Development and Use of Compound 1080 in Coyote Control, 1944-1972

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ABSTRACT: Compound 1080® is a man-made sodium salt of fluoroacetic acid or fluoroacetate, which occurs in nature as the toxin in many species of poisonous plants. The toxicity of such plants had long been recognized, but the toxic agent was not identified as fluoroacetate until 1944. By that time, the pesticidal potential of synthesized sodium fluoroacetate (code number 1080-44) was being explored in the United States in wartime, crash program aimed at finding new rodenticides. Compound 1080, the main product of that program, proved to be the best rodenticide known up to that time. It was found to be even more toxic to canids than to rodents, so was used experimentally for coyote control beginning in November 1944.

Compound 1080 was authorized for operational use in governmental predator control in 1946. Large meat baits, or bait stations, injected with 1080 solution and placed on livestock ranges in winter quickly became a preferred method for reducing coyote populations that preyed on sheep and cattle. The use of 1080 bait stations peaked in Fiscal Year (FY) 1963, when over 16,000 stations were placed by the U.S. Fish and Wildlife Service Predator and Rodent Control program. After 1963, numbers of 1080 stations declined year by year to 1972 when the use of 1080 and other predacides on Federal lands and in Federal programs was stopped by President Nixon's Executive Order 11643, followed by Environmental Protection Agency suspension and cancellation of registrations for 1080 and other predacides. The 1080 cancellation was based partly on high potential hazard to humans, even though no human had ever been killed or seriously injured in connection with the use of this toxicant in coyote control.

Paradoxically, most of the political agitation over Compound 1080 focused on its use in predator control, even though much greater amounts were used for rodent control. The total amount of 1080 sold in the U.S. during 1968-1972, the last 5 years in which 1080 bait stations were used, was approximately 10,003 lb. Only 1.3% (129 lb) of that amount was used for predator control. The largest amount of 1080 used for coyote control in the United States in any one year was about 42.4 lb, in FY 1963.

KEY WORDS: canids, *Canis latrans*, Compound 1080, coyote, predacide, Predator and Rodent Control, predator control, rodenticide, sodium fluoroacetate, vertebrate pest control

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INTRODUCTION

When Compound 1080 first appeared in the 1940s it was hailed as a miracle and a wonder, a rat control marvel without precedent, and the best predator poison ever invented. Only a few decades later 1080 was being denounced as one of the worst evils ever perpetrated by modern science. As with most contradictory rhetoric, the truth lies somewhere between these extremes. Vertebrate pesticides in general are controversial and, over the past 40 - 50 years, Compound 1080 probably has been the most controversial of them all.

Few people working in vertebrate pest management today have first-hand experience with Compound 1080, particularly in predator control. As one of those few, I have attempted in this paper to give a factual account of the discovery and use of this interesting pesticide. Because the entire 1080 story is too large for adequate coverage in the space available here, this article focuses on coyote control, my area of expertise[1]. Also, I have concentrated on the early history of 1080, from 1944 to 1972, because that period is less well documented compared to events since 1972. This paper is concerned primarily with technical and scientific aspects of 1080, but I recognize that the most important decisions about toxicants also involve political and sociological considerations that, strictly speaking, lie outside the bounds of science as presented here.

Compound 1080® is Tull Chemical Company's registered trademark for a technical grade (90% active ingredient) of sodium fluoroacetate (FAC), which is the sodium salt of fluoroacetic acid. This chemical, formula $C_2H_2FNaO_2$ (Windholz 1983), CAS number: 62-74-8, also has been known by a variety of other names including sodium monofluoroacetate, SMFA, "Tenate" (O'Brien 1988), Ten-Eighty, Fratol, Ratbane, and simply "1080".

Almost all of the 1080 used in predator control in the U.S. has been in the form of poisoned large meat baits– 1080 bait stations– that were placed on western rangelands to kill coyotes in winter. This practice began experimentally in 1944 and became fully operational in 1946. It ended, for all practical purposes, in February 1972 when President Nixon restricted the use of predacides on Federal lands and in Federal programs by Executive Order 11643. The Order stated, in part, "It is the policy of the Federal Government to (1) restrict the use on Federal lands of chemical toxicants for the purpose of killing predatory mammals or birds; (2) restrict the use on such lands of chemical toxicants which cause any secondary poisoning effects for the purpose of killing other mammals, birds, or reptiles; and (3) restrict the use of both such types of toxicants in any Federal programs of mammal or bird damage control that may be authorized by law" (Nixon 1972).

[1] The author worked in predator depredations control research at the Denver Wildlife Research Center (DWRC) during 1975-1985, leading field research on the Compound 1080 LPC and on 1080 SDBs.

Executive Order 11643 was followed in March 1972 by Environmental Protection Agency (EPA) action to suspend and cancel existing registrations for predacidal uses of Compound 1080 and other toxicants (Ruckelshaus 1972). Later, six western states sued EPA in Federal district court, seeking to reverse the cancellation on grounds that EPA had failed to prepare an environmental impact statement and had not conducted an administrative hearing prior to issuing the 1972 order. The district court issued a preliminary injunction prohibiting EPA enforcement of the order. While the injunction was in place, the State of Wyoming continued to use 1080 bait stations in the winters of 1975-1976 and 1976-1977. This activity ceased when the injunction was vacated and the cancellation order was upheld (USEPA 1981). Except for that Wyoming program, only small amounts of 1080 have been used legally in coyote control since 1972, and only in Livestock Protection Collars (LPCs) and experimentally in single-dose baits (SDBs).

The history of 1080 is paradoxical in several ways. One is the fact that this chemical was developed and used primarily as a rodenticide, yet most of the political agitation over 1080 has revolved around its use in predator control. About 98% of the 1080 used in the U.S. before 1972 was for rodent control, and the few human fatalities attributed to 1080 were all associated with rodenticidal uses. Nevertheless, in 1972, EPA canceled only the predacidal uses of 1080[2]. And, since 1972, it has seemed to me that any proposed new use of 1080 in predator control, even for such restricted techniques as the LPC, has drawn much more opposition than might have been expected based on objective assessment of the risks.

The political and regulatory history of Compound 1080 as a predacide in the U.S. has been the subject of many published and unpublished reports including Dunlap (1988), Feldman (1996), Howard and Schmidt (1984), MacIntyre (1982), USEPA (1981), Wade (1980, 1986), and Wagner (1988). The 1972 predacide cancellation also was debated at length in the U.S. Congress (U.S. Senate 1972, 1973; U.S. House of Representatives 1973, 1974). Since that part of the story is well known, this paper concentrates on less publicized aspects of 1080 history. Much of this history is preserved in unpublished documents and obscure publications that are on file at the USDA APHIS Wildlife Services' National Wildlife Research Center (NWRC) in Fort Collins, Colorado. The NWRC is the organizational descendant of the former Denver Wildlife Research Laboratory (WRL)[3], where Compound 1080 was developed for use in rodent and predator control in the U.S.

FLUOROACETATES IN NATURE

From the dawn of human history, certain plants have been known to be toxic or harmful to animals. One such plant in South Africa, *Dichapetalum cymosum*, known locally as "Gifblaar", had long been recognized as one of the most deadly poisons to livestock, but not until 1944 was monofluoroacetic acid identified as its toxic principle (Marais 1944). Naturally-occurring organic fluorine compounds had been unknown before Marais' discovery (Chenoweth 1949, Pattison 1959).

Subsequently, FAC also was identified as the toxin in many species of shrubs in Western Australia (Aplin 1973) and in a rat weed native to Brazil (DeOliveira, cited by Atzert 1971). In Western Australia, certain plants of the genera *Gastrolobium* and *Oxylobium*, with common names such as Heart-Leaf Poison, Prickly Poison, and Bullock Poison, had caused serious economic loss to stock-raisers from the earliest days of European settlement. Attempts to identify the toxic principle in these plants did not succeed until 1964; FAC eventually was found in concentrations up to 2,650 ppm in parts of certain *Gastrolobium* species. FAC content varies greatly among species and within each species, but generally is higher in the active stage of growth, at flowering. A detailed account of 34 toxic *Gastrolobium* and *Oxylobium* species, including means of identification, illustrations in color, geographic distribution, and management recommendations, was provided by Aplin (1973). Native mammals that evolved with these toxic plants exhibit unusually high tolerance to 1080 (King et al. 1978).

Outside of Africa, Australia, and South America, hazardous FAC concentrations have not been found in plants except in localities where atmospheric fluoride levels were abnormally high. Forage plants collected within 2 miles of a phosphate plant, where grazing horses showed severe fluoride injury, contained significant amounts of fluorocitrate and FAC (Lovelace et al. 1968). The identity and location of this phosphate plant were not specified; presumably, it was in the U.S.

Further research has established that trace amounts of FAC are natural and normal features of our environment. Fluorocitrate has been found in commercial specimens of tea and oatmeal in England (Peters and Shorthouse 1972), and Finnish workers found trace amounts of FAC in plants both from high-fluoride and low-fluoride areas as well as in 21 samples of ordinary tea (Vartiainen and Kauranen 1984). Fluorocitrate and FAC also have been found in soybean and crested wheatgrass plants that had been exposed to atmospheric fluoride (Miller et al. 1973).

THE DISCOVERY OF COMPOUND 1080

Once FAC had been identified in nature as a potent plant toxin, as described above, one might suppose that this finding led to the development of FAC for use as a pesticide. Such a supposition would be wrong; FAC was made in the laboratory and its pesticidal properties were recognized several years before this compound was found to occur in nature. FAC was first synthesized in Belgium

[2] Registrations for rodenticidal uses of Compound 1080 were cancelled by EPA in 1988 - 1989 due to lack of supporting data, and all pending applications for Federal registration were denied by August 1990 (USEPA 1995).

[3] The Wildlife Research Laboratory was created as part of a governmental reorganization in FY 1940, when the USDA Biological Survey was transferred to the USDI Fish and Wildlife Service. At this time the Biological Survey's Control Methods Research and Food Habits Laboratories were combined to form the Wildlife Research Laboratory, headquartered in downtown Denver. After WW II the WRL moved to the Denver Federal Center in Lakewood, Colorado. It was renamed the "Denver Wildlife Research Center" in 1959. In 1996 all facilities and personnel were relocated to Fort Collins, Colorado as the "National Wildlife Research Center".

by Swarts in 1894 (Chenoweth 1949), but its pesticidal properties were not recognized at that time.

