during pest control programs is unknown.

ISLAND POPULATIONS AND THE RETENTION OF TOLERANCE

Once a tolerance to the poison evolves in a species it does not appear to decline when animals are separated from exposure to the plants which are the reason for the evolution of that tolerance. Many populations of native animals which are not currently in contact with toxic plants still retain high levels of tolerance to 1080. This is of particular importance as many of Australia's rare and endangered species of mammals now occur only on island reserves off the coast of Western Australia which have been separated from the mainland within the last 8000 to 15000 years. During that period sea levels have risen greatly and most of the islands now off the coast became isolated. They now have major conservation implications. Few of the islands have *Gastrolobium* or *Oxylobium* growing upon them as their soils are generally inappropriate. Mondrain Island in the Recherche Archipelago and Bald Island near Albany are important exceptions to this. Mammals which now occur on Barrow, Bernier, Dorre, West Wallabi, Rottnest, Garden, Mistaken and several islands in the Recherche Archipelago in W.A. and Kangaroo Island in South Australia retain high levels of tolerance to 1080 although no fluoroacetate-bearing plants occur on those islands. Some mainland populations which occur in areas where toxic species of *Gastrolobium* or *Oxylobium* are not found also retain high levels of tolerance, presumably for the same reasons. The levels of tolerance of populations not currently in contact with toxic plants can thus not always be predicted correctly on the basis of their current distribution and degree of contact with poison plants.

IMPACT OF POISONING PROGRAMS ON NON - TARGET SPECIES

The effect of poisoning programs on non-target species is very difficult to determine directly. Most species of birds are highly mobile and may travel long distances in search of food, water, or other needs, and thus the number present in an area can vary considerably from day to day, often in an unpredictable manner. Most species of native mammals are nocturnal and many are very small, sparsely distributed, secretive and difficult to trap. It is therefore difficult to determine whether populations have declined following baiting, and if they have, whether it is because of the baiting or because of natural fluctuations of their numbers. Attempts have been made, however, to investigate the effect of baiting programs on non - target species. In New South Wales, prior to and after two trail baiting programs for the control of wild dogs, bird populations were counted daily along transects. Small mammals were trapped in cage traps, marked and released. Population assessments were done in the area to be baited and in a nearby area which was similar but not to be baited. Changes in numbers in the two areas after baiting were compared to give an indication of whether they might be due to the baiting. Populations of neither birds nor small mammals seemed to have been significantly affected by the poisoning programs.

Because of the uncertainty involved in interpreting these sorts of results, most studies of the possible hazards posed to non - target species by baiting have been done on captive animals in the laboratory. Studies of the tolerances of many species have now been conducted by C.S.I.R.O. in southeastern Australia and by the Research Section of the A.P.B. in Western Australia. These trials include a study on small mammals from the pastoral areas of W. A. The sensitivity of the animals to 1080 (Table 1, Appendix) and their daily food consumption rates in the laboratory were determined. The extent to which they will eat the bait material (when other food is available or when it was the only food provided) was also determined for 6 species of rodents and 9 species of dasyurid marsupials. Combining the results on what and how much they will eat and how sensitive they are to 1080 gives an indication of how susceptible they would be to poison baiting with 1080. The results indicated that 4 of these species would theoretically be at risk of poisoning from feeding on meat baits used for dingo control. Of these, the Northern Quoll (*Dasyurus hallucatus*), also known as the Northern Native Cat, was the most likely to be poisoned because of its large size (it would be able to eat more bait than the smaller species, and thus ingest more 1080) and its voracious appetite. A radiotracking study of this species was thus carried out in the field to determine the actual risk they faced under normal conditions. Quolls were trapped, fitted with collars containing radio - transmitters and released. They were then located daily, when possible, for periods of up to two weeks to determine the location and size of the areas in which they lived. Aerial baiting with 1080 meat baits was then done by A.P.B. field staff. The movements and survival rate of the collared animals was then monitored for a further two weeks after the baiting. It was expected, on the basis of the results from the laboratory study, that some of the Quolls would be killed by eating the baits. However, all 10 animals which were wearing collars at the time of baiting were still alive at the end of the monitoring period. As the Quoll was the species considered to be most at risk, this strongly suggests that the aerial baiting programs in the pastoral regions have little or no effect on them or on other less susceptible non-target species.

