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FIELD EVIDENCE OF SECONDARY POISONING OF FOXES (*Vulpes vulpes*) AND BUZZARDS (*Buteo buteo*) BY BROMADIOLONE, A 4-YEAR SURVEY

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Abstract

This paper presents the result of a 4 year survey in France (1991-1994) based on the activity of a wildlife disease surveillance network (SAGIR). The purpose of this study was to evaluate the detrimental effects of anticoagulant (Ac) rodenticides in non-target wild animals. Ac poisoning accounted for a very limited number of the identified causes of death (1-3%) in most species. Predators (mainly foxes and buzzards) were potentially exposed to anticoagulant compounds (especially bromadiolone) via contaminated prey in some instances. The liver concentrations of bromadiolone residues were elevated and species-specific diagnostic values were determined. These values were quite similar to those reported in the litterature when secondary anticoagulant poisoning was experimentally assessed. ©1997 Elsevier Science Ltd

Introduction

This study reports anticoagulant (Ac) poisoning in wildlife. The Toxicology Laboratory of the Veterinary school in Lyon is involved in a unique nation-wide network for wildlife diseases surveillance (see material and methods). Ac poisoning is seldom described or investigated in wild animals, despite extensive use of rodenticides in the fields. We observed a series of suspected anticoagulant poisoning in several species and it appeared advisable to evaluate the actual impact of anticoagulant rodenticides on wildlife. A

literature survey also showed that very limited information was available, apart from individual case reports [1, 2, 3, 4].

Ac rodenticides are used in major field-treatments in France during fall and winter. Bromadiolone is used extensively against field vole (*Arvicola terrestris*) and coypu (*Myocastor coypus*) as baits (100 mg/kg or ppm for field uses), either carrots/apples (wet baits) or cereals (dry baits). In this retrospective study, only carrots were distributed. Bromadiolone is only applied by official Pest Control Operators (PCO). Wet baits are buried in holes or by means of a special plough, 15 cm below ground. Field application of bromadiolone is under strict regulatory control [5, 6]. Another Ac compound, chlorophacinone, is widely distributed and used against rats, mice, voles, and other rodents. It is mostly sold as 75 ppm baits (against field-voles) and 50 ppm baits (domestic uses) but also available as a concentrated formula (2.5 g/L). It is less strictly regulated than bromadiolone. Chlorophacinone baits can be prepared by farmers and are usually not buried [5, 6].

Material and Methods

Ac concentration in liver samples was determined with a new High Performance Thin Layer Chromatography (HPTLC) [7]. All reagents were HPLC grade. Briefly, 1 g liver was extracted with acetone (10 mL), centrifugated, filtered, evaporated under a nitrogen flux and resolubilized in 1 mL methanol. 10 µL of the final extract were sprayed automatically with an ATSIII automatic sampler[1] on a 10x20 RP-18 HPTLC plate[2]. The plates were eluted with methanol and orthophosphoric acid (4.72 µM) 9:1, allowed to dry for 20-30 minutes, and read under UV light at 286 nm for spot detection. Each peak recorded was then analyzed by the ScannerII[1] and a solid-phase UV-spectrum was recorded. Samples were compared to standards (8 substances were included, based on the available products in Europe: chlorophacinone, difenacoum, bromadiolone, warfarin, coumachlor, coumatetralyl, difethialone and brodifacoum). Confirmed identification required: Rf identical (± 5%) to one of the standards and UV spectrum comparable, if Rfs' were similar. Results from our laboratory [7], show that there is a very high specificity of this analytical technique (no interfering peaks on blank liver extracts) and high sensitivity (sensitivity defined as % positive results in animals known to be exposed is > 90% in a validation trial). Percent recoveries were also high: around 90% for all compounds tested, with a coefficient of

[1]Camag, Basel, Switzerland
[2]Merck-Clevenot laboratory,

variation below 5%. These results compare favorably with a previously published technique using HPLC procedures [8]. Analyses were conducted on eight Ac compounds. Our validation protocol included the testing of blank liver extracts and of decaying liver extracts (we used buzzard and red fox livers) to determine the specificity of the technique and to be certain that no other endogenic compound could be confused with any of the 8 anticoagulants tested. None of these extracts contained any misleading peak [7].