The earliest record I have found of a pesticidal application dates from 1930 when FAC was patented in Germany as a mothproofing agent (Pattison 1959). A German worker (G. Schrader; cited by Pattison 1959) also studied the toxicity of fluorine compounds to warm-blooded mammals in the 1930s, and the use of fluoroacetic acid salts as rodenticides was patented there before World War II. These developments apparently were not known in Great Britain and the U.S. until many years after the war.

The discovery and development of Compound 1080 in the U.S. during World War II resulted from a crash project to develop new rodenticides. Before the war, strychnine, red squill, thallium, zinc phosphide, and other rodenticides had been readily available but, with the onset of war, shortages of the more effective rodenticides became imminent. In August 1943, the Federal government's Office of Scientific Research and Development (OSRD) contracted with the U.S. Department of the Interior (USDI), Fish and Wildlife Service (FWS), to identify and test new rodenticides (Anonymous n.d.). Over the next 2 years, more than 1,000 substances were evaluated by this project ("Research in Rodenticides"; OSRD Contract No. 3167). Materials identified by FWS investigators or obtained from cooperators were submitted for bioassay at the FWS Patuxent Research Refuge in Maryland. Following initial screening, the most promising substances were forwarded to the Denver WRL for further testing in laboratory trials with caged animals, followed by tests of the best materials under actual field conditions. The outstanding product among thousands of chemicals screened in this effort was sodium fluoroacetate, or sample number 1080-44, which within a few years would be known far and wide as Compound 1080.

On September 30, 1943, Dr. Ray Treichler, a chemist at the Patuxent Research Refuge, wrote to Dr. W. R. Kirner at OSRD requesting help in identifying toxic chemicals that might have potential application as rodenticides. The response was a detailed assessment of the pros and cons of numerous materials including fluoroacetate derivatives, one of which was "TL 869 Na fluoroacetate" (Memorandum, "Animal Poisons", B. Renshaw, OSIR Division 9 to W. R. Kirner, December 30, 1943; 6 pp.). Further correspondence resulted in a submission of 13 sample materials to Dr. Treichler for evaluation. On April 29, 1944, they were entered in the Chemistry Laboratory log book at Patuxent as sample numbers 1072-44 to 1084-44. Sodium fluoroacetate received the number '1080-44'. (The '44' refers to the year 1944.)

Sample number 1080-44 was first assayed for toxicity to rodents (albino rats) at Patuxent on June 21, 1944. On June 30, twenty-two compounds including number 1080-44 were forwarded to Denver for more testing (Memorandum, "New and substitute economic poisons – forwarded to Denver from Patuxent", R. Treichler to J. C. Ward, June 30, 1944; 1 p.). Out in Denver, Ward soon reported that "...sodium fluoroacetate is still showing a great deal of promise...I would prophesy that the fluoroacetates will prove to be one of our most logical new poisons" (Memorandum, J. C. Ward, WRL, Denver to R. Treichler, Patuxent Research Refuge, August 4, 1944; 1 p.).

In August 1944, the WRL was advised that compound 1080-44, as well as other materials, were classified as 'Secret' under the Espionage Act (Memorandum, R. Treichler to J. C. Ward, WRL, Denver, Colorado, August 10, 1944; 1 p.). The classification of compound 1080 was later changed from 'Secret' to 'Restricted' (Letter from J. C. Ward, Rodent Control Subcommittee, OSRD to E. R. Kalmbach, Denver, Colorado, January 22, 1945; 1 p.), and still later from 'Restricted' to 'Open' (Memorandum, J. C. Ward to W. R. Kirner, NDRC, April 10, 1945; 1 p.). Nevertheless, from August 1944 to about June 1945 when the public announcement of the discovery of 1080 (Kalmbach 1945) was prepared for publication, this chemical was identified in written reports by its code number, 1080-44.

By September 1944, the scientists in Denver were urgently seeking larger quantities of 1080-44 for expanded testing (Memorandum, J. C. Ward to R. Treichler, September 11, 1944; 1 p.). One kilogram was promised for delivery to Mr. Ward by October 2 (Memorandum, A. C. Cope, NDRC to R. Treichler, September 21, 1944; 1 p.).

On October 26, 1944, Dr. Treichler advised J. C. Ward by letter "...that 1080-44 is 100 times more toxic to dogs than to man, and that it should be an excellent poison for use against coyotes." This is the earliest document I have seen that identifies FAC as a potential predacide. Four days later, J. C. Ward wrote to Dr. Treichler requesting 10 pounds of 1080-44, and referring to arrangements for testing 1080 against coyotes. This subject will be developed later (see *Use of Compound 1080 in Predator Control*).

Meanwhile, on the rodenticide front, OSRD set up a Rodent Control Subcommittee to coordinate and expedite testing as soon as scientists recognized that 1080 could be the new poison that had been sought by the armed forces and public health agencies to fight rodent-borne diseases. Field tests were conducted by the WRL and many cooperators including the U.S. Public Health Service, the Surgeon General's Office of the Army, the Bureau of Medicine and Surgery of the Navy, U.S. A. Typhus Commission, Chemical Warfare Service, University of Chicago Toxicity Laboratory, Texas State Department of Public Health, British Commonwealth Scientific Office, the Pan American Sanitary Bureau, and others (Ward 1946). Within approximately a year, these agencies completed an amazingly large number of field tests. An interim report to OSRD (Spencer n. d.) noted that 1080 had been tested as a raticide in 117 cities and towns in 17 states between October 1944 and November 15, 1945. Spencer concluded that 1080 was highly effective against rats.

A contemporary summary listed 43 unpublished reports of 1080 trials against rats, field rodents, and insects (Ormsbee 1945). "The consensus expressed in these reports," Ormsbee wrote, "is that 1080 represents a major advance in progress toward an all-purpose rodenticide. The outstanding features appear to be high toxicity to all species of rodents tested, excellent accep-

tance, relatively quick action, absence of objectionable taste and odor, chemical stability, non-volatility, non-toxicity on the skin and non-irritation to the skin of workers."

Disadvantages of the new material included its high solubility in water which may result in the poison being washed out of baits by rain, and the rapidity of absorption in the gastro-intestinal tract which may produce warning symptoms in field rodents, causing them to avoid eating a lethal dose. This rapidity of absorption also was seen as a disadvantage in the treatment of accidental poisoning in man and other animals. Yet another drawback to 1080 was the extreme susceptibility of dogs and cats to both primary and secondary poisoning. In addition, there was human hazard from accidental poisoning by reason of 1080 having no odor and a non-repellent, only slightly salty taste, and the danger from accidental poisoning was increased by lack of any specific therapy. "Treatment of poisoning is entirely symptomatic," Ormsbee (1945) wrote, "and it has proved impossible to save an animal poisoned by 1080 once ventricular fibrillation has set in". Considering the risks and benefits, Ormsbee concluded that 1080 is a useful poison for rat and mouse control. He suggested that it might largely replace all rodent poisons in both field and urban areas, other than in residential districts.

These conclusions were reiterated in early published accounts (Kalmbach 1945, Ward 1946) that hailed Compound 1080 as a rodent control poison without equal while also emphasizing the hazards, including secondary poisoning of dogs and cats that ate poisoned rodents and the lack of effective antidotes. Ward (1946) presented a toxicity table showing the exceptional susceptibility of domestic dogs and coyotes to 1080. In these publications and in unpublished correspondence from that era, it is clear that the essential characteristics of Compound 1080 were well understood at a very early stage of its development.

One of these characteristics was very high toxicity, and therefore high hazard, to humans. By April 1945, if not before, research workers who had been involved in the development of 1080 came to believe that this potent substance was too dangerous to be made available in pure form to the general public and were considering steps to prevent wide distribution of it. One possibility to assure governmental control would have been for the responsible investigators to obtain a patent and assign it to USDI (Memorandum, J. C. Ward to W. R. Kirner, NDRC, April 10, 1945; 1 p.). After due deliberation, however, WRL researchers decided instead to protect the government's interest by means of an early publication that would describe the characteristics and potential value of 1080, thereby making it impossible for anyone other than the authors to secure a patent once the information had been made public (Memorandum, J. C. Ward to W. R. Kirner, April 25, 1945; 2 pp.).

The resulting publication was in final draft form by June 1945; it appeared in Science magazine on August 31. In this report, Kalmbach (1945) wrote that sufficient tests had been completed with 1080 to warrant the announcement that a promising new rodenticide had been discovered. Studies were continuing, but "It is reasonably certain that the discovery of '1080' assures this nation of a highly effective economic poison which can not be denied this country through any future interruptions of world trade." Kalmbach credited four individuals with the development of Compound 1080: Dr. Ray Treichler at Patuxent, and Justus C. Ward, D. A. Spencer, and H. J. Spencer of the Denver WRL.

Following this announcement, scientists at the WRL continued to seek ways to control the supply and distribution of 1080 in order to protect the public from the hazards of misuse. It was proposed that FWS and other agencies should approach the manufacturer, Monsanto, with Federal orders to buy all the 1080 that could be produced for as long as possible, thereby preventing shipments to anyone else. During this period, a distribution system would be worked out with Monsanto to insure that the chemical would be shipped only to "responsible" users (Memorandum, E. R. Kalmbach, Director, WRL, to Director, FWS, Chicago IL, October 10, 1945; 1 p.). Subsequent publicity stressed the hazards as well as the benefits of this new material: "Because Compound 1080 is such a dangerous poison, it has been used by the Fish and Wildlife Service so far only on an experimental basis...it has not been made available to the public...The use of this potent poison must be provided with every possible safeguard" (Memorandum and "Radioscript – 1080—Powerful New Rat Killer", L. K. Couch, Asst. Chief, Division of Wildlife Research, FWS to H. J. Deason, Special Assistant to the Director, FWS, May 21, 1946; 5 pp.).

By the time of Kalmbach's (1945) official disclosure that identified the wonderful new rodenticide as sodium fluoroacetate, it was already known far and wide as Compound 1080. The original commercial manufacturer, Monsanto Chemical Corporation, promptly registered 'Compound 1080' as a trademark to take advantage of this name recognition. The trademark subsequently passed to Tull Chemical Company in 1955 when Tull purchased the 1080 manufacturing process and facilities from Monsanto (Telephone communication, C. Wigley, Tull Chemical Co. with the author, November 17, 2003). This sequence of events helps to explain why the toxicant has always been most commonly known in the U.S. as 'Compound 1080', rather than sodium fluoroacetate or some other name.

