PREDACIDAL USES OF 1080:
TECHNICAL REVIEW DOCUMENT

Environmental Protection Agency
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I. INTRODUCTION

The use of the highly toxic pesticide sodium fluoroacetate, commonly called "1080," has long been a controversial issue. Since its introduction in the United States in 1944, 1080 has been used to kill coyotes suspected of preying on livestock. Livestock ranchers have consistently praised its efficacy and safety, while environmentalists have claimed that 1080 has caused the death of countless non-target wild animals, from the skunk to protected species like the bald eagle and California condor. Despite EPA's decision in 1972 to suspend and cancel the federal registration of any pesticide containing 1080 for use as a predacide, the controversy has persisted. Livestock producers and others have constantly urged EPA to reconsider its position on chemical toxicants, particularly compound 1080. In order to assist the Agency in deciding whether the cancellation order should be reconsidered, EPA in late July 1981 conducted informal public hearings in Denver, Colorado and Washington, D.C. to solicit the views of interested persons concerning these issues.

II. The Regulatory Framework and Applicable Standards for Reviewing Requests for Reconsideration of a Prior Cancellation Order

Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) 7 U.S.C. 136 et seq., EPA has the congressionally mandated responsibility for ensuring that pesticides marketed in the United States do not pose "unreasonable adverse effects on the environment," a term which is defined as "any unreasonable risk to man or the environment taking into account the economic, social, and environmental costs and benefits of the use of the pesticide." FIFRA §§2(bb), 3(c)(5), 6(b). This responsibility is exercised primarily by Agency decisions on whether to register (license) pesticide products. Toxicants intended to control predators are pesticides under FIFRA, and therefore are subject to EPA registration.

Under current law, if it appears to the Administrator that a pesticide no longer meets registration requirements and appears to cause unreasonable adverse effects on the environment, the statute provides that the Administrator, after affording an opportunity for hearing, may cancel or suspend the pesticide's registration. FIFRA §6(b), (d). The burden of proof of a pesticide's registrability remains on proponents of registration at all times. (See Environmental Defense Fund v. Environmental Protection Agency, 548 F. 2d 998 (D.C. Cir. 1976), cert. denied 431 U.S. 925).

In Subpart D of the Agency's Rules of Practice governing hearings under FIFRA, EPA has established regulations for reviewing applications for registration or for emergency use exemptions for pesticides which have been previously cancelled or suspended. (See 40 CFR §164.130 et seq). These regulations provide that any application for registration under FIFRA §3 or request for an emergency exemption under FIFRA §18 to allow use of a pesticide whose registration has been finally suspended or cancelled shall be considered a petition to reconsider the prior cancellation or suspension order. (See 40 CFR §164.130.)

Under the Subpart D regulations, the Administrator shall determine that reconsideration of a prior cancellation or suspension order is warranted only if the Administrator finds that:

1) the applicant has presented substantial new evidence which may materially affect the prior cancellation or suspension order and which was not available to the Administrator at the time he made his final cancellation or suspension decision, and

2) such evidence could not, through the exercise of due diligence, have been discovered by the parties to the cancellation or suspension proceeding prior to the issuance of the final order.

(See 40 CFR §164.131(a).)

The regulations further provide the Administrator shall publish in the Federal Register her determination as to whether reconsideration of the prior order is warranted and the basis for the determination. If reconsideration is warranted, the notice shall announce that a formal adjudicatory hearing will be held to examine the evidence and to determine whether to modify or reverse the prior order. (See 40 CFR §164.131(c)). During the hearing the applicant(s) has the burden of proof. (See 40 CFR §164.132(a)). Under the regulations, the issues in the hearing consist of whether substantial new evidence exists and, if so, whether such substantial new evidence requires reversal or modification of the suspension order. (See 40 CFR §164.132(c)). At the end of the hearing, the presiding officer will make findings of fact and regulatory conclusions. This preliminary decision may be appealed to the Administrator for final Agency decision.

Thus, two procedural stages normally occur before a cancellation or suspension decision can be reversed or modified:

1) the presentation of substantial new evidence which may materially affect the previous order and 2) a notice and opportunity for an adjudicatory hearing concerning whether the existing cancellation or suspension order should be reversed or modified.*

Finally, the entry of an order modifying or reversing the 1972 cancellation decision concerning predacide use of 1080 would not constitute registration or an approval of an emergency exemption. Rather, the order would only specify the conditions (if any) under which 1080 could be used to kill predators. EPA would refuse to register any product that did not satisfy those conditions. An applicant, however, would still need to fulfill additional requirements in order to obtain a section 18 emergency exemption** or a section 3 registration (see 40 CFR Sections 162.18-1 through -5).