Ac poisoning was confirmed by: 1) signs and/or lesions compatible with Ac poisoning; 2) liver Ac concentration $\geq$ 0.2 mg/kg. This value was selected because it is the routine limit of detection of Ac compounds with the analytical technique described above and also because Ac poisoning is always associated with liver concentration well above that value. Routine Ac analysis on hundreds of animals over 10 years in our laboratory never found both clinical evidence of Ac poisoning and Ac liver concentration <0.2 mg/kg [9]. The liver appears as the most reliable organ for confirmation of Ac poisoning. Ac liver concentrations are a cumulative indicator of Ac poisoning because signs develop within 2-10 days after ingesion, i.e. well after all the Ac present in the GI tract has been eliminated.

Samples were submitted to the laboratory according to the SAGIR network procedure. Basically, hunters detect unusual mortality cases of game species in the fields. A SAGIR representative is in charge of the submission of samples of dead animals to the local veterinary diagnostic laboratories. If poisoning is suspected, the appropriate samples are submitted to the ENVL Toxicology laboratory [10, 11].

Ac rodenticides are unique. All the compounds marketed so far have a similar anticoagulant mode of action, manifested by severe hæmorrhages and clotting disorders. It is very characteristic at necropsy, even several days after death. Acs' do not appear to have any subtle subchronic effect on laboratory animals: non specific signs such as anorexia and depression usually precede the clinical signs shortly. Other common hæmorrhagic pathologies in wildlife include trauma (blood will usually clot, at least partially), viral hæmorrhagic diseases (in Lagomorphs especially) and various viral and bacterial diseases. These disorders can usually be distinguished from Ac poisoning at necropsy. When Ac poisoning was confirmed, we tried to obtain information from local authorities regarding the time of treatment in the fields, the compound used, its concentration, the kind of bait used and an estimate of the local field vole population density. Liver Ac concentrations were compared by means of non-parametric statistical tests (Mann-Whitney) , since most data appeared highly skewed to the right. A p-value of 0.05 was selected.

Results

Field and necropsy data

This wide-scale field study includes all the cases received from 1991 to 1994. The number of cases submitted is presented in Table 1. Red foxes (*Vulpes vulpes*) (31 cases), *buzzards (Buteo buteo)* (16 cases) and hare (*Lepus capensis*) (15 cases) were most frequently seen. Many other species were also submitted for suspected anticoagulant poisoning. Table 1 presents data on the number of animals suspected of Ac poisoning, the number of animals submitted for analysis and the number of animals with confirmed Ac poisoning. Most cases occurred during fall and winter (see figure 1). The ratio of Ac poisoning cases to suspected Ac poisoning was maximum in late fall and spring, two major seasons of Ac use in the fields in France (ACTA, 1990). Interestingly, the typical seasonals (indices of the amount of variation attributable to seasonal influences) [12] determined from January 1991 through December 1994, to correct for the annual variations in the number of samples submitted to the laboratory, confirmed this definite seasonal trend, with a peak in late fall and winter-early spring (typical seasonals >1 i.e. statistically significant).

Figure 1: Monthly distribution of animals with Anticoagulant (Ac) poisoning and typical seasonals for Ac poisoning