USE OF COMPOUND 1080 IN PREDATOR CONTROL

Large Meat Bait Stations

Almost all of the 1080 that has been used by Federal agents in predator control in the U.S. has been injected into large meat baits that were placed on western rangelands in winter to reduce coyote populations. The use of 1080 bait stations, as they were commonly known, for coyote control began experimentally in 1944. Operational use began in 1946 and continued into 1972.

The poisoning of large animal carcasses in winter to kill predators was common practice long before USDA's Bureau of Biological Survey appeared on the scene with its government hunters and research workers. An account of strychnine use by fur hunters in Montana during the 1870s told how a buffalo (bison) carcass loaded with

three-eighths of an ounce of crystallized strychnine, then allowed to freeze, might kill from 10 to 50 large wolves (Quaife 1926). Early instructions issued to government hunters also prescribed the treatment of horse or other large animal carcasses with strychnine to kill predators (Day 1932). Thus, it is clear that the concept of poisoning mammalian predators by means of toxic, large meat baits originated at least several decades before Compound 1080 was discovered.

Experimental Use of Compound 1080 in Large Meat Baits

Wintertime use of large toxic baits was developed by the WRL as an adjunct to other control methods, particularly steel traps, which could not be used effectively when freezing weather and snow limited travel by government hunters and prevented traps from functioning efficiently (Robinson 1948). The WRL studies of toxic meat baits began in 1937 with thallium sulfate. Seven years later, when 1080 came along, baiting techniques that had been developed with thallium were readily adapted to the new toxicant.

Compound 1080 was first used experimentally for coyote control in autumn of 1944. Ten 1080-impregnated stations were placed in Routt, Moffat, and Jefferson Counties, Colorado, from November 1944 to January 1945, visited several times during the winter, and destroyed in April or May 1945. Each station consisted of either a horse carcass treated with 80 g of 1080 (4 stations) or 2 or 3 sheep, each of which contained 10 g of 1080 (6 stations). Several methods were tried for applying toxicant to the carcasses, including dusting the toxic powder into scored flesh, as had been done previously with thallium stations, and injection of 1080 solution into muscular tissue by means of hypodermic needles. The newly-devised injection method, which had not been practical with thallium due to its low solubility, was preferred with 1080 for ease, safety, and evenness of poison distribution throughout the meat (Spencer 1945). This soon became the standard technique for preparing 1080 bait stations.

Researchers visiting the ten 1080 stations during that first winter found a total of 15 poisoned coyotes, including 7 that were trailed away from stations to places where they died plus 8 more that were found more or less by accident near the baits. Sheep men in the study areas reported 21 more, for a total of 36 coyotes known to have been poisoned by the 10 stations. It was obvious that many other coyotes were killed but not found. Biologists found carcasses of poisoned coyotes at distances ranging from 100 yards to 1.5 miles away from the bait stations; the average was a little over half a mile.

In his first report on these experiments, Robinson (1945) suggested that 1080 might be superior to thallium in predator control. "It does not at present have thallium's bad name, but if not properly handled 1080 might acquire a reputation fully as bad if not worse." Recognizing that the 1080 concentrations used at first might have been much higher than necessary, Robinson suggested further studies with reduced amounts of toxicant so that the median lethal dose could be determined. He envisioned that these studies might produce a station that would give effective coyote control and at the same time be less dangerous to other carrion eaters.

For the second year of experiments, the number of 1080 bait stations increased to 45 in Colorado and 33 each in Idaho and Nevada (Robinson and Spencer 1946). The stations in Colorado were placed in November, at a density of about 1 per township (36 sq mi) over a block of some 1,600 sq mi in Moffat County, and were destroyed in March. Amounts of 1080 in each station were reduced from the previous year. Sixteen stations were treated with 64 g per horse carcass or 8 g per sheep. Thirteen others contained one-fourth of these amounts, and the remainder were prepared at the intermediate concentration of 32 g and 4 g, respectively, per horse and sheep.

Forty of the 45 lethal stations in Colorado were fed upon by coyotes. Coyotes invariably fed lightly – so sparingly, in fact, that at first it was questionable whether the bait was acceptable. In the spring, however, researchers concluded that there was no unusual reluctance on the part of the coyotes to start feeding, but that some factor– either a warning feature of 1080 or distasteful meat– prevented their eating any great quantities. Nevertheless, the amounts ingested appeared to be lethal to coyotes at all toxicant concentrations.

Reactions of coyotes that fed on 1080 stations were studied whenever possible by following their tracks in the snow. Robinson and Spencer (1946) described two typical cases from Moffat County, Colorado:

> January 3, 1946: A coyote ate approximately half a pound from the hip of a sheep carcass that had been treated with 8 g of 1080. After eating, the coyote rested for some time near the station, then left, walking normally for about half a mile. During the next half mile, it occasionally made short runs. About one mile away from the station, it laid down briefly, then rose and ran excitedly for 300 yd. "At this point the coyote vomited station material about the size of a man's fist. There followed running in circles, after which the coyote straightened its course and ran for about 1½ miles, circling in the brush and running straight while in the open. It died in convulsions in the bottom of a wash about two air-line miles from the station; in all it had traveled 2½ to 3 miles. The animal was unable to leave the site of the first knock-down convulsion."
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> March 9, 1946: Three coyotes visited a station that consisted of the hind quarter and trunk of a horse treated with 32 g of 1080 by inter-muscular injection. "After eating meat twice the size of a man's fist, the 3 coyotes left the station together traveling normally for ½ to ¾ mile. All three then laid down on a bare hillside where tracking was quite difficult. Several pieces of solid vomitus were noted at this point. Coyote No. 1 ran approximately 300 yards over the crest of the hill and died in convulsions. Coyote No. 2 ran about a half mile over the crest of the hill, vomited mucus, chewed on the branches of a cedar, then staggered another 50yd. Here the animal died following 3 convulsions. Coyote No. 3, a pregnant female carrying 9 embryos, walked over the crest of the hill, vomited mucus at 3 points, but did not appear

excited. After traversing a half mile the coyote laid down, arose, vomited mucus, and ran in circles. It then fell over the bank of a deep wash and died in convulsions. The 3 coyotes, after feeding at the station, had traveled 1 to 1½ miles and died within a half mile of each other."

In analyzing results from the 45 stations in Colorado, Robinson and Spencer (1946) recognized that the number of coyotes destroyed could not be determined with certainty because relatively few poisoned animals are ever found. Nevertheless, the scientists computed numbers of coyotes poisoned based upon the amount of feeding correlated with sign observed at the stations. On this basis, they estimated that 299 to 394 coyotes were destroyed by the 45 stations. Total numbers of animals actually found dead around the 45 stations included 70 coyotes, 4 dogs, 14 magpies, 3 eagles, and 2 badgers. Sheep men in the area reported an 85% reduction in lamb losses to predators when 1080 had been used, compared to the previous year without 1080. The effectiveness of coyote control was better on ranges at high elevation than in lower country.

The 1080 stations in Idaho and Nevada were monitored less intensively than those in Colorado, but in general, the results were similar. Feeding by coyotes was generally light. As in Colorado, it was much heavier at high elevation stations than at lower sites. In both states during the ensuing lambing season, sheep men found large numbers of dead coyotes scattered over the ranges and were unanimous in their statements that predator losses were much less than in former years. In all 3 states, excellent coyote control was achieved, ranging from near extirpation in the higher localities to less effective reductions in the lower regions.

From the very beginning of experiments with 1080 in predator control, researchers were concerned about adverse impacts to non-target species and did their best to avoid or minimize them. They also documented such impacts to the best of their ability, both by noting all animal species that fed on toxicant stations and keeping daily records of carrion-eating birds observed in the area where 1080-treated bait was exposed. These field observations were backed up by laboratory evaluations of the toxicity of 1080 to non-target mammals (badgers, foxes, raccoon, opossum), as well as to carrion-eating birds such as eagles, vultures, hawks, owls, and magpies.

Summing up the second year of studies on 1080-treated coyote bait, Robinson and Spencer (1946) wrote, "Besides coyotes, the principal station feeders were the carrion-eating birds – chiefly magpies, ravens, crows, and, to a lesser extent, eagles. Hawks, badgers, domestic dogs, and rodents fed irregularly. The reductional effects appeared greatest with respect to coyotes. Magpies, no doubt, were locally reduced, but their numbers as a whole not materially affected. Little is known regarding the population trends of crows and ravens. Some eagles were found dead, but these birds maintained sizeable populations in the presence of the stations. Due to a wide dispersal of stations, which gave some protection to the more sedentary mammals, and the fact that hawks were scarce during the period of station exposure, the other carrion feeders were killed only in small numbers."

Robinson and Spencer (1946) concluded that the new toxicant was superior to thallium for ease of application, availability, cost, speed of action, and safety in handling. Despite some undesirable features, particularly the scattering of vomitus and the lack of an antidote, the biologists suggested that 1080 should be included with thallium in FWS policy then being formulated to authorize the use of toxic meat stations for coyote control operations. And because stations with the lowest 1080 concentrations had been as effective against coyotes as stations containing larger amounts of toxicant, Robinson and Spencer proposed that the lower amounts– 16 g of 1080 per 1,000-lb horse and 2 g for the average 125-lb sheep– should be used in future to minimize hazards to nontarget animals. The authors' computations indicated that, at these levels, 1080 stations would be lethal to coyotes and magpies, less dangerous to badgers, and relatively safe for eagles and hawks.

The third season of research on 1080 stations focused directly on improving selectivity for coyotes by reduction of poison content; that is, by studying both efficacy (against coyotes) and nontarget impacts of baits containing the lowest concentration tested in the previous year (1.6 g of 1080 per 100 lb of meat). Noting that this formulation had given excellent coyote control during the winter of 1945-1946, Robinson (1947) confirmed this effectiveness with 25 stations in southern Las Animas County, Colorado.

These stations were put out in December 1946 and destroyed in late March 1947. Extensive feeding by coyotes was recorded, approximately half of the treated burro and horse meat being consumed. An excellent control of coyotes was obtained. Coyote feeding and activity had practically ceased by the time the stations were destroyed. Sheep men's reports following lambing season in 1947 confirmed that coyote numbers, as well as lamb losses to coyotes, had been substantially reduced.

