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ABSTRACT: Single acute doses of the rodenticide brodifacoum were administered orally to 13 species of birds which are at risk from accidental poisoning during rabbit or possum control operations. Median lethal dose values from less than 1 to more than 20 mg/kg were obtained for some species. Gulls and Canada geese appear to be particularly susceptible. Several species, particularly the gulls, waxeyes, sparrows, mallard ducks and harrier hawks, seem to be vulnerable to lead poisoning.

INTRODUCTION

The use of anticoagulant poisoned baits in agricultural settings is increasing throughout the world. With this extensive use rather than the intensive commercial rodent control operations typical of earlier anticoagulant use, more nontarget species are potentially at risk, both from primary and secondary poisoning (Mendenhall and Pank 1980).

Due to the delayed action of anticoagulants (Evans and Ward 1967), poisoned prey may be exposed to predators for some time. Similarly, baits are usually intended to be available to the target species and therefore also to nontarget species for some time (Mendenhall and Pank 1980).

In New Zealand many species of birds are exposed to toxic baits during rabbit (Oryctolagus cuniculus) and possum (Trichosurus vulpecula) control operations. To reduce this hazard all poison baits are dyed green, oats are cleaned to remove small seeds, and carrots may be sieved after they are chopped to remove chaff.

The most commonly used toxin in New Zealand is sodium monofluoroacetate (1080). Rammel and Fleming (1978) reported median lethal doses (LD_{50}) for several species of birds as follows: hawk (Buteo), 10 mg/kg; sparrow (Passer domesticus) 3 mg/kg (95% confidence limits 2-4 mg/kg); blackbird (Euphagus cyanocephalus) 3 mg/kg; pheasant (Phasianus colchicus) 6 mg/kg (4-11); duck (Anas platyrhynchos) 9 mg/kg (6-15); and quail (Coturnix c japonica) 18 mg/kg (18-20).

The LD_{50} of 1080 for rabbits is 0.4 mg/kg and for possums 0.8-2.0 mg/kg (Rammel and Fleming 1978). Thus it would be desirable for any other toxins used in rabbit and possum control operations to have a similar or greater ratio between the toxicity to the target and nontarget species. The acute oral LD_{50} of brodifacoum for rabbits is 0.20 mg/kg (0.15-0.28) (Godfrey et al. 1981) and for possum is 0.17 mg/kg (Fleming, pers. comm.).

This paper describes two trials in which the toxicity of brodifacoum to 13 species of birds held in captivity was investigated. Representatives of nine major families were included. The species used were black-backed gull (Larus dominicanus), black-billed gull (Larus bulleri), mallard duck (Anas platyrhynchos), paradise shelduck (Tadorna variegata), Canada goose (Branta canadensis canadensis), California quail (Lophortyx californicus), ring-necked pheasant (Phasianus colchicus), pukekos (Porphyris porhyris melanotus) blackbird (Turdus merula), house sparrow (Passer domesticus), hedge sparrow (Prunella modularis occidentalis), waxeye (Zosterops lateralis) and harrier hawk (Circus approximans). The amount of lead found in the livers of many of the birds necropsied was determined incidental to the main trials.

MATERIALS AND METHODS

The study was divided into two trials to take advantage of the availability of different species. The second trial was extended to retest some species which were found to be more sensitive to brodifacoum than expected. The birds, excluding the pheasants which were bought from a commercial breeder, were caught in the wild and held in small groups in aviaries and flight pens. The numbers treated in each trial, the doses administered, and the resulting mortality are given in Table 1.

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Table 1. Species, dose, number of birds treated and mortality for acute oral dosing with Brodifacoum.

Species	Trial 1 Dose (mg/kg)				Trial 2 Dose (mg/kg)			
	5.0	10.0	20.0	40.0	0.75	1.5	3.0	6.0
Black-backed gull	3/3*	6/6	2/2	3/3	5/5	5/5	5/5	6/6
Black-billed gull	2/2	4/4	4/4	4/4	-	-	-	-
Mallard duck	2/4	4/5	2/4	4/4	-	-	-	-
Paradise shelduck	2/4	1/4	1/4	-	-	-	-	-
Canada goose	-	-	-	-	5/5	5/5	5/5	5/5
California quail	4/5	5/5	4/5	5/5	0/4	0/3	2/4	4/4
Ringnecked pheasant	-	2/4	7/8	4/4	-	-	-	-
Pukeko	3/4	3/4	2/4	5/5	1/5	4/5	4/5	4/4
Blackbird	-	-	-	-	0/3	0/3	1/3	-
House sparrow	-	-	-	-	1/5	0/5	1/5	2/5
Hedge sparrow	-	-	-	-	1/7	0/5	0/5	-
Waxeye	-	-	-	-	1/5	1/5	0/5	1/3
Harrier hawk	1/4	2/4	3/4	-	-	-	-	-

* Three dead of three treated.

In Trial 1 technical grade brodifacoum powder (3-[3-[4'-Bromo[1 ,1'-biphenyl]-4-yl)-l ,2,3,4-tetrahydro-l-naphthalenyl]-4-hydroxy-2H-l-benzopyran-2-one) was suspended in solutions of 2% tragacanth powder and water such that 1 ml/kg body weight contained the required dose. For Trial 2 the powder was dissolved in triethanolamine, polyethylene glycol 200 and propane-1,2-diol(3:3:94) such that 10 ml/kg body weight contained the required dose at each dosing level. This change in formulation was adopted because of the difficulty in ensuring a uniform suspension of brodifacoum in tragacanth solutions. The manufacturers indicated that there should not have been a difference in the toxicity of brodifacoum between the two preparations (Leonard, pers. comm.).

Birds were randomly allocated to treatment groups and they were dosed by oral intubation. Food and water were provided freely.