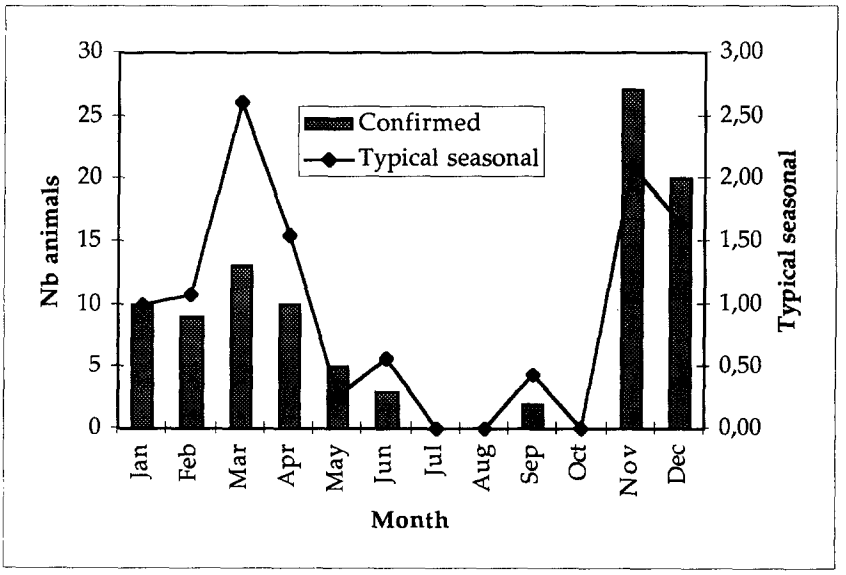


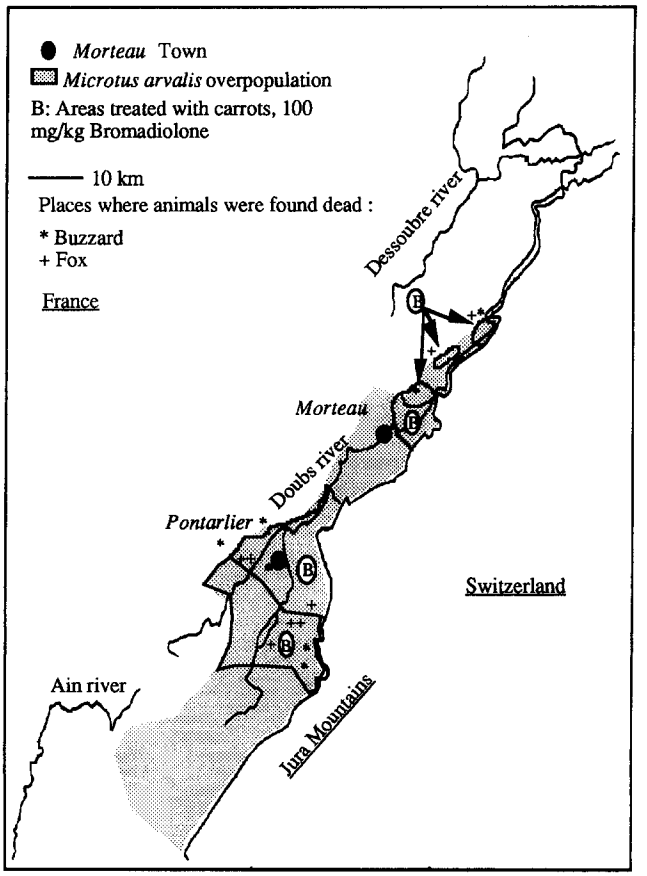
Table 1: Wild animals with suspected° Anticoagulant (Ac) poisoning, submitted for analysis* and with confirmed poisoning** (1991-1994), with the Ac detected#, median concentration and ranges

Species	Animals Suspected°	Animals Submitted*, (Confirmed)°°	Ac detected#	median concentration (µg/g)	range (µg/g)
Red fox Vulpes vulpes	34	31 (31)	Broma (22) Chloro (7)†	1.5 0.3	0.8 - 6.9 0.2 - 0.6
Buzzard Buteo buteo	16	16 (15)	Broma (15) Chloro (6)†	0.4 0.3	0.2 - 1.3 0.2 - 0.5
Hare Lepus capensis	59	15 (13)	Broma (2) Chloro (12)	1.4 2.3	1.2 - 1.6 0.2 - 8.3
Rabbit Oryct. cuniculus	16	13 (12)	Broma (2) Chloro (8)	1.35 2.9	1.3 - 1.4 1.1 - 14.3
Wild boar Sus scrofa	8	6 (6)	Broma (3) Chloro (3)	0.6 1.2	0.4 - 3.6 0.6 - 1.4
Roe deer Capreolus c.	2	2 (2)	Broma (2)	1.55	1.2 - 1.9
Stone-marten Martes foina	1	1 (1)	Broma (2)	0.8	0.6 - 1.0
Lynx Lynx lynx	1	1 (1)	Broma (1)	1.3	1.3
Badger Meles meles	1	1 (1)	Broma (1)	0.9	0.9
Pigeon Columba livia	22	4 (4)	Chloro (3)	3.4	1.7 - 3.5
Kite Milvus migrans	5	5 (5)	Broma (5)	0.4	0.3 - 0.6
Eagle Aquila sp	1	1 (1)	Chloro (1)	6.2	6.2
Harrier Circus pygargus	1	1 (1)	Broma (1)	6.1	6.1
Barn owl Tyto alba	7	1 (1)	Chloro (1)	0.3	0.3
Mallard Anas plathyrhynchos	4	1 (1)	Broma (1)	2.3	2.3
Swan Cygnus sp.	1	1 (1)	Broma (1)	2.5	2.5
Heron Ardea cinerea	1	1 (1)	Broma (1)	0.2	0.2