BAIT DESIGN

The disparity in tolerance of 1080 between native and introduced species in Western Australia can be used to advantage in designing baiting strategies which present little or no threat to non - target species. Baits can be produced which are large enough and contain a low enough concentration of 1080 so that the small native species cannot eat enough of them to take in a fatal dose of the poison, yet are small enough to enable the pest species, such as dingoes or foxes, to easily eat the whole bait. Other aspects of bait design and presentation can be used to further reduce the risk posed to native species during baiting programs. These include the type of bait material chosen and its acceptability to target and non-target species, bait placement, the timing of baiting, and quality control in bait preparation. Appropriate size of baits is important in ensuring that the maximum level of target specificity is attained. Adequate drying of the baits will prevent loss of 1080 from them and will minimize the extent to which ants and other insects can damage them. It will also further improve target specificity of the baits as it is very difficult for the small native mammals to eat significant amounts of dry meat baits.

1080 AND CONSERVATION

Most 1080 use in Australia is for the purpose of protecting primary industry by controlling pest species. The disparity in 1080 tolerances between native and introduced species in W.A. is important in that it makes target specificity in control programs easier to achieve than usual. The disparity is also important in the management and conservation of native species. Pest species such as rabbits and foxes also damage native flora and fauna in reserves and national parks. Baiting programs using 1080 are employed by conservation authorities as the major means of controlling these pests. A low level of risk is posed to native fauna by well designed 1080 baiting programs which consider bait size and food intake of non-target animals. For areas which contain rare and endangered fauna special attention to the methods of bait preparation or distribution may be warranted to reduce even further the threat posed to those species by using 1080 baits.

SUMMARY

Compound 1080 is highly toxic to most vertebrates. It is used in many countries to control a number of vertebrate pest species. Its use in Australia began in the early 1950's and large amounts of it are now used to poison rabbits, dingoes, foxes and some other species of pests.

In 1944, 1080 was found to occur in plants in South Africa which were known to be poisonous to livestock. It was not known until 10 years after it was first used in Australia that it also occurred naturally in native plants which occur over a large area of this country. Most of the more than 30 species which contain 1080, including the most toxic species, are only found in the southwest of Western Australia.

Most species of native animals in the southwest have evolved a high level of tolerance to 1080 through feeding on the plants which contain the poison. Some have developed increased tolerance directly by eating the plants while others have developed it indirectly by eating other animals which have eaten those plants. Levels of tolerance to 1080 reflect the extent of exposure to the plants which a species or population of animals has had during its evolutionary history.

The high levels of tolerance to 1080 which native animals have makes it much easier to achieve target-specificity in pest control programs which use 1080 in Western Australia than is the case in most other countries. The main reason for this is the disparity in levels of tolerance between native species of animals and the major pest species. Most vertebrate pest species in Australia have been introduced from other countries where 1080 does not occur naturally. It is probably unique to find that the main poison used as a pest control agent is found in high concentrations in plants which are abundant in that country.

The target-specificity of a control program can be increased by designing baits of an appropriate size to further capitalize on that disparity. Most Australian native carnivores are smaller than the pest animals. Meat baits can be made large enough so most small native animals cannot eat enough of them to ingest a lethal dose of 1080 whereas they can be entirely eaten by the introduced pest species. One bait contains more than enough 1080 to kill the pest. The frequency of encounters by non-target species with meat baits can also be be reduced by appropriate choice of bait material, timing of control programs and placement of baits. These factors should also be considered where feasible, but special requirements for bait placement may involve extra effort and cost. Grain bait should contain only enough 1080 to ensure that the pest species will be killed if it eats the bait. Placing too much 1080 in bait will pose unnecessary risks to native and domestic non-target species and can actually result in less effective control of the pest species.

The occurrence of the high levels of tolerance to 1080 in Western Australian animals is a very fortunate coincidence and care must be taken to maximise the benefits from the situation. Proper use of the poison will go a long way towards achieving that goal. Recommended dose levels should be strictly adhered to and quality control of bait material and size should be diligent. Much research effort, time and money has gone into determining what is required to satisfactorily control pest species. Procedures should only be varied if new ideas or information have been adequately examined and the results indicate a need for revising the methods, materials or quantities of bait material or poisons which are used.

Care must be taken when using 1080 to minimise the risks posed to the operator and to others , and to domestic or native non-target species of animals . If it is not used properly, 1080 is a very dangerous substance. There is no antidote for it and it is fatal to ingest a large dose of 1080. When it is used properly, it is a very effective poison and presents no risk to the user. It also presents a mimimal risk to non-target species, and does not accumulate in the environment , as it is detoxified in the bodies of tolerant animals and is degraded in the soil. There are thus no rational grounds for restricting its use further as long as there is compliance by users with the guidelines for its use.