As expected, impacts on nontarget creatures were low. In 75 visits by biologists to the 25 stations during the period of exposure, feeding by coyotes and unidentified canines (probably coyotes) were noted 47 times. For nontarget species, bobcat feeding was seen once, magpies 20 times, eagles 4 times, crow once, kangaroo rat once, and 'unidentified animal' once. Robinson (1947) concluded that effective control of coyotes by means of 1080 bait stations could not be achieved without also killing many of the other mammals that fed on the bait. Fortunately, carnivorous birds are more resistant to 1080, so that very few of them would eat enough treated bait to be killed. With scattered placements to reduce feeding opportunities for sedentary mammals, and regulation of the 1080 concentration to protect the more resistant and nomadic predatory birds, Robinson wrote that 1080 stations may become the most selective means of coyote poisoning yet devised. It was recommended that 1080 should continue to be used in bait stations at a rate of 1.6 g per 100 lb of bait meat.

In his first published paper on 1080 bait stations, Robinson (1948) noted that regurgitated bait material posed a direct hazard to other animals that might eat it, but he concluded that such poisoning did not appear to be extensive. He had felt that scattered vomitus from coy-

otes might result in the killing of dogs even after removal of the 1080 stations. However, following the use of 146 stations over a 3-year period, during which hundreds of sheep-herding dogs were employed in 1080-treated areas in the spring, only one report was received of the possible poisoning of a dog in this manner. Therefore, Robinson concluded, the vomitus disintegrates rapidly and becomes relatively harmless in warm weather.

Effects of 1080 stations on nontarget fur-bearing animals in forested and high mountainous regions were studied during the winters of 1947-1948 through 1951-1952 (Robinson and Cummings 1949; Robinson 1951b, 1953c). This research showed that, with proper placements, 1080 stations could be employed without seriously damaging populations of martens, weasels, and minks. Proper placement consisted of putting stations in open areas as far as possible away from preferred marten habitat (timber or brush) and at least a quarter of a mile away from streams that harbored minks. Damage to bears could be avoided by exposing 1080 baits only when bears were hibernating. Red foxes were vulnerable to 1080 stations and could be protected only by avoiding bait placements where foxes occurred. However, coyotes appeared to move down elevationally in winter more than foxes, so the placement of 1080 stations only at lower elevations "...may reduce coyote numbers with a minimum loss of foxes" (Robinson 1953c). As an operational guideline, Robinson (1951b) proposed that the lower limits of the spruce-fir vegetative type could be designated as the upper limit for placement of lethal stations.

Other studies in Arizona (Arrington and Edwards 1951) and Wyoming, Colorado, and New Mexico (Robinson 1953b) during this period showed that coyote numbers were greatly reduced following the use of 1080 stations, but the smaller carnivores such as gray foxes, badgers, skunks, bobcats, and raccoons were more numerous than before. Therefore, Robinson concluded, it is evident that the exposure of 1080 stations has not reduced the populations of mammalian predators and fur animals other than the coyote.

In addition to the research aimed at documenting and minimizing nontarget impacts of 1080 bait stations, other studies in the 1950s evaluated the possible use of buried, late-summer 1080 baits in Idaho, Utah, and Wyoming (Robinson 1951a, 1952a, 1953a). This concept originated with Idaho District Agent L. S. Twitchell, who needed an additional method of coyote control on the desert ranges where winter poisoning was not very effective because of the short winter season and interference by sheep and dogs. Twitchell's experience with 100 buried stations put out in mid-August and removed in late October or early November 1949 reportedly gave good coyote control with little apparent effect on other animals and birds (Robinson 1951a). Weldon Robinson participated in the evaluation of such baits in Idaho in 1950, and the study was expanded to Utah and Wyoming in 1951.

Robinson found that the excellent control obtained from buried baits in 1949 did not continue in subsequent years. Results were disappointing in 1951 and 1952, and ultimately it was concluded that widespread use of the buried stations was not desirable in Wyoming because of their doubtful effectiveness in controlling coyotes (Robinson 1952a, 1953a). Summer stations continued to be used in Idaho as late as 1957, but I have found no record of their use elsewhere. The practice apparently was discontinued late in the 1950s.

When 1080 bait stations were first authorized for operational coyote control by FWS Predator and Rodent Control (PARC) hunters, their use was prohibited "...in the humid Pacific coast areas, except when specifically authorized by the Director's office" (Presnall 1946). For several years after 1946, the District Agent in Oregon requested such authorization, but his requests were repeatedly denied. During the winter of 1952-1953, however, the WRL worked with the Oregon District to study toxicant-impregnated stations in the coastal regions of Oregon. This project was designed not only to collect data on efficacy and hazards of 1080 stations, but also to evaluate stations treated with anticoagulants as an alternative to 1080 as well.

A total of 23 stations were established in Oregon that year– 7 treated with 1080, 7 with warfarin, and 9 with pival. At least 19 of the stations were fed upon by coyotes or canine-like mammals. The feeding by creatures other than coyotes was not so extensive as to suggest that their populations were endangered. Neither warfarin nor pival appeared to be as effective as 1080 in controlling coyotes, in contrast to earlier findings from Nebraska where warfarin had appeared to be a viable alternative to 1080 in large meat baits (Robinson 1952b). In his report on the western Oregon project, Robinson (1953d) stated that 1080 should not be widely used there, but there are some isolated, uninhabited locations where coyote control is vitally needed and where these stations may be employed with only minimum danger to other carnivores.

During 1958-1959, the Idaho district tested 1080 stations made of ground jackrabbit meat, as a potential substitute for traditional livestock meats that were sometimes hard to obtain. The ground rabbit meat, obtained from a commercial processor, was treated with 1080 at the standard concentration (1.6 g 1080 per 100 lb of meat), placed in cardboard boxes in approximately 25-lb lots, and frozen. The jackrabbit baits were kept frozen until they were placed in the field. The stations were accepted by coyotes as well as or better than conventional sheep and horse meat stations, and were cheaper and more convenient to use (Circular Letter, "Ground Rabbit Meat Bait". N. E. Buell, Chief, PARC to FWS Regional Directors, PARC Regional Supervisors, and District Agents, October 23, 1959; 3 pp.). Though successful, the ground jackrabbit baits were never used in significant numbers outside Idaho. Even in Idaho, the practice was discontinued within a few years.

A few 'rabbit stations' using whole jackrabbits were tried in Utah. A 'rabbit station' consisted of six 1080-treated rabbits tied together. Each station was tied to a sagebrush or other bush and buried to keep birds from feeding on them (pers. commun., D. Hawthorne, former District Supervisor, FWS Division of Wildlife Services, Utah, to the author, February 7, 2004; 2 pp.).

Little if any formally planned research on 1080 bait stations was conducted through the 1960s, even though

1080 baits continued to be relied upon as the most important operational technique used to reduce coyote predation on livestock (Gottschalk 1970). By 1970, FWS researchers recognized that the era of 1080 bait stations might be coming to an end. The Director, Denver Wildlife Research Center (DWRC) advised the Director, Bureau of Sport Fisheries and Wildlife (Memorandum, "Status of 1080 Research", September 1, 1970; 3 pp.) "...if we must develop an antidote and do further research on such chemical properties as systemic action and degradation rates, it may be cheaper and wiser in the long run to concentrate our efforts on finding a substitute...It is our opinion that further research on 1080 is likely to prove or confirm its negative aspects and contribute to its being ruled out as a control chemical rather than saving it."

Two months later at a research coordination meeting in Denver, Weldon Robinson reported that existing registrations of 1080 for coyote control would expire in April and May 1972 (Memorandum, "Summary of Wildlife Research – Wildlife Services Coordination Meeting held in Denver November 4-6", to Director, DWRC. November 13, 1970; 3 pp.). Robinson suggested that, if these registrations are to be extended, data that we do not now have may be required and research should get underway as soon as possible. At this meeting, it was decided that DWRC would gather the necessary data to support reregistration of 1080 for coyote control when current registrations ran out. That research wasn't done, perhaps because DWRC scientists believed such studies would have contributed little if anything toward preserving the registrations in the climate of anti-pesticide, environmental activism that was sweeping the nation at that time.

Years later, DWRC scientists were still talking about the 1080 research that hadn't been done during the bait station era. Don Balser, Chief of the DWRC Predator Damage Section, wrote in 1974 that the DWRC had conducted virtually no research on predator damage to livestock during the 1950s and 1960s. The abrupt loss of predacides in 1972 brought increased controversy over toxicants and coyote control, followed by increases in predator research funding. However, most of the new money went to new research on nonlethal control methods while lethal methods, including predacides, were deemphasized (Balser 1974).

When this subject arose again at EPA hearings in 1981, another DWRC scientist testified that there was no new information on 1080 large meat baits because no new research had taken place since 1972. "My personal opinion is that the available information on both efficacy and nontarget hazards of 1080 baits is inadequate to support any general conclusion either for or against the widespread use of 1080 baits to protect livestock from coyotes. The information on this subject was inadequate in 1972 and it remains inadequate today. This is one of the reasons the controversy is still with us in 1981, nine years after predacidal uses of 1080 were banned" (Connolly 1981). He went on to identify specific issues that could be studied, but these ideas were not translated into research. The fact remains that there has been no significant field research on 1080 large meat baits in coyote control since the 1950s.

Operational Use of 1080 Bait Stations in Coyote Control

In October 1946, PARC employees were officially authorized to use Compound 1080 for coyote control (Presnall 1946). Up to that time, the use of 1080 had been limited to research. The new rules specified that Compound 1080 was to be used only by FWS employees who were specifically authorized by the Chief of the Division of PARC. "Stations containing 1080 shall be employed primarily on acute predation areas where other methods have not gained the desired degree of control... Stations are to be sparingly and judiciously located, averaging not more than one per township. They shall be used...in no area east of the 100th meridian[4], nor in the humid Pacific Coast areas, and they are to be confined to areas not readily accessible." Special care was to be taken to avoid using 1080 near human habitations or where humans, domestic stock, or dogs would be endangered.

The policy also required special reports from each District Agent[5] at the close of each poisoning season, to include specific times and places where 1080 stations were exposed and destroyed as well as "...a frank and complete statement of all details gathered concerning observations of predators and other animals or birds which may have been killed by 1080."

These instructions were supplemented one month later by a second memorandum (Green 1946) that summarized research findings and suggested that, in all operational work, 1080 should be applied at the rate of 16 g and 2 g, respectively, of 1080 for the average bait horse and sheep. Robinson's (1947) more general recommendation– 1.6 g of 1080 per 100 lb of bait– was adopted as official policy in autumn of 1947 (Kalmbach 1947). It is interesting to note that the FAC content of this bait– 1 mg per oz of meat, or 35 ppm– is lower than some naturally-occurring FAC concentrations in certain Australian plants (Aplin 1973).