° suspected : clinical/necropsy finding compatible with Ac poisoning, *submitted : animals sent for analysis, °°confirmed : clinical/neropsy compatible and liver Ac > 0.2 µg/g. Ac detected# : number of animals concerned in brackets. Broma = bromadiolone, Chloro = chlorophacinone

Further analysis of the data collected indicated that 28 animals were collected between November 1993 and January 1994 in one area of France. Local investigation indicated that bromadiolone had been used at the end of October and beginning of November 1993 as carrot-baits (100 mg/kg) in several locations in this area. Foxes, buzzards, one heron and one ermine were found dead with signs of internal hæmorrhages, coagulation disorders, in the vicinity of treated areas (< 5 km in any case). All these species are carnivorous and potential consumers of field voles (*Arvicola terrestris*). It is also interesting to point out that these non-target animals were found in areas were the population density of field voles was considered very high (> 300/hectare) (see figure 2).

Figure 2: an area treated with bromadiolone baits in relation to *Microtus arvalis* overpopulation and predators found dead of anticoagulant poisoning (1993-1994 campaigns)



Two Ac compounds were primarily found in wild animals. Bromadiolone was detected mostly in red foxes and buzzards. Liver concentrations were significantly higher in foxes (median 1.5 µg/g) than in buzzards (median 0.4 µg/g, $p<0.05$).

Chlorophacinone was found in hare and rabbits, but also (less frequently) in red foxes and buzzards. In the two predator species, low concentrations of chlorophacinone were associated with higher concentrations of bromadiolone (see Table 1). This association was observed only in foxes and in buzzards in one part of the country. In all other cases, animals were found dead with either bromadiolone or chlorophacinone and liver concentrations were highly variable. Warfarin was found in one hare and difenacoum in a stone-marten, in 1 pigeon and in 2 rabbits.

Table 2 gives an overview of the main identified causes of death in wild animals in France during the same period and the proportion of death attributed to Ac poisoning, based on the SAGIR network for the 3 most commonly hunted species (hare, rabbit, wild boar).

Table 2: Anticoagulant poisoning in game species and major identified causes of death from the data collected by the SAGIR network in hares, in rabbits and in wild boars (1991-1994)

Species	No of animals submitted	Nb Ac poisoning	% Ac poisoning (suspected)	Major identified causes of death
Hare	3931	59	1,5	EBHS*, Pasteurellosis, yersinia
Rabbit	523	16	2,7	HVD**
Wild boar	465	8	1,7	Porcine Plague

*EBHS: European Brown Hare Syndrom ** HVD: Haemorragic Viral Disease

Discussion

Anticoagulant poisoning is among the most common causes of poisoning in domestic and wild animals in France: a prior survey indicated that anticoagulant poisoning accounted for 14% of all the cases submitted in animals [9]. However, it is very seldom described in wild animals [13, 14]. Obviously, investigation of suspected poisoning cases is difficult in wild species, because animals may die without notice. Secondly, necropsy findings are often limited when animals are discovered several days after death (decayed animals or partially eaten carcasses). Some species may be underepresented, simply because dead animals are not easily found. When animals (other than game species) are found dead with

hæmorrhages, hunters may not consider it necessary to submit samples for analysis (selection bias) and the cost of analysis may be a limiting factor. Regardless, the SAGIR network has been dealing with animals found dead for almost 10 years and investigated thousands of cases which form a very useful databank on wild animal pathology [11].

We found Ac poisoning only occasionnally. Only 188 suspected cases over 5 years, among the several thousands of animals submitted to the network. Ac poisoning is confirmed in less than 1% of the cases submitted to the SAGIR network, especially in the hundreds of animals from game species collected annually. Despite an obvious selection bias, Ac poisoning does not appear to affect the overall populations of wild birds and mammals in France [10, 11], based on the SAGIR samples. The seasonal pattern observed is obviously related to the field use of Ac : primarily in fall and early spring. The seasonal index are maximum in spring. This could be related to the high food intake associated with breeding [9].