The use of 1080 is important in Western Australia for both primary production and conservation of the environment. Control of pest species is of benefit to domestic livestock, native flora and fauna. Because of its effectiveness in killing pest species and the high levels of tolerance of the native fauna to it, 1080 is a very useful and safe poison for the control of the main vertebrate pest species in Western Australia.

APPENDIX

TABLE 1 TOLERANCES OF AUSTRALIAN FAUNA - DETERMINED BY LABORATORY TESTING

Southwest and Wheatbelt

	LD50 mg kg^{-1}	Approx LD50	ALD	Group
REPTILES				
Bobtailed Lizard (*Tiliqua rugosa*)		500 - 800		E
Sand Goanna (*Varanus gouldii*)		50		H
Rosenberg's Goanna (*Varanus rosenbergi*)		200-300		E
BIRDS				
Emu (*Dromaius novaehollandiae*)	102			E
Black Duck (*Anas superciliosa*)		15 - 20		M
Wood Duck (*Chenonetta jubata*)		12. 5		M
Common Bronzewing (*Phaps chalcoptera*)		40		E
Crested Pigeon (*Ocyphaps lophotes*)		25		H
White-tailed Black cockatoo (*Calyptorhyncus baudinii*)		2		V
Galah (*Cacatua roseicapilla*)		5 -6		S
Regent Parrot (*Polytelis anthopeplus*)		12. 5		M
Port Lincoln Parrot (*Barnardius zonarius*)		11. 5		M
Western Rosella (*Platycercus icterotis*)		75		E
Red-capped Parrot (*Purpureicephalus spurius*)		25		H

** Indicates that more than 1 population has been tested and that values for them differed.*

Group refers to the general level of tolerance of the species as follows :

V = very sensitive		*- LD50 up to 2 mg /kg*
S = sensitive		*- LD50 2-5 mg /kg*
M = moderately tolerant		*- LD50 between 5-20 mg /kg*
H = highly tolerant		*- LD50 between 20-100 mg/ kg*
E = extremely tolerant		*- LD50 greater than 100 mg /kg*

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	LD50 mg kg^{-1}	Approx LD50	ALD	Group
MAMMALS				
Southern Brown Bandicoot (*Isoodon obesulus*)		20		H
Common Ringtail Possum (*Pseudocheirus peregrinus*)		2		V
Common Brush-tailed Possum (*Trichosurus vulpecula*)		125		E
Western Pygmy Possum (*Cercartetus concinnus*)		10		M
Red-tailed Phascogale (*Phascogale calura*)		17. 5		M
Yellow-footed Antechinus (*Antechinus flavipes*)		12. 5		M
Fat-tailed Dunnart (*Sminthopsis crassicaudata*)			3	S
Grey-bellied Dunnart (*Sminthopsis griseoventer*)			4. 5	S
White-tailed Dunnart (*Sminthopsis granulipes*)			8. 5	M
Dibbler (*Parantechinus apicalis*)		10		M
Chuditch (*Dasyurus geoffroii*)		7. 5		M
Quokka (*Setonix brachyurus*)		10, 40 *		H
Brush-tailed Bettong (*Bettongia penicillata*)		100		E
Tammar Wallaby (*Macropus eugenii*)		2, 5		S
Western Brush Wallaby (*Macropus irma*)		5-10		M
Western Grey Kangaroo (*Macropus fuliginosus*)		20		M
Ash-Grey Mouse (*Pseudomys albocinereus*)	Highly variable - see text			
Western Mouse (*Pseudomys occidentalis*)			25	H
Heath Rat (*Pseudomys shortridgei*)			25	H
Bush Rat (*Rattus fuscipes*)	Highly variable - see text			