The official spacing specification of not more than one 1080 station per township, on the average (Presnall 1946), also originated in early research (Robinson and Spencer 1946, Robinson 1948). In operational use, stations were to be sparingly and judiciously located, with placements maintained as closely as possible to an average of not more than one per township on any given range (Green 1950). A 1970 policy revision that consolidated and superseded all previous instructions on the use of 1080, avoided specific numerical guidance and directed only that the minimum number of stations needed to achieve effective management shall be used (Gottschalk 1970).

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[4] The 100th Meridian, as an arbitrary eastern boundary for 1080 operations, was later found to be unsatisfactory and was replaced by an essentially similar "boundary of range territory" following county lines. The "boundary of range territory" had been established by USDA in 1936 as the standard line of demarcation between range and farm country (Green 1950).

[5] The 'District Agent' position was analogous to 'State Director' in today's Wildlife Services program.

In preparing 1080 stations, government hunters were instructed to use horses, burros, cattle, or sheep for bait meat. Horses, burros, and cattle were to be butchered and quartered but not skinned. Sheep were usually prepared by removing the entrails only. The toxicant was dissolved in water and injected into the flesh with a hypodermic syringe equipped with a 4- to 6-inch, multiple-outlet needle. The flesh preferably was treated while it was still warm. The needle was to be inserted at close intervals, making frequent injections about 2 in apart. Treated bait was then allowed to cool overnight, or for at least 12 hr, to prevent the poison solution from draining off while treated bait was being transported. Great care was taken to keep pets and domestic animals away from treated bait or any fluids exuded from it (Presnall 1950).

In the early days, one or two sheep or a quarter of a horse or burro usually sufficed for a single 1080 station. Later, the amounts of treated bait placed at each station were adjusted up or down depending upon prior experience and hunters' judgment as to how much bait might be consumed. Baits were firmly wired to bushes, stakes, or trees to prevent coyotes from dragging them away. Proper warning notices were placed at conspicuous locations near each station.

Government hunters typically butchered bait animals at remote locations, treated the meat promptly, and left the bait to cool overnight at the treatment site. Coyotes usually would not feed on warm bait, but there were exceptions. Charles Cadieux (1983) described an episode in Maverick County, Texas when a 1,400-lb horse was butchered and treated one night. "The eight portions were left on large branches, to allow air to circulate under them overnight. We came back in the morning, expecting to pick up our 8 baits to be placed at prescribed locations around the county. But the entire horse had been eaten and the bones gnawed! We found more than a hundred dead coyotes in the surrounding chaparral that day." This was most unusual; government agents rarely found many poisoned animals near 1080 bait stations.

Ten-eighty stations usually were put out in autumn. Stations in the most remote locations normally were not visited again until late winter or early spring. In more accessible areas of Oklahoma, and perhaps Texas, New Mexico, and Arizona, government hunters checked the bait stations every 3 or 4 weeks, replenishing them as necessary with new bait (pers. commun., D. Hawthorne, former State Director of ADC Programs in Texas and Oklahoma, to the author, February 7, 2004; 2 pp.). All station sites were visited in late winter or early spring, when unused bait material was collected for disposal by burning or burial. Complete burning followed by burial of the ashes was preferred but deep burial or disposal in abandoned mining shafts or other deep holes was permissible (Presnall 1950).

The 1946 policy that released 1080 for operational coyote control led to rapid deployment of 1080 bait stations in most of the contiguous western states. By the late 1940s and early 1950s, government hunters were placing 1,000 or more 1080 stations annually in each of several states: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Wyoming. In Montana and Nevada, 2,000 or more stations were used in some years. Hundreds of stations also were used in California, Nebraska, North and South Dakota, Oklahoma, Texas, and Washington[6].

Preparation and placement of 1080 stations soon became routine. Bait station sites were approved ahead of time (Figure 1), and stations were later established at most approved sites depending availability of bait, weather constraints on travel to the off-road locations, and local professional judgment as to which sites should receive priority. Many regularly-used bait station locations were marked with red-topped, wood posts. After the Leopold (1964) report came out, these red-topped posts were taken down. By that time, many of those locations were no longer being used for bait stations (pers. commun., D. Hawthorne, former District Supervisor, FWS Division of Wildlife Services, Utah, to the author, February 7, 2004; 2 pp.).

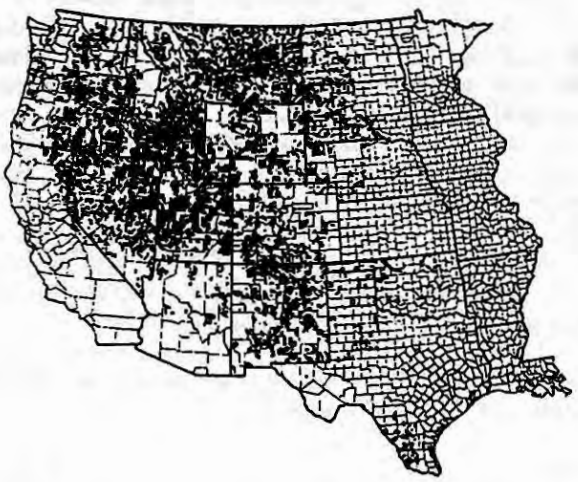

Figure 1. Areas approved by USFWS Division of Predator and Rodent Control for exposure of sodium fluoroacetate-treated baits for coyote control in Fiscal Year 1964, at a rate of one bait per township[7].

Routine, annual placements of 1080 stations at the same sites was common, but by no means was this a universal practice. In Arizona, PARC agents realized as early as 1948 that it might not be necessary to treat the same areas every year. A baiting rotation system was adopted there, so no one area would be treated with 1080 bait stations more often than every other year or every third year. A similar practice of avoiding new bait placements in areas treated in the previous year was being followed in parts of Texas as early as 1950.

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[6] Data from FWS Branch of Predator and Rodent Control (Division of Wildlife Services after FY 1965) State Annual Reports unless noted otherwise.

[7] From PARC Circular Letter, "Use of sodium fluoroacetate-impregnated bait stations for coyote control", C. C. Presnall to FWS Regional Directors, PARC Regional Supervisors and District Agents. June 15, 1964; 3 pp.

Peak years for the use of 1080 stations in coyote control differed from state to state. In Colorado, the record high year was 1949 when 1,477 stations were used. The all-time high number of stations in Montana was 2,378, in 1948. In Texas, 1080 bait stations were tried first in the Panhandle region in 1946 and were being used there on a large scale within a few years, 182 stations being placed in 22 counties in 1950. The work was extended into the Trans-Pecos beginning in 1953, and to South Texas in 1959. In Texas as a whole, the average annual number of stations placed during 1949-1972 was 459. The peak year there was 1963, when 1,023 baits were used (pers. commun., G. L. Nunley, State Director, Texas Wildlife Services Program to the author, November 28, 2003).

One interesting fact about Texas is that 1080 bait stations were never used in the major sheep and goat region there, the Edwards Plateau, because coyotes were not abundant in that region during the 1080 baiting era. Rather, an array of techniques including toxicants was used around the perimeter to keep the sheep- and goat-raising area essentially coyote free from about 1945 to 1970. After predacides were withdrawn in 1972, success in prohibiting coyote ingress into the Edwards Plateau waned and sheep and goat losses to predators increased significantly. The loss of 1080 and other predacides made it impossible for the Texas Animal Damage Control program to protect sheep and goats from coyotes as effectively as they had before 1972 (Nunley 1981).

In the western U.S. as a whole, large numbers of 1080 stations were used from about 1950 through the mid-1960s, after which annual bait placements dropped each year until 1972 when they stopped altogether. As late as 1970, Compound 1080 was still "...the principal tool used in Bureau programs for the prevention of livestock depredations" (Gottschalk 1970).

West wide, the FWS-supervised control program used 15,000 or more 1080 meat baits, or bait stations, annually during 1960-1964 (Cain et al. 1972:139). Based on those numbers, the peak year for 1080 in coyote control west wide was 1963 when 16,693 meat baits were used. Because Cain et al. (1972) provided no details other than total numbers of 1080 meat baits used annually during 1960-1970, I recompiled the data for the peak year, FY 1963, and for adjacent years (FY 1962 and 1964) from PARC annual reports for each state where 1080 baits were used.

This compilation (Table 1) yielded numbers that are similar but not identical to those in the Cain report. My totals are slightly higher for each of the 3 years. Of the two data sets, I think the information in Table 1 is more useful because it provides details that are lacking in Cain et al. (1972). However, both data sets show very plainly that many thousands of 1080 stations were used in those years. The states in which greatest numbers of 1080 bait stations were used during FY 1962-1964 were Nevada, Montana, Utah, Idaho, Wyoming, Oregon, New Mexico, and Colorado (Table 1, Figure 1).

In terms of reducing coyote predation on livestock, the initial results obtained with 1080 bait stations were generally excellent and sometimes spectacular. Following the placement of 1,380 stations in Colorado during the winter of 1947-1948, for example, many stockmen reported that this was the first time since they had been in operation that their predator losses were practically eliminated. Such field reports were consistent with earlier research findings showing that lamb losses to predators had been reduced by 85 to 99% in 1944-1945 and 1945-1946 (Robinson 1948).

Splendid results continued to be reported for several years, though in Colorado as early as FY 1948 the annual report noted that less bait was eaten in counties where

Table 1. Numbers of 1080 bait stations and amounts of toxicant used by FWS, Branch of Predator and Rodent Control, for coyote control in the United States in Fiscal Years 1962-1964[8].

State	*FY 1962*		*FY 1963*		*FY 1964*	
	No. Stations	1080 (oz.)	No. Stations	1080 (oz.)	No. Stations	1080 (oz.)
Arizona	325	14.30	950	40.40	279	8.60
California	218	6.83	253	9.48	169	5.70
Colorado	1,198	77.60	1,310	78.10	1,141	46.40
Idaho	1,685	68.33	1,754	65.87	1,575	66.36
Kansas	20	2.35	0	0	0	0
Montana	1,939	90.00	2,026	75.00	2,054	87.00
Nebraska	211	17.24	221	12.02	203	0.80
Nevada	2,132	67.19	2,119	72.57	2,176	72.98
New Mexico	1,157	36.06	1,292	45.29	1,027	38.04
North Dakota	143	3.46	182	4.84	131	4.09
Oklahoma	113	13.00	108	8.44	155	12.11
Oregon	1,394	55.60	1,254	51.00	1,141	40.70
South Dakota	392	11.05	440	15.00	423	3.00
Texas	674	47.59	1,023	62.05	943	45.00
Utah	1,797	78.67	1,996	75.45	1,900	73.20
Washington	414	11.10	410	10.80	388	9.10
Wyoming	1,345	49.00	1,391	52.00	1,376	70.00
All States	***15,157***	***649.37***	***16,729***	***678.31***	***15,081***	***586.08***

[8] Compiled from "Table P-3. Reductional Methods Used" in Predator and Rodent Control program annual reports for each state. Each fiscal year began on July 1 of the previous calendar year.