Rabbits and hares are very seldom affected (between 1 and 2% of the animals collected each year), although they are likely consumers of treated cereals and carrots. Many animals suffered from viral hæmorrhagic diseases (25-50% of the animals collected) (see table 2) [10, 11]. In non-game species such as foxes and buzzards, Ac poisoning is recognized in a large proportion of cases, but very few animals are submitted each year [10, 11]. Our results confirm a prior report [2] stating that non-target species are not endangered by the appropriate use of Ac rodenticides. They also compare quite well with published data [3] indicating that death attributed to Ac poisoning in barn owls found dead does not account for more than 2% of the animals.

Fletcher and Grave [4] reported only 6 recent accidents involving rodenticides in Great-Britain. The authors mentioned that birds and mammals found dead after rodenticide use always had direct access to the bait source. Fletcher *et al.* [13] also investigated 763 suspected poisoning incidents in animals in Great Britain in 1993, pesticides were cited as the cause in 212 cases and Ac poisoning in 20 cases (4 cases of brodifacoum poisoning, 8 cases of bromadiolone poisoning and 8 cases of chlorophacinone poisoning in foxes, little owls, mallards, cats and dogs). These accidents were supposedly related to misuse and abuse of Ac.

Among the Ac compounds used only 2 (chlorophacinone and bromadiolone) are of major interest in France. Chlorophacinone was most detected in rabbits and in hares, and in trace

amounts in the liver of predator species occasionnally. The liver concentrations of chlorophacinone measured in most species are high (usually >1 mg/kg) and comparable to laboratory exposure [15, 16]. The concentrations measured when chlorophacinone was detected in conjunction with bromadiolone were not high compared to cases in which chlorophacinone ocurred alone. When both compounds were detected in an animal, the primary cause of poisoning was probably bromadiolone. Liver bromadiolone concentrations were significantly higher in foxes than buzzards. This is suggestive of higher suceptibility of buzzards to bromadiolone.

Field evidence of poisoning related to the use of bromadiolone is extremely limited. A series of poisoning cases attributed to bromadiolone field-application was reported in Switzerland in 1982 [17], but the bait used was dry and with a higher bromadiolone concentration (140 mg/kg compared with 50 mg/kg in our survey) and residual concentrations in the animals were not published and available for comparison. Furthermore, it was estimated that most of the species involved died of direct ingestion of the bait, because it was a sweet-based product [18].

More striking is the finding that mostly predators (foxes and buzzards) were poisoned with bromadiolone. Direct poisoning of foxes and buzzards after ingestion of a bait, although it cannot be absolutely excluded, appears extremely unlikely for several reasons. Bromadiolone is applied under very strict official control and by PCO's only. It is not likely that foxes and buzzards will eat considerable amounts of carrot or apple-based baits. Wet baits disappear shortly after application (G. Grolleau, personnal communication). If direct bromadiolone poisoning was the most common cause, it should be more common in other species such as rabbit, hare, mallards, etc. and our results show that bromadiolone is seldom detected in these species. Under laboratory conditions, bromadiolone is known to be a potential threat to non-target animals, via secondary poisoning (15). A study was conducted in ermines (*Mustela hermina*) and buzzards (*Buteo buteo*) [16]. The results indicated that secondary poisoning, although unlikely, was possible in ermines fed bromadiolone-poisoned rodents 5 days in a row. This protocol exceeds what should occur under natural circumstances, since bromadiolone baits are not attractive after 3 days and small carnivores usually do not depend solely on one rodent species for food. Their results also indicated that buzzards could potentially be poisoned by bromadiolone-contaminated rodents after 3 days of consecutive administration or repeated feeding trials (8-10 days apart). Although the number of buzzards affected was limited (2 out of 10), the potential for secondary

poisoning appeared more realistic than for ermines. The authors concluded that secondary poisoning was possible, although very unlikely under usual field conditions. The liver bromadiolone residues were measured and found to average 0.4 mg/kg in buzzards, which is equivalent to the median obtained in our survey.