Liver samples were removed at necropsy and analyzed for lead.

Dose response mortality rates and confidence limits were calculated by probit analysis (Finney 1971) where possible.

RESULTS AND DISCUSSION

The data and results of the toxicant dosing are summarized in Tables 1 and 2. Both species of gulls appeared to be very susceptible to brodifacoum as were Canada geese and pukekos. Mallard ducks, California quail, blackbirds, house and hedge sparrows, and waxeyes seemed to be less vulnerable, while the harrier hawks, ring-necked pheasants and paradise shelducks were apparently the most resistant of the species tested. Nine of the 13 results were inconclusive due to the small numbers of birds in several groups and the high intraspecific and interspecific variations known to occur with anticoagulant poisoning (Garner and Papworth 1976). The inconsistent results obtained where in several cases more birds died from a small dose than a substantially larger dose, e.g., the hedge sparrow, pukeko and mallard duck (Table 1), appear to be an unfortunate, unavoidable consequence of this type of testing. Mendenhall and Pank (1980) found that the different effects of the same anticoagulants on the same and different owl species, after comparable toxic diet intake, could not be readily explained as variations and limitations of the protocols made dose-response effects and comparisons difficult to determine. Similarly Kaukeinen (1982) commented that captive testing has many almost insurmountable problems; bruising and wounds from the efforts of capture confound the results obtained, necessitating prohibitively large test groups. This trial would support this view. Many of the birds had superficial wounds caused by contact with the cages and aviaries. Other birds did not adapt well to captivity and their feeding was irregular. Thus it is likely that several were under considerable stress which may have confounded the results obtained.

Table 2. Species and toxic doses likely to cause 50% mortality of a test group (LD_{50}).

Species	LD_{50} (mg/kg) (95% confidence) limits
Black-backed gull	< 0.75+
Black-billed gull	< 5.0+
Canada goose	< 0.75+
Pukeko	0.95 (0.43-2.05)
Mallard duck	4.6 (0.6-34.5)
California quail	3.3 (2.2-5.2)
Blackbird	> 3*
House sparrow	> 6*
Hedge sparrow	> 3*
Waxeye	> 6*
Harrier hawk	10.0 (4.6-21.6)
Ringnecked pheasant	10.0 (5.3-19.5)
Paradise shelduck	>20*

+ Lowest dose administered
* Highest dose administered

In assessing the impact of toxic chemical use in the field on nontarget animals, chemical, biological and ecological aspects must be investigated in the field to assess the actual exposure as pharmacological susceptibility bears little relationship to ecological vulnerability (Moore 1966). Thus the data reported here are only guides to allow some assessment of the relative risk to the different species tested and are not easily extrapolated to allow assessment of the risk of exposure to other related or unrelated species. During rabbit-poisoning operations, quail, harrier hawks, ducks, geese and many species of smaller birds are likely to be exposed to toxic baits. Consideration of the data obtained in these trials and examination of their feeding habits and life styles would allow some prediction of the actual risk created. Thus a duck which may eat substantial quantities of carrot baits would probably be at more risk than a quail which is likely to eat smaller amounts. At the maximum toxic bait loading of 0.005% suggested for brodifacoum (Godfrey and Lyman 1980) the risk of accidental poisoning of birds is probably no greater than when 1080 is used at the recommended strength of 0.02%. While the quantity of bait needed to give a fatal dose of brodifacoum is greater for some species, an accumulated toxic dose from multiple feedings over several days is more likely with brodifacoum than 1080 due to the delayed onset of symptoms. The possible advantages derived from the use of brodifacoum may be greater during possum poisoning operations where about 10 times more 1080 is used than would be necessary if brodifacoum was used.

Other means of reducing the hazard to nontarget birds include changes in the bait materials used and the characteristics of the baits to make them less attractive to birds. The initial dosage levels were determined after consultation with the manufacturers and were based on very sparse data. The second series of doses were decided after consideration of the results of Trial 1. In retrospect the second trial dose rates were probably higher than desirable. Some of the inconsistent results obtained may be due to the uneven mixing of brodifacoum in the tragacanth solution and possible differences in activity in the two solutions used.

The results of the lead analyses are given in Table 3. The waxeyes, hawks and both gull species had very high incidences of sublethal lead poisoning. As the gulls were caught around garbage dumps they presumably ingested lead from the garbage or vehicle exhaust pollution. The lead in the mallard ducks probably came from lead shot, either directly from hunting injuries or from ingesting expended lead shot. Similarly the lead found in the harrier hawks, one of which apparently died from lead poisoning with 18.9 ppm lead, may have come from feeding on shot water fowl or game birds or from scavenging on road-killed animals and breathing or ingesting lead contaminants along highways.

Table 3. Frequency of lead poisoning and levels of lead analyzed from liver samples of birds.

Species	Frequency[z]	Lead concentration[y]
Harrier hawk	8/8	4.36 (0.8 - 18.9)
Mallard duck	3/8	0.43 (0.0 - 1.6)
Paradise shelduck	0/12	-
Pukeko	2/29	0.04 (0.0 - 0.7)
California quail	2/34	0.90 (0.0 - 1.8)
Black-backed gull	20/22	1.54 (0.0 - 5.0)
Black-billed gull	13/14	1.02 (0.0 - 2.3)
Hedge sparrow	0.5	-
House sparrow	3/4	1.34 (0.0 - 4.8)
Blackbird	1/1	1.6
Waxeye	5/5	1.22 (0.4 - 2.2)
Ring-necked pheasant	0/16	-

[z] 8/8 = Eight of 8 tested contained lead
[y] Mean (range) ppm

The data indicate that there may be some potential hazard to several species of birds from lead contamination of the environment.

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