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* The regulations also provide that the Administrator may dispense with the requirement of convening a hearing when she determines (40 CFR §164.133):

(1) That the application presents a situation involving need to use the pesticide to prevent an unacceptable risk: (i) To human health, or (ii) to fish or wildlife populations when such use would not pose a human health hazard; and

(2) That there is no other feasible solution to such risk; and

(3) That the time available to avert the risk to human health or fish and wildlife is insufficient to permit convening a hearing as required by §164.131; and

(4) That the public interest requires the granting of the requested use as soon as possible.

** Generally, a request for an emergency exemption from FIFRA's requirements must show that significant pest control problems are occurring or are about to occur, and that there is no registered pesticide or non-pesticide method that can effectively control the problem. The request must also provide information on the nature of the control program, the risks associated with the program and the anticipated benefits. (See 40 CFR Part 166.)

III. The Cancellation of 1080 and Its Subsequent Regulatory History

A. The Cancellation of Pesticides Registered for Predator Control

In the 1960's wildlife protection groups began to express concern that, because of its acute toxicity, 1080 was causing the death of wildlife other than coyotes. This public concern led in 1972 to a decision by EPA to cancel and suspend all federal registrations for the use of 1080 products--as well as products containing three other toxicants, sodium cyanide, strychnine, and thallium--as predacides. Earlier in the same year, President Nixon issued Executive Order 11643 which prohibited the use of all chemical toxicants including 1080 on federal lands or in federally administered animal damage control programs, except in an emergency.*

* Under the Executive Order, an emergency requiring the use of a chemical toxicant may be declared only by the head of an agency having jurisdiction over the federal land where the toxicant would be used, or having responsibility for the predator control program if the use would be by federal employees on private land. Prior to declaring an emergency, the agency head must consult with the Secretaries of Interior, Agriculture, and Health and Human Services and with the Administrator of EPA. In addition, the agency head must make a written finding that the emergency cannot be dealt with by means which do not involve use of a toxicant and that such use is necessary to protect human health or safety, to preserve threatened or endangered species, or to prevent substantial and irretrievable damage to nationally significant natural resources.

The Executive Order has been amended twice, but the amendments do not affect the provisions concerning emergency exceptions to the general prohibition against federal use of chemical toxicants.

EPA's 1972 cancellation and suspension decision relied heavily on information from three sources, "The Cain Report," * the Natural Resources Defense Council petition to ban 1080, and "The Leopold Report." "The Leopold Report," officially titled "Predator and Rodent Control in the United States," was written in 1964 by a special advisory committee appointed by the Secretary of Interior to study wildlife management. Chaired by Dr. A. S. Leopold, the group prepared a brief report recommending sweeping changes in the federal predator control program. In its discussion of the existing program, "The Leopold Report" (p. 10) noted that 1080 was often misused and that considerable damage to other forms of wildlife could occur as a result. "The Leopold Report" also stated, however, that "when properly applied . . . 1080 [does] as effective and humane job of controlling coyotes and [has] very little damaging effects on other wildlife." Id.

The petition submitted in 1971 by the Natural Resources Defense Council and six other environmental groups strongly opposed even the legal use of 1080, charging that use of 1080 and other chemical toxicants had destroyed hundreds of thousands of "non-target" animals including members of rare and endangered species. The petition contained numerous references to articles and studies to substantiate its contentions.

Finally, EPA relied on "The Cain Report," which was published in 1972. This report, the most comprehensive of the three sources, surveyed a large body of data on predation loss rates, predator control methods, wildlife toxicology, and a number of other subjects. "The Cain Report" (pp. 5-6) strongly recommended that any use of toxic chemicals for predator control be prohibited.

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* The report is officially known as "The Report to the Council on Environmental Quality and the Department of the Interior by the Advisory Committee on Predator Control." The report is commonly called "The Cain Report," and the Advisory Committee on Predator Control is called the Cain Committee after the chairman, Dr. Stanley A. Cain.

EPA's cancellation decision contained the following findings of fact:

- 1080 is highly toxic to all species. The dangerous dose for man is 0.5-2.0 mg/kg. The chemical acts rapidly on the central nervous and cardiovascular systems with cardiac effects. Effect is usually too quick to permit treatment, and antidotes are relatively valueless.

- According to one authority, prior to 1963, there were 13 proven fatal cases, five suspected deaths, and six non-fatal cases of 1080 poisoning in man.

- There is evidence that a certain number of non-target animals are being adversely affected by 1080 products, particularly in the case of carrion-eating birds and mammals, by secondary poisoning.

- There is no reliable data as to the loss of sheep that might occur without a predator control program using these poisons.

- Effective non-chemical alternatives exist, including denning, shooting, and trapping--methods that have long been available and effective, though more costly than poisons.

B. The Regulatory History of 1080 Since the 1972 Cancellation

Since cancellation of the predacide use of compound 1080, numerous groups have tried to obtain authority to use 1080 to kill coyotes preying on livestock. With the exception of three experimental use permits issued in 1977, 1980, and 1981 for the 1080 toxic collar, EPA has not permitted the use of 1080 as a predacide. This section briefly describes the various attempts to obtain reconsideration of the 1972 cancellation decision.