In other predator species, secondary poisoning with bromadiolone is described in experimental trials only. It is known that red foxes usually eat most of the visceral content of their preys and may be exposed that way [19]. Bernex [20] fed coypus (*Myocastor coypu*) 1 kg bromadiolone baits (100 μg/g). Dead animals were administered to foxes and 4 out of 5 animals died of bromadiolone poisoning (liver concentrations not measured). The author also studied secondary toxicity of three compounds in dogs from warfarin, bromadiolone and difenacoum. Only the latter two were found to be potentially hazardous. Grolleau et al [16] also found that secondary poisoning could also occur in ermines, under very severe experimental conditions.

Field evidence of secondary poisoning with Ac compounds is limited as well. Newton *et al.* [3] detected brodifacoum and difenacoum at very low concentrations (< 0.5 mg/kg) in 10% of all barn owls found dead and submitted to their laboratory for a survey period of 5 years. Only one animal presented hæmorrhages and higher liver concentrations of brodifacoum, an Ac compound known to persist for up to several months in mammalian liver (3) and, thus, highly likely to induce secondary poisoning. Similarly, Merson *et al.* [21] measured brodifacoum in pellets rejected by Screech Owls (*Otus asio*) and concluded that raptors were exposed to brodifacoum, via contaminated preys. None of the animals developed signs of Ac poisoning. In a recent survey of incidents involving pesticides in wildlife in Great-Britain, Fletcher and Grave [4] reported only one suspected case of secondary poisoning with brodifacoum.

These results should be compared with ours: several animals (several species) were found dead, with hæmorrhagic disorders and liver concentrations of bromadiolone known to be associated with clinical poisoning in other birds or mammal species. There was an obvious chronological relationship between the application of bromadiolone-based baits and the finding of dead predators (around 2 weeks), but this time-interval is too long to be associated with primary poisoning (< 10 days) [22]. All the animals found dead were in an area where bromadiolone was applied and where field vole populations were extremely dense and only predators were affected (even herons are known to eat, if necessary, field voles). It is also known that Ac-poisoned rodents are more easily captured by predators

than their "normal" counterparts, because they cannot escape rapidly during the early phase of poisoning.

In other locations in France, where bromadiolone was in use and field voles were not as numerous, there was no report of animals dead of hæmorrhagic disorders. These observations are suggestive of secondary poisoning with bromadiolone under "field" conditions, when predators feed almost exclusively on field-voles., especially foxes and buzzards. There is no other field evidence of secondary poisoning in diurnal raptors, eventhough Falconidæ (buzzards) are considered to be more susceptible to Ac poisoning than other raptors [16]. Within the treated area, very few nocturnal raptors (1 Barn owl) were poisoned.

One very unusual finding is that trace amounts of chlorophacinone were measured in several animals (buzzards and foxes). Since chlorophacinone is widely available in France and its use is not under as strict a regulation as bromadiolone, it was not possible to determine the origin of the compound. We hypothesized that non-official uses were also conducted at the same time. The concentration measured in most instances were small (close to the limit of detection) and this product does not seem to be responsible for secondary poisoning in any species [20]. It does not accumulate to the same extent as newer generation products like brodifacoum or even bromadiolone. Nevertheless chlorophacinone may have played its part in the coagulation disorders oberved as well.

Conclusion

This investigation of Ac poisoning in wildlife shows that only chlorophacinone and bromadiolone are of importance in field incidents in France. Both products are used extensively against field voles. In France, bromadiolone distribution is restricted to PCO's and it is used under strict control. Our results indicate that Ac poisoning is not a major threat to non-target species, compared to other pathologic disorders. Our data also show that, in some instances (field-rodent control campaign, high population density of fiel-voles) bromadiolone may result in secondary poisoning in predators feeding mostly on these abundant prey. To our this is the first field-evidence of secondary poisoning with bromadiolone under normal conditions in diurnal raptors such as buzzards. Lastly, the concentrations measured in the liver of affected animals suggest that buzzards may be more susceptible than foxes.