	LD50 mg kg^{-1}	Approx LD50	ALD	Group
Pastoral Areas				
BIRDS				
Wedge-tailed eagle (*Aquila audax*)	9. 5			M
Little Crow (*Corvus bennetti*)	13. 4			M
MAMMALS				
Northern Brush-tailed Possum (*Trichosurus arnhemensis*)		0. 5		V
Golden Bandicoot (*Isoodon auratus*)	8. 9			M
Western Barred Bandicoot (*Perameles bougainville*)		10		M
Bilby (*Macrotis lagotis*)		15		M
Wongai ningaui (*Ningaui ridei*)			3	S
Pilbara Ningaui (*NIngaui timealeyi*)			12	M
Yvonne's Ningaui (*Ningaui yvonnae*)			3	S
Common Planigale (*Planigale maculata*)			4	S
Ooldea Dunnart (*Sminthopsis ooldea*)			1, 5 *	S
Hairy-footed Dunnart (*Sminthopsis hirtipes*)			7	M
White-tailed Dunnart (*Sminthopsis granulipes*)			8. 5	M
Fat - tailed Dunnart (*Sminthopsis crassicaudata*)			3	S
Little Long-tailed Dunnart (*Sminthopsis dolichura*)			8	M
Spectacled Hare Wallaby (*Lagorchestes conspicillatus*)		5		M
Banded Hare Wallaby (*Lagostrophus fasciatus*)		100-125		E
Brush-tailed Rock Wallaby (*Petrogale penicillata*)		1. 0+		?

	LD50 mg kg^{-1}	Approx LD50	ALD	Group
Rothschild's Rock Wallaby (*Petrogale rothschildi*)		2. 0+		S
Agile Wallaby (*Macropus agilis*)	0. 2			V
Common Wallaroo, Euro (*Macropus robustus*)		2		S
Red Kangaroo (*Macropus rufus*)		2 - 4		S
Sandy Inland Mouse (*Pseudomys hermannsburgensis*)			2, 5, 14	V-M
Bolam's Inland Mouse (*Pseudomys bolami*)		1		V
Shark Bay Mouse (*Pseudomys praeconis*)		4 - 5		S
Lakeland Downs Mouse (*Leggadina lakedownensis*)			4	S
Mitchell's Hopping Mouse (*Notomys mitchelli*)		10, 20 *		M
Common Rock-Rat (*Zyzomys argurus*)	3, 5 *			S
Tunney's Rat (*Rattus tunneyi*)			3	S
Long-haired Rat (*Rattus villosissimus*)	1. 4			V

	LD50 mg kg^{-1}	Approx LD50	ALD	Group
Eastern and Central Australia				
AMPHIBIA				
Spotted Grass Frog (*Lymnodynastes tasmaniensis*)		60		H
REPTILES				
Bearded Dragon (*Pogona barbatus*)		110		E
Sand Goanna (*Varanus gouldii*)	43. 6			H
Lace Monitor (*Varanus varius*)		100		E
Blotched BlueTongue (*Tiliqua nigrolutea*)	336			E
Bobtail Lizard (*Tiliqua rugosa*)	206			E
BIRDS				
Black Duck (*Anas superciliosa*)	18. 9			M
Maned Duck (*Chenonetta jubata*)	12. 6			M
Black Kite (*Milvus migrans*)	18. 5			M
Bar-shouldered Dove (*Geopelia humeralis*)	16. 3			M
Diamond Dove (*Geopelia cuneata*)	35. 5			H
Galah (*Cacatua roseicapilla*)	6			M
Sulphur-crested Cockatoo (*Cacatua galerita*)	3. 5			S
Budgerigar (*Melopsittacus undulatus*)		2		S
Crimson Rosella (*Platycercus elegans*)		0. 9		V
Eastern Rosella (*Platycercus eximius*)		3. 5		S
Port Lincoln Parrot (*Barnardius zonarius*)		9		M

	LD50 mg kg^{-1}	Approx LD50	ALD	Group
Red-rumped Parrot (*Psephotus haematonotus*)		5		M
Fan-tailed Cuckoo (*Cuculus pyrrhophanus*)		6		M
Laughing Kookaburra (*Dacelo novaeguineae*)		6		M
White's Thrush (*Zoothera dauma*)		12		M
Eastern Yellow Robin (*Eopsaltria australis*)		11. 7		M
Grey Shrike-thrush (*Colluricincla harmonica*)		12		M
Golden Whistler (*Pachycephala pectoralis*)		18		M
Superb Fairy Wren (*Malurus cyaneus*)		3. 4		S
White-browed Scrubwren (*Sericornis frontalis*)		4. 5		S
Little Wattlebird (*Anthochaera chrysoptera*)		7. 8		M
New Holland Honeyeater (*Phylidonyris novaehollandiae*)		8		M
Yellow-faced Honeyeater (*Lichenostomus chrysops*		8		M
Yellow-tufted Honeyeater (*Lichenostomus melanops*)		7. 5		M
Silvereye (*Zosterops lateralis*)		9. 3		M
Red-browed Firetail (*Emblema temporalis*)	0. 6			V
Zebra Finch (*Poephila guttata*)		3		S
White-winged Chough (*Corcorax melanorhamphos*)		1. 8		V
Australian Magpie-lark (*Grallina cyanoleuca*)	8. 8			M
Australian Magpie (*Gymnorhina tibicen*)	9. 9			M
Pied Currawong (*Strepera graculina*)	13. 1			M