1080 baits had been used in prior years, compared to counties in which lethal baits had not been previously placed. By FY 1950, the sizes of some stations in Colorado were being reduced because only a small amount had been eaten from most baits in the previous year. Similar reductions were made in 1951, and it was found in most areas that the small station gave as satisfactory results as the larger one.

Within a few more years, however, coyote acceptance of lethal baits had fallen dramatically. In 1957, only 29 stations were placed in eastern Colorado where several hundred stations had been used previously, because in 1956 coyotes had almost completely rejected the 1080 stations placed at altitudes under 6,000 ft. Retrospective analysis in 1958 revealed that the 1080 poisoning program in Colorado had reached its most effective point in about 1950 or 1951, after which coyote acceptance of 1080 bait began to decline and coyote numbers increased. About 34% of the 1080-treated bait put out in Colorado in FY 1958 was consumed and, as in earlier years, bait acceptance was poor at stations located at elevations below about 5,500 - 6,000 ft.

In other states, too, coyote acceptance of 1080 bait meat was excellent at first but declined after a few years. This was a primary reason for research in the early 1950s on alternative toxicants for use in large meat baits (Robinson 1952b), as discussed previously. Alternatives were tested in field operations too. In Wyoming, for example, it became apparent by FY 1955 that coyotes were harder and harder to take with 1080, so thallium sulfate was used in some large meat baits as an alternative to 1080. After a 2-year trial, however, nearly all personnel agreed that compound 1080 was far superior and, from 1958 on, all stations in Wyoming (nearly 1,000) were again treated with 1080 (Phillips and Martley 2000).

The experiences recorded in Colorado and Wyoming reflect the typical pattern wherever 1080 bait stations were used: initial, spectacular successes in the early years were followed by declines in coyote use of 1080-treated bait and apparent, corresponding increases in coyote numbers and livestock losses to coyotes. Efficacy of 1080 stations over the years remained acceptable, even if the sensational results obtained in early years were not sustained. Bait consumption by coyotes was best on rangelands at the highest elevations, and noticeably poorer at low elevations. Year-to-year fluctuations in bait consumption were common and were speculatively attributed to such variables as the severity of winter weather, snow depth, and availability of other foods.

In the late 1940s and early 1950s, PARC state annual reports across the West abounded in enthusiastic testimonials from stockmen about the efficacy of 1080 baits. The prevailing theme in these reports was that 1080 had reduced coyote predation on livestock more effectively than any other method used previously, and more than anyone had believed possible. In those years it seemed inconceivable that anyone could doubt the efficacy of 1080 in protecting livestock. Later, however, stockmen would find their opinions discounted as "ill-defined and speculative benefits" when EPA cancelled and suspended the use of 1080 in predator control (Ruckelshaus 1972).

As noted earlier (see *Experimental Use of Compound 1080 in Large Meat Baits*), the impacts of 1080 bait stations on nontarget wildlife received much attention in early research (from 1944 through the early 1950s) but not much thereafter. The findings of (Robinson 1948), the main research publication that addressed this topic, probably overstated the nontarget hazards of 1080 stations as used in operational coyote control. Robinson's data included information from thallium baits as well as from 1080 baits that contained much more toxicant than the later operational standard of 1.6 g of 1080 per 100 lb of bait. Little or no scientific assessment of nontarget impacts was performed after the PARC had embarked upon routine, annual use of thousands of such 'standard' baits across the West. Later, of course, nontarget impacts of such baiting became a major issue and, ultimately, an important factor in the 1972 decision to remove predacides from use in Federal programs and on Federal lands (Nixon 1972, Ruckelshaus 1972).

Throughout the 1080 bait station era (1946-1972), FWS officials consistently asserted that the use of such baits in accordance with prescribed procedures suppressed coyote populations effectively without adversely affecting the populations of most other animals in the baited areas. An independent review of PARC procedures in 1964 agreed, concluding that 1080 bait stations, placed no more frequently than one to a township and properly applied according to regulations, do an effective and humane job of controlling coyotes and have very little damaging effect on other wildlife (Leopold et al. 1964). However, the Leopold committee also found that, in a good many instances, the regulations were not being followed and, under those circumstances, considerable damage could occur to other forms of wildlife as well as to domestic dogs. The committee expressed a need for much stricter adherence to established, operational rules.

In 1971, the Natural Resources Defense Council and other environmental protection organizations asked EPA to suspend and cancel the registrations for 1080 and other predacides. Their petition (NRDC 1971) charged that the use of 1080 and other chemical toxicants had destroyed hundreds of thousands of nontarget animals including some members of rare and endangered species. At about the same time, environmentalist groups also sought court injunctions to shut down FWS-supervised animal damage control activities (U.S. House of Representatives 1974:231-240). In response to their allegations, Jack Berryman, Chief of the FWS Division of Wildlife Services, provided evidence to back up his contention that the animal damage control program as presently conducted had not significantly reduced the breeding population or threatened the future of a single species, endangered or not. He contended that there is long experience and evidence to show that the toxicants used by FWS have not had an adverse impact upon the general environment, nor had they threatened human health and safety (U.S. House of Representatives 1974:204-230).

Nevertheless, EPA proceeded to suspend and cancel the registrations of 1080 and other predacides (Ruckelshaus 1972), based in part on "...evidence that a certain number of nontarget animals are being adversely

affected by 1080 products, particularly, in the case of carrion eating birds and mammals, by secondary poisoning". According to a later analysis (USEPA 1981), the 1972 cancellation and suspension decision relied heavily on information from three sources: the Cain Report (Cain et al. 1972); the Natural Resources Defense Council petition to ban 1080 and other toxicants (NRDC 1971); and the Leopold Report (Leopold et al. 1964).

Throughout the period of 1080 baiting for coyote control (1946-1972), the main objective was to reduce coyote populations for the protection of domestic livestock. However, such baiting was widely seen as beneficial to wildlife species as well. For example, the Idaho Fish and Game Department noted in its 23rd Biennial Report (July 1, 1948 - June 30, 1950) that antelope and sage hens have shown a marked increase on ranges where coyotes have been largely eliminated. During those years, the Department was a financial cooperator in Federal predatory animal control work. The Idaho program conducted by PARC relied heavily on 1080 bait stations in those years, using 1,552 stations in FY 1949 and 1,913 regular 1080 stations plus 100 summer stations in FY 1950.

During those same years, a detailed analysis of coyote control in northern Arizona showed that Compound 1080 baiting provided cheap and effective protection for antelope, making it possible to open hunting seasons in the protected antelope herds in 1949 and again in 1950. "Without the effective predator-control operations, resulting primarily from the use of compound 1080 beginning in 1947, there is little reason to believe these hunts would have been possible" (Arrington and Edwards 1951).

Compound 1080 bait stations reduced coyote predation on livestock and wild herbivores, such as deer and antelope, primarily by reducing coyote population numbers, thereby reducing the frequency of coyote attacks on vulnerable livestock and other prey. But coyote population reductions also affected other species of carnivores, particularly smaller furbearing mammals such as bobcats, skunks, badgers, raccoons, and kit foxes. In general, the smaller furbearers increased after coyote numbers were decreased (Robinson 1953b, 1961). Such effects, though unintended, would generally be regarded as beneficial impacts of coyote control. Persons who trapped bobcats for fur in the 1080-treated areas certainly would have seen bobcat population increases as desirable, whereas poultry raisers faced with increased bobcat predation might have felt otherwise. Thus, increases of other wildlife species following coyote population reduction with 1080 could have been either desirable or undesirable, depending upon one's point of view. But there is no doubt that the use of 1080 coyote baits had positive impacts on populations of some nontarget species.

Aside from protecting domestic livestock and wildlife, at least one large project with 1080 bait stations was carried out for rabies control in Baja California just south of the U.S. border (Cocozza and Alba 1962). From September 1959 to June 1960, residents of the contiguous border areas of Mexicali Valley, Baja California, and Imperial Valley, California, had been exposed to an explosive outbreak of rabies affecting mainly the urban dog populations of both valleys. Dog vaccination was temporarily helpful, but the frequency of contact between coyotes and dogs was seen as an important factor provoking the epizootic. Therefore, coyote population reduction was deemed essential to bring rabies under control.

In March 1961, eighty-one horsemeat bait stations containing 1080 at the standard concentration were placed across a 4,960-sq-mi area in the northern part of the Baja California peninsula between the U.S. border and the 32nd parallel. Subsequent reports from ranchers in the area indicated that at least half of the bait was accepted by feral dogs, coyotes, foxes, and skunks, and some carcasses of these species as well as crows were found. Cocozza and Alba (1962) reported that coyotes virtually disappeared from the area. They concluded that this program was effective in reducing the wildlife and feral dog population for a considerable area around the bait station, which justified the use of the poisoning method. Surprisingly, these authors offered no conclusion about the efficacy of 1080 baiting for the stated purpose of rabies control.

Drop Baits and Single-Lethal-Dose Baits (SDBs)

Before 1080 appeared on the scene, government hunters were advised to use only strychnine in operations against predatory animals. Strychnine was sometimes applied directly to livestock carcasses, as noted earlier, but the most common practice was to place "drop baits" (small pieces of perishable fats containing strychnine tablets) around unpoisoned "decoy" livestock carcasses on remote stock ranges in winter (Day 1932, Presnall 1950). This technique had been in widespread use for many decades before Compound 1080 appeared, so the new toxicant naturally was tried in drop baits as well as in the larger, meat bait stations.