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References cited

1- V.M. Mendehall, L.F. Pank, Secondary poisoning of owls by anticoagulant rodenticides. *Wildl. Soc. Bull.* **8**, 311-315 (1980)

2- D. Kaukeinen, A review of the secondary poisoning hazard potential to wildlife from the use of anticoagulant rodenticides in *Proceedings of the 10th vertebrate pest conference,* Univ California, Davis. p 151-158 (1982)

3- I. Newton, I. Wyllie and P. Freestone, Rodenticides in British barn owls. *Environ. Poll.*, **68**, 101-117 (1990)

4- M.R. Fletcher and R.C. Grave, Post-registration surveillance to detect wildlife problems arising from approved pesticides. Brighton Crop Protection Conference - Pets and diseases - 793-798 (1992)

5- Association de Coordination Technique Agricole, Réglementation française des produits phytosanitaires, ACTA Ed, Paris (1990)

6- Association de Coordination Technique Agricole, Index phytosanitaire 1996, ACTA Ed, Paris (1996)

7- P.J. Berny, T. Buronfosse and G. Lorgue, A new simple High performance thin layer chromatographic technique (HPTLC) for the simultaneous determination of eight anticoagulant compounds in the liver of animals. *J. anal. Toxicol.*, **19**: 576-580 (1995)

8- M.F. Morin, N. Merlet, M. Dore, J.C. Lechevin, Analyse de résidus de bromadiolone (rodonticide anticoagulant) dans l'eau et les tissus animaux. Techniques d'extraction et de purification. *Analusis*, **17**: 526-531 (1989)

9- G. Lorgue, K. Nahas, G. Keck and M. Rampaud, Intoxication of domestic and wild animals by anticoagulant rodenticides - a synthesis of data from the French National Veterinary Antipoison Centre. *Proceedings Twelfth Vert. Pest. Conf.* University of California Ed, Davis., 82-87 (1986)

10- J. Barrat and Y. Gérard, Réseau SAGIR, Bilan d'activité 1993 p. 21 Office National de la Chasse, Paris (1993)

11- J. Barrat, Y. Gerard, M. Artois, F. Lamarque and P. Berny, Bilan annuel réseau SAGIR 1994. p. 17 Office National de la Chasse, Paris 17 p. (1994)

12- R.D. Smith Veterinary epidemiology: a problem oriented approach Ed Butterworth-Heinemann, Boston 235 p (1991)

13- M.R. Fletcher, K. Hunter and E.A. Barnett, Pesticide poisoning of animals 1993: investigation of suspected incidents in the United Kingdom-A report of the Environmental Advisory Committee on Pesticides, p. 52 MAFF Publications, London (1993)

14- C.T. Eason and E.B. Spurr, Review of the toxicity and impacts of brodifacoum on non-target wildlife in New-Zealand. *N. Zeal. J. Zool* **22**, 371-379 (1995)

15- G. Lorgue, Etude de la toxicité du chlorophacinone sur le canard milouin, 153-158 (incomplete reference) (1974)

16- G. Grolleau, G. Lorgue and K. Nahas, Toxicité secondaire, en laboratoire, d'un rodenticide anticoagulant (bromadiolone) pour des prédateurs de rongeurs champêtres : Buse variable (*Buteo buteo*) et hermine (*Mustela erminea*) Symposium Intern. Ecol. Terr. Les Arcs. (1985)

17- L. Rebeaud, La revanche du rat des champs *L'Express* 24-30 Déc 1982, p 89.

18- G. Grolleau, Le rodenticide anticoagulant bromadiolone est-il dangereux pour les animaux prédateurs et en particulier les rapaces ? *Déf. Vég.*, **219**, 14-22 (1983)

19- F. Schitoskey, Primary and secondary hazards of three rodenticides to kit fox. *J. Wildl. Manage.* **39**, 416-417 (1975)

20- F. Bernex, Intoxication secondaire du chien par les rodonticides anticoagulants: étude expérimentale. Thèse Méd. vét., Lyon (1989)

21- M.H. Merson, R.E. Byers and D.E. Kaukeinen, Residues of the rodenticide brodifacoum in voles and raptors after orchard treatment *J. Wildl. Manage.*, **48**, 212-216 (1984)

22- G. Lorgue, A. Rivière and J. Léchenet, Précis de toxicologie clinique vétérinaire. p. 208, Point vét Ed., Maisons-Alfort (1987)

23- A. Gray, C.V. Eadsforth and A.J. Dutton, The toxicity of three second-generation rodenticides to barn owls. *Pest. Sci.* **42**,179-184 (1994)