	LD50 mg kg^{-1}	Approx LD50	ALD	Group
Australian Raven (*Corvus coronoides*)		5		M
Little Raven (*Corvus mellori*)	3. 1			S
Mammals				
Brown Antechinus (*Antechinus stuartii*)	1. 9			V
Dusky Antechinus (*Antechinus swainsonii*)	3. 2			S
Fat-tailed Dunnart (*Sminthopsis crassicaudata*)	2. 1			S
Stripe-faced Dunnart (*Sminthopsis macroura*)	1			V
Kowari (*Dasyuroides byrnei*)		2. 9		S
Eastern Quoll (*Dasyurus viverrinus*)	3. 7			S
Tiger Quoll (*Dasyurus maculatus*)	1. 9			V
Tasmanian Devil (*Sarcophilus harrisii*)	4. 2			S
Long-nosed Bandicoot (*Perameles nasuta*)	7. 7			M
Southern Brown Bandicoot (*Isoodon obesulus*)		7		M
Eastern Barred Bandicoot (*Perameles gunni*)		5. 4		M
Common Brush-tailed Possum (*Trichosurus vulpecula*)	0. 8			V
Common Wombat (*Vombatus ursinus*)	0. 2			V
Southern Hairy-nosed Wombat (*Lasiorhinus latifrons*)	0. 2			V
Tasmanian Bettong (*Bettongia gaimardi*)		1		V
Long-nosed Potoroo (*Potorous tridactylus*)		0.2		V
Red-bellied Pademelon (*Thylogale billardieri*)	0. 1			V

	LD50 mg kg⁻¹	Approx LD50	ALD	Group
Tammar Wallaby (*Macropus eugenii*)	0. 3			V
Bennett's Wallaby (*Macropus rufogriseus*)		0. 2		V
Western Grey Kangaroo (*Macropus fuliginosus*)		20		H
Eastern Grey Kangaroo (*Macropus giganteus*)		0.3		V
Spinifex Hopping Mouse (*Notomys alexis*)	32. 7			H
Mitchell's Hopping Mouse (*Notomys mitchelli*)	19. 4			M
Plains Mouse (*Pseudomys australis*)	1. 2			V
Sandy Inland Mouse (*Pseudomys hermannsburgensis*)	39. 3			H
Long-tailed mouse (*Pseudomys higginsi*)	9. 0			M
Water Rat (*Hydromys chryogaster*)		3		S
Bush Rat (*Rattus fuscipes*)	1. 1			V
Swamp Rat (*Rattus lutreolus*)	1. 7			V
Canefield Rat (*Rattus sordidus*)	1. 3			V

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	LD50 mg kg^{-1}	Approx LD50	ALD	Group
Introduced Pests				
BIRDS				
Laughing Dove (*Streptopelia senegalensis*)	5. 9			M
Barbary Dove (*Streptopelia roseogrisea*)		7. 5		M
Pigeon (*Columba livia*)	4.0			S
Blackbird (*Turdus merula*)		9. 5		M
House sparrow (*Passer domesticus*)	2. 8			S
Starling (*Sturnus vulgaris*)		4. 8		S
MAMMALS				
House mouse (*Mus musculus*)	8. 3			M
Black Rat (*Rattus rattus*)	0. 8			V
Rabbit (*Oryctolagus cuniculus*)	0. 4			V
Pig (*Sus scrofa*)	4. 1			S
Goat (*Capra hircus*)		0.5		V
Cat (*Felis catus*)	0. 4			V
Fox (*Vulpes vulpes*)		0. 13		V
Dingo (*Canis familiaris dingo*)	0. 11			V

REFERENCES

Calver, M.C., McIlroy, J.C., King, D.R., Bradley, J.S. and Gardner, J. L. (1989). Assessment of an approximate lethal dose technique for determining the relative susceptibility of non-target species to 1080 toxin. Aust. Wildl. Res. 16, 33 -40.