The very first field experiments with 1080 in coyote control, in fact, included 5 drop-bait stations in addition to the 10 large meat stations that were discussed earlier in this report (Robinson 1945). Little information on efficacy or hazards of 1080 drop-baits was gained in that first winter, but an expanded study with 34 drop bait stations was carried out in Malheur County, Oregon during the next winter, 1945-1946. Five kinds of experimental drop baits were used; each bait contained 25, 50, or 100 mg of 1080. In all, 7,765 drop baits were placed at the 34 stations. Only a few creatures were found dead: 11 coyotes, 6 ravens, 7 magpies, a deer mouse, and a kangaroo rat. None of these were recovered from the two stations where 100-mg baits had been used. It was obvious that, regardless of the amount of 1080 per bait, there could be no appreciable recovery of coyotes from 1080 drop baits. Robinson and Spencer (1946) concluded that 1080 had no advantage over strychnine in drop baits, and 1080 drop baits were not studied further by these workers.

Drop baits weren't mentioned at all in the first published report on Compound 1080 in coyote control (Robinson 1948). From contemporary documents it is clear that PARC administrators had decided as early as 1946 that, for coyote control, 1080 was to be applied only in large meat baits while strychnine would be the toxicant of choice in drop baits. In fact, the original policy announcement releasing 1080 for use in coyote control prohibited its use in drop baits (Presnall 1946). Subse-

quent instructions to the field reinforced the dictum that strychnine would be used exclusively in drop baits, whereas Compound 1080 was preferred for use in large meat baits (Presnall 1950).

Official policy not withstanding, a few PARC field men probably experimented with 1080 in small baits. However, it seems that most professional hunters preferred the faster-acting strychnine for drop baits and weren't interested 1080 drop baits as long as strychnine remained available for this application. Both strychnine and 1080, in fact, remained available and continued to be used, in drop baits and large meat baits respectively, until 1972.

The concept of a single-lethal-dose 1080 bait (SDB), or a drop bait containing only the minimum amount of 1080 needed to kill a coyote, seems not to have received serious consideration in governmental predator control research or operations during the 1080 bait station era (1946-1972). A DWRC researcher was directed in 1970 to prepare a study plan for 1080 place-baits (Memorandum, "Summary of Wildlife Research-Wildlife Services Coordination Meeting held in Denver November 4-6", W. B. Robinson, Chief, Division of Behavioral Research to Director, DWRC. November 13, 1970; 3 pp.), but no such study was carried out.

After predacidal uses of 1080 were cancelled in 1972, the States of Montana, Wyoming, and South Dakota applied for EPA approval to use SDBs or drop baits containing up to 5 mg of 1080 for coyote control (USEPA 1981). These applications were based in part on a "standard guideline" that described the preparation and use of small, perishable baits, each containing a single lethal dose of 5 mg for coyotes (Wade 1976). EPA denied those applications but did grant experimental use permits to the FWS for field studies with 1080 SDBs. These studies, carried out by the DWRC in Idaho, Montana, Texas, and Utah during 1983-1986, did not produce a registerable SDB for operational use to protect livestock from coyotes. I regret that space limitations preclude detailed discussion of these developments here.

It may be noted that, in addition to their main intended use for protecting livestock from coyote predation, some special applications have been found for 1080 SDBs. One was to kill stray dogs and cats in a rabies control project in Guam (Glosser and Yarnell 1970). Another was the elimination of introduced arctic foxes from several islands within the Alaska Maritime National Wildlife Refuge, resulting in spectacular recoveries of breeding bird populations that had been decimated by the predators (Bailey 1993). Bailey wrote that 1080-laced bait was the best means of eliminating foxes from islands, up to 1972 when predacide bait registrations were cancelled by EPA.

Other Predacidal Applications of 1080

Smear Posts or Smear Pens[9]

The 1080 smear pen concept originated with Freeman E. Taber, a PARC Mammal Control Agent in Arizona, about 1954. Mr. Taber established 34 smear pens in Mohave County at an approximate density of one pen per township. Each pen consisted of a 24- by 24-ft barbed wire enclosure with stakes fastened in the center. An attractant paste similar to coyote getter bait was applied to each stake. No lethal agent was used at first, as the initial objective was to determine if coyotes would enter these pens and take the paste. They did.

In December 1954, Weldon Robinson arrived on the project and, under his direction, Compound 1080 was added to the smear attractant. Two months later, as Mr. Taber removed the lethal stakes for disposal, he found some dead coyotes in the area and others were reported by ranchers. Fifteen smear pens in Pinal and Pima Counties also showed good results, so this new method of controlling coyotes appeared at first to be very promising.

In FY 1956, the 34 smear pens in Mohave County continued to show good results, but in Apache County, coyotes fed on two pens but not on two others. Generally good results also were obtained in FY 1957, except at low elevations where the smear was less effective than in previous years. In FY 1958 it was noted that the success of smear stations depends on the quality or ability of the smear to attract coyotes. Apparently this quality was hard to maintain, because smear pens weren't mentioned in the Arizona reports after FY 1958. Ten smear-type 1080 stations were used on the Idaho desert in FY 1957, with negligible results. Lethal smears may have received limited trials in other states as well, but the technique seems to have been dropped before 1960. I have found no published accounts that describe this technique.

Livestock Protection Collar (LPC)

The LPC was invented in Texas in 1969 by Roy T. McBride (1972), following an earlier idea to apply 1080 or other toxic solutions directly to the necks of sacrificial lambs that were placed where coyotes would attack them. Any coyote that attacked and bit the neck of a treated lamb would ingest a lethal dose of toxicant (Knowlton 1969). Knowlton proposed this concept to FWS research leaders in 1970 for possible study as a coyote depredation control technique, but research on it was deferred (Memorandum, "Summary of Wildlife Research-Wildlife Services Coordination Meeting Held in Denver November 4-6", W. B. Robinson, Chief, Behavioral Research to Director, DWRC. November 13, 1970; 3 pp.).

In 1974, after Roy McBride had developed the LPC and demonstrated its feasibility, the "Predator Protection Collar for Livestock" (McBride 1974) was patented in his name by USDI. The DWRC subsequently initiated a major effort aimed at bringing the LPC into operational use, and EPA registration for the Compound 1080 LPC was obtained in 1985. These developments occurred after 1972 so are not reviewed in detail here. For further information, see Connolly (1980, 1993) and Connolly and Burns (1990).

AMOUNTS OF 1080 SOLD AND USED

Few specifics are available as to the amounts of 1080 made or used for various purposes in the U.S. from 1944 to 1972, but enough information is available to show that

[9] Information from Arizona and Idaho Districts, Branch of Predator and Rodent Control, Annual Reports, FY 1954-59, on file at the National Wildlife Research Center, Fort Collins, Colorado.

the amounts used in coyote control were very small compared to rodenticidal uses.

The original manufacturer of 1080 in the U.S. was Monsanto Chemical Company, headquartered in St. Louis, Missouri. Monsanto made 1080 at its Phosphate Division in Anniston, Alabama. In 1948, Monsanto representatives (Jenkins and Koehler 1948) reported that the full commercial demand for 1080 was about 10,000 lb per year. An unknown, but undoubtedly small, fraction of this production was sold to the Federal government. In 1955 the FWS was using approximately 250 lb of Compound 1080 annually (Circular Letter, "Availability of Compound 1080", D. D. Green, Chief, Branch of PARC to FWS Regional Directors and PARC District Agents. January 31, 1955; 1 p.).

More complete data are available from 1968-1972, the last 5 years when 1080 bait stations were used in Federal/cooperative animal damage control programs. These records (Table 2) show that approximately 12,868 lb of sodium fluoroacetate were sold by the two U.S. manufacturers during that period. Approximately 22% (2,865 lb) was exported. The remaining 10,003 lb, or about 2,000 lb annually, went to private and governmental entities in the U.S. during calendar years 1968-1972.

Similar data for "...the past three years" (presumably 1968-1970) were presented by Atzert (1971), who noted that the two U.S. manufacturers, Tull Chemical Company and Fike Chemicals, Inc., sold an average of approximately 2,600 lb of Compound 1080 annually. About 18% (468 lb) of this product was exported, so that an annual average of approximately 2,130 lb was sold within the U.S. during Atzert's 3-year period.

Based on the data in Table 2, only about 10% (977 lb) of the 1080 sold in the U.S. during 1968-1972 went to the Federal government. During this same approximate period (Fiscal Years 1968-1972), a total of 1,104 lb of 1080 was used in FWS-supervised cooperative predator and rodent activities. Most of this (975 lb, or 88% of the total) was for rodent control. Both rodenticidal and predacidal uses of 1080 in Federal programs declined year by year through the period (Table 2). Annual amounts used for predator control dropped from 37 lb in FY 1968 to 17 lb in FY 1972.

From these figures, it is clear that the total amount of 1080 used in FWS-supervised predator control during FY 1968-1972 (129 lb) amounted to only a small fraction (1.3%) of the 10,003 lb sold within the U.S. during calendar years 1968-1972. And in FY 1972, the last year of 1080 bait stations, the 17 lb of 1080 used in predator control was less than 1% of the 1,957 lb of 1080 sold in the U.S. in calendar year 1972.

Even though most of the 1080 sold in the U.S. during 1968-1972 went to non-Federal entities, only the Federal government had a registration authorizing 1080 to be used for coyote control. Therefore, these statistics (Table 2) represent total, legally-authorized use of 1080 in coyote control during those years. And, it appears that the largest amount of 1080 used for coyote control in any one year was about 42.4 lb (678.31 oz), in FY 1963 (Table 1).

1080 POISONING IN HUMANS

No person has ever been killed or seriously injured by the use of 1080 in coyote control. Nevertheless, the EPA cancellation of 1080 use for predator control was based partly on a finding that "...prior to 1963 there were 13 proven fatal cases, 5 suspected deaths, and 6 nonfatal cases of 1080 poisoning in man, although it is not clear to what extent predator control materials were implicated" (Ruckelshaus 1972). Actually, it was common knowledge among animal damage control professionals that all known 1080 poisoning incidents had been linked to rodent control, and none to predator control. All but two of the cases cited by EPA in 1972 occurred in the 1940s and were clearly associated with rat control (Moore 1950). Four of the cases listed by Moore were suicides. Of the accidental poisonings, most occurred when people drank "1080" rat poison solutions, either from paper soufflé cups that had been put out to poison rats or from beverage bottles that were being used as containers for toxic solutions.

Atzert (1971) noted that, in 25 years of 1080 use in the U.S., there had been 4 suicidal deaths, 12 definite accidental deaths, and 4 more possible accidental deaths due to sodium fluoroacetate poisoning. Only one of the accidental fatalities was connected with FWS use of 1080 to control commensal rodents.

I am aware of two recorded cases of people eating 1080-treated bait station meat. One was reported from Fort George, Prince George, British Columbia (Letter,

Table 2. Amounts of Compound 1080 (sodium fluoroacetate) sold in the United States and used in predator and rodent control by the FWS-supervised animal damage control program, 1968 - 1972[10].

	1968	1969	1970	1971	1972	1968-1972
Annual Sale Volume (lbs) by Purchaser Group (Calendar Year Basis)						
Private	1,388.0	1,307.0	1,430.0	1,064.5	1,276.0	6,465.5
City, County and State	778.5	308.0	271.0	522.5	681.0	2,561.0
Federal	325.0	316.0	336.0	0	0	977.0
Export	976.0	316.0	400.5	639.0	533.5	2,865.0
Totals	***3,467.5***	***2,247.0***	***2,437.5***	***2,226.0***	***2,490.5***	***12,868.5***
Amounts (lbs) Used Annually by FWS and Cooperators (Fiscal Year Basis)						
Rodenticide	287	242	205	171	70	975
Predacide	37	27	26	22	17	129
Totals	***324***	***269***	***231***	***193***	***87***	***1,104***

[10] data from U.S. House of Representatives (1973:79).

"Theft of 1080 Baits", M. W. Warren, Predator Hunter, "D" Game Division to G. A. West, Supervisor of Predator Control, Vancouver B.C. February 16, 1956; 2 pp.). On February 1, 1956, Mr. Warren stored some 1080-treated horse and moose meat baits that had been cut up into 15-pound pieces for dropping from aircraft. He returned to his storage shed on February 6 and found that it had been entered and quite a few baits were missing. On February 7 and 8, the Royal Canadian Mounted Police reported that several dogs had been poisoned in the Fort George area. The Mounties soon received a tip about hidden moose meat, and on February 10 the man who had stolen the baits was caught just as he was digging them out of a snow bank late at night.

The suspect confessed that he had taken the baits to town and buried them. Subsequently he had to move the baits because dogs kept digging them up. He and four other persons had eaten some of the meat. They all had one symptom in common after eating the poisoned meat, and that was diarrhea. "One fellow couldn't even make the door and messed his pants. They all seem to be o.k. now."

On February 14, the thief was charged with breaking and entering the meat cache, and was sentenced to 4 years. A total of 15 dogs reportedly died between the time the poisoned meat was stolen and the thief was apprehended; no more poisoned dogs were reported thereafter. In a cover letter transmitting this information to colleagues in the U.S., Predator Control Supervisor G. A. West reported that the 1080 concentration in this treated bait was not in excess of 1.8 g per 100 lb (Letter, "Poison – General Correspondence", Department of Recreation and Conservation, Fish and Game Branch, Vancouver BC to G. M. Hansen, FWS, Portland, Oregon. April 23, 1959; 1 p.).

Another human consumption incident involved a sheep carcass that had been treated with Compound 1080 (Cadieux 1983). The carcass was placed as a 1080 station, with accompanying warning signs, near the boundary of an Indian reservation in North Dakota. The government trapper who placed it went on his way but returned to the location 4 hr later and saw that the carcass was missing. He followed tracks in the snow to a nearby Sioux village. There he went from door to door, telling all who would listen that the sheep contained a deadly poison and that it would kill any person who ate even a bit of the meat. The hunter then went to the Bureau of Indian Affairs to enlist help in spreading the word. However, no trace of the missing sheep was found.

A week later, one of the Sioux told what had happened. They had stolen the sheep, skinned it, and tacked the sheepskin up on the wall of an old building to dry. They cut the mutton into small pieces and boiled it in a big kettle of water. When it was completely cooked, they poured out the water and at least 11 people ate parts of the sheep. None of these people had ill effects, not even a stomachache. But 6 dogs died after they licked fluids that ran down the wall from the sheepskin. The only explanation for the sheep dinner not affecting the people, Cadieux thought, is that most of the toxicant had been dissolved out of the meat by cooking.

DISCUSSION

While preparing this report, I spent hundreds of hours reading old documents, mostly unpublished reports and correspondence, from the 1080 coyote bait station era (1944-1972). These documents gave me a new appreciation for several aspects of 1080 history that may be unknown to most modern-day vertebrate pest management professionals. Some of these are identified here.

One significant point is that, before President Nixon issued Executive Order 11643 in February 1972, USDI and FWS officials had planned to stop using 1080 in predator control and probably would have done so later that year if the President had not acted first. Earlier I cited correspondence in which a leading DWRC scientist asserted that FWS registrations for the use of 1080 in coyote control would expire in April and May 1972, and suggested that, if these registrations were to be extended, research should get underway as soon as possible to develop data that might be required (see *Experimental Use of Compound 1080 in Large Meat Baits*). As noted there, the research wasn't done.

Other contemporary documents indicate that the coyote control registrations would not actually have expired in April and May 1972, but they were scheduled for review in those months. The review probably would have been followed by a decision to discontinue the registrations. In fact, USDI had already committed itself secretly to such a decision late in 1971. In a "Stipulation Filed Under Seal" (U.S. District Court for the District of Columbia, Civil Actions No. 564-71 and 775-71, Defenders of Wildlife et al. and The Humane Society of the United States et al., Plaintiffs, v. Rogers C. B. Morton, et al., Defendants; 2 pp.), USDI stated that it intended "...to conclude the present predator control program insofar as killing by poison is concerned".

Once such a decision became public, it would have provoked immediate opposition and political agitation from livestock producers. If USDI and FWS had actually taken this decision themselves, one wonders how their leaders would have dealt with the ensuing firestorm of opposition. This potential burden on USDI and FWS was averted, to some degree, when President Nixon decided to announce the decision himself in his environmental message to Congress in January 1972, followed in February by the now-famous Executive Order 11643 (Nixon 1972) and in March by the EPA cancellation order (Ruckelshaus 1972). In taking this course, the President deflected much of the subsequent controversy away from USDI and FWS to himself and EPA. Looking back on it now, one cannot help but wonder how the situation would have played out if President Nixon had not seized the initiative when he did.

Returning to the realm of science, I was impressed to learn how quickly early researchers identified the essential properties of Compound 1080. By 'essential properties', I mean the characteristics that define both the advantages and disadvantages of 1080 for use in predator and rodent control. These essentials include such factors as high toxicity to most species of mammals, extremely high toxicity to dogs and cats (and, because of this, high risk of secondary poisoning when they eat carcasses of

1080-poisoned rodents), lower toxicity to primates than to most mammals, generally lower toxicity to birds than to mammals, low dermal toxicity, chemical stability, high solubility in water, lack of repellant or aversive taste, cheapness of manufacture, and lack of an antidote. All of these properties were known by the end of 1945, only 18 months after 'compound 1080-44' was first tested for toxicity to rats.

Early workers also recognized that 1080 leaves much to be desired as far as its killing action is concerned. Robinson (1948) wrote that the spasm period of 1080 victims, particularly the canines, seems unduly violent. After emesis, the animals generally pass through a period of excitement– cowering, yelping, or violently running as though in fear– before falling in convulsions. Robinson concluded that the severe spasms associated with 1080 constitute an outstanding objection to the use of this poison.

Later, scientists found that animals poisoned with 1080 perceive no pain because they are insensate during the final death throes. In rabbits, convulsions occur only after the animal loses consciousness and is insensible to pain (Williams 1996). Likewise, Gregory (1996) concluded that symptoms of central nervous system stimulation caused by fluoroacetate poisoning in dogs are not associated with pain. Nevertheless, the fits and contortions exhibited by poisoned dogs or coyotes before they die are extremely upsetting to human observers, and scientists' arguments that the animals actually feel no pain do not make it easier to watch them die.

Another disadvantage that was identified very early is the characteristic emesis associated with 1080 poisoning of canids. J. C. Ward described the problem in a letter to Col. C. P. Rhoads, Edgewood Arsenal, Maryland (March 15, 1945; 1 p.) and requested help in finding "...a drug which could be included with the 1080 to reduce the tendency of a coyote to vomit." No such drug was found, then or later.

Yet another little-known aspect of 1080 history is that Denver WRL researchers and administrators made a concerted effort, beginning in 1945, to control the supply of this highly toxic substance so as to keep it out of the hands of the general public (see *The Discovery of Compound 1080*). This was an unusual thing for public servants to do in those days, when government regulation of sales and shipments of dangerous chemicals was lax compared to the situation today. Whatever the merits or demerits of government efforts to control the 1080 supply, the scientists' motives were pure. Their actions probably contributed to the excellent safety record obtained with this chemical over the years.

Looking at the whole era of 1080 bait stations for coyote control, it is interesting to trace the evolution over time of recorded opinions about the efficacy of 1080 in reducing coyote populations and coyote predation upon livestock. As reported previously (see *Large Meat Bait Stations*), this toxicant gave spectacular results in the early years. In many places where 1080 baits were used, coyotes seemingly vanished and sheep losses dropped sharply. The results were so dramatic and so obvious that, after Robinson's (1948) definitive report was published, it seemed not to occur to anyone that more efficacy studies would ever be necessary. Annual reports from PARC state programs in the late 1940s convey a sense, at least to this observer, that it would be inconceivable for anyone to question the livestock protection efficacy of 1080 baits. In the wisdom of hindsight, however, we now know that efficacy was questioned by the Leopold committee in 1964 and again by the Cain committee in 1971. When EPA cancelled predacidal uses of 1080 and other toxicants (Ruckelshaus 1972), a lack of credible efficacy data was cited as one of the reasons for cancellation.

Similarly, early research findings showed and subsequent field experience confirmed that 1080 bait stations had minimal adverse impacts on populations of nontarget animals in baited areas. Again, as with efficacy, nontarget impacts were not systematically studied during most of the years when 1080 was used, and unacceptable environmental impacts eventually became one of the grounds for cancellation in 1972. Looking back now and realizing that the cancellation was based more on political considerations than on science, it is not clear to me that any amount of research would have led to a different decision, even if that research had shown 1080 baits to be both efficacious for livestock protection and environmentally safe. What does seem clear is that large-scale use of 1080 baits to protect livestock from predators isn't coming back.

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Compound 1080 and its use was one of the most controversial topics in predator damage management during the 20th Century, so this historical account of 1080 necessarily identifies and discusses contentious issues. Opinions expressed by the author should not be construed as official positions of USDA, APHIS, Wildlife Services, or any other government agency.

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