Calver, M.C., King, D.R.Bradley, J.S., Gardner, J.L. and Martin, G., (1989). An assessment ofthe potential target specificity of 1080 predator baiting in Western Australia. Aust. Wildl. Res. 16, 625 - 38.

King, D.R., Oliver, A.J. and Mead, J. R. (1978). The adaption of some Western Australian mammals to food plants containing fluoroacetate. Aust. J. Zool. 26, 699 - 712.

King, D.R., Oliver, A.J. and Mead, R.J. (1981). *Bettongia* and fluoroacetate : a role for 1080 in fauna management. Aust. Wildl. Res. 8, 529 - 36.

King, D.R., Twigg, L.E. and Gardner J.L. (1989). Tolerance to sodium monofluoroactate in dasyurids from Western Australia. Aust. Wildl. Res. 16, 131 - 46.

McIlroy, J.C. (1981). The sensitivity of Australian animals to 1080 poison II. Marsupial and eutherian carnivores. Aust. Wildl. Res. 8, 385 - 99.

McIlroy, J.C. (1982a). The sensitivity of Australian animals to 1080 poison III . Marsupial and eutherian herbivores. Aust. Wildl. Res. 9, 487 - 503.

McIlroy, J.C. (1982b). The sensitivity of Australian animals to 1080 poison IV . Native and introduced rodents. Aust. Wildl. Res. 9, 505 - 17.

McIlroy, J.C. (1983a). The sensitivity of Australian animals to 1080 poison V . The sensitivity of feral pigs, Sus scrofa, to 1080, and its implications for poisoning campaigns. Aust. Wildl. Res. 10, 139 - 48.

McIlroy, J.C. (1983b). The sensitivity of Australian animals to 1080 poison VI. Bandicoots. Aust. Wildl. Res. 10, 507 - 12.

McIlroy, J.C. (1984). The sensitivity of Australian animals to 1080 poison VII . Native and introduced birds. Aust. Wildl. Res. 11, 373 - 85.

McIlroy, J.C., King, D.R. (1990). Appropriate amounts of 1080 poison in baits to control foxes, *Vulpes vulpes*. Aust. Wildl. Res. 17, 11 - 13.

McIlroy, J.C., King, D.R. and Oliver, A.J. (1985). The sensitivity of Australian animals to 1080 poison VIII. Amphibians and reptiles. Aust. Wildl. Res. 12, 113 - 18.

Mead, R.J., Oliver, A.J., King, D.R. and Hubach, P.H. (1985a). The co - evolutionary role of fluoroacetate in plant - animal interactions in Australia. Oikos 44, 55 - 60.

Mead, R.J., Twigg, L.E., King, D.R. and Oliver, A.J. (1985b). The tolerance to fluoroacetate of geographically separated populations of the Quokka (*Setonix brachyurus*). Aust. Zool. 21, 503 - 11.

REFERENCES

Oliver, A. J. and King, D. R. (1983). The influence of ambient temperatures on the susceptibility of mice, Guinea - pigs and possums to Compound 1080. Aust. Wildl. Res. 10, 297 - 301.

Oliver, A.J., King, D.R. and Mead, R.J. (1977). The evolution of resistance to fluoroacetate intoxication in mammals. Search 8, 130 - 2.

Oliver, A.J., King, D.R. and Mead, R.J. (1979). Fluoroacetate tolerance, a genetic marker in some Australian mammals. Aust. J. Zool. 27, 363 - 72. Twigg, L.E., Mead, R.J. and King, D.R. (1986) Metabolism of fluoroacetate in the skink (*Tiliqua rugosa*) and the rat (*Rattus norvegicus*). Aust. J. Biol. Sci. 39, 1 - 15.

Twigg, L.E., King D.R. and Bradley, A.J. (1988). The effect of sodium monofluoroacetate on plasma testosterone concentration in *Tiliqua rugosa* (Gray). Comp. Biochem. Physiol. 91C, 343 - 347.

Twigg L.E., King, D.R., Davis, H., Saunders, D. and Mead, R.J. (1988). Tolerance to, and metabolism of, fluoroacetate in the emu. Aust. Wildl. Res. 15, 239 - 247.

Wheeler, S.H. and Hart, D.S. (1979). The toxicity of sodium monofluoroacetate to wild rabbits, *Oryctolagus cuniculus* (L.), from three sites in Western Australia. Aust. Wildl. Res. 6, 57 - 62.