1. Initial Efforts to Overturn or Modify the 1972 Decision

Most of the attempts to overturn or create exceptions to the 1972 ban on the use of 1080 as a predacide have been made by state Departments of Agriculture. During the last nine years they have submitted several applications for registration (under FIFRA §3) or emergency exemptions (under FIFRA §18). The first group of applications was submitted in 1973, and a second, larger group was submitted in 1977. EPA has denied all of these applications on the grounds that none of the applicants submitted substantial new evidence which would indicate that the 1972 decision should be reconsidered. See 43 FR 14,100; April 4, 1978 (EPA ruling that Wyoming and other state applicants had not provided sufficient evidence to warrant holding a Subpart D adjudicatory hearing on 1080).

In addition to these attempts to use the administrative process to modify or reverse the 1972 cancellation order, during the summer of 1974 six western states sued EPA in federal district court. The plaintiffs asked the court to rule that EPA's 1972 cancellation order was illegal because EPA had failed to prepare an Environmental Impact Statement (EIS) and because EPA had not conducted an administrative hearing prior to issuing the 1972 order. The district court issued a preliminary injunction prohibiting EPA enforcement of the 1972 order. On appeal the U.S. Court of Appeals for the Tenth Circuit held that EPA was not required to prepare an EIS on the cancellation of 1080. The Tenth Circuit also held that EPA was not required to hold an adjudicatory hearing before allowing the cancellation and suspension order to become final because no registrant or applicant had requested such a hearing. Moreover, once that order had become final, the Agency was not required to hold a hearing, even if requested to do so.

Finally, the court of appeals noted that, under FIFRA, a person adversely affected by the cancellation and suspension order (e.g., user groups such as the plaintiffs) could have obtained judicial review of that order, but only by petitioning for review within sixty days after the order was entered. Since no one had sought judicial review within the time period allowed by statute, the soundness of the 1972 decision to ban 1080 could not be challenged in court. (See Wyoming v. Hathaway, 525 F.2d 66 (10th Cir. 1975) cert. denied 426 U.S. 906). Accordingly, the injunction entered by the district court was vacated, and the suit was remanded for further proceedings. In 1979 the proceeding before the district court was dismissed.

2. Experimental Use Permits

In August 1975, EPA Administrator Russell Train established a policy governing the issuance of experimental use permits for previously cancelled pesticides. Because registration of such compounds requires, as an initial step, the showing of substantial new evidence, Administrator Train required that any field testing with these compounds should hold some reasonable promise of producing evidence that might persuade the Administrator to reconsider the prior cancellation order. EPA would not issue permits for experimental programs which did not meet this standard.

Since then, EPA has received several requests for experimental use permits involving 1080. In December 1975, Wyoming asked EPA for permission to use 1080 in a series of experimental field studies. EPA made several suggestions about the design of the experimental programs and indicated that if such changes were made, it would probably issue an experimental use permit. Wyoming did not respond to these suggestions, and no experimental use permit was issued.

Texas requested a permit the next year to use 1080 in single lethal dose drop baits. EPA rejected the request, noting that the experimental design was unlikely to produce any substantial new information, especially concerning the hazards to non-target species. EPA recommended that Texas perform some preliminary studies with non-lethal drop baits to determine which kind of baits were accepted by predators and least attractive to non-target species. Such studies might indicate that a particular kind of bait was sufficiently selective for predators to justify research using drop baits containing 1080. EPA rejected, for the same reason, a similar request submitted by Montana in 1977. Neither Texas nor Montana has submitted studies of the sort suggested by EPA in an application for an experimental use permit for single lethal dose drop baits.

In 1977, the U.S. Department of the Interior (USDI) requested, and EPA issued, an experimental use permit for 1080 in a "toxic collar." EPA concluded that this delivery mechanism might significantly reduce the hazards to non-target species and thus, that such research could produce substantial new evidence which might warrant reconsideration of the 1972 cancellation decision. EPA has renewed this permit each year since 1977, and the permit is now scheduled to expire in November 1981. The results of this testing constitute the largest part of new information on the 1080 toxic collar. In addition, EPA has approved an experimental program for use of 1080 in a toxic collar by the Texas Agricultural Experiment Station, a part of Texas A&M University. This permit was issued in May 1980 and expired a year later. EPA has also issued a permit to New Mexico to experiment with use of 1080 in a toxic collar. EPA expects information from New Mexico's studies to be valuable because of the differences in terrain and husbandry practices between Texas and New Mexico. This one year permit expires in February 1982.

Finally, EPA has rejected two other requests for experimental use permits for 1080 in vessels to be attached to livestock. The first, made by the Texas Department of Agriculture, was denied because at the time EPA had issued two other permits (to USDI and the Texas Agricultural Experiment Station) which authorized studies with 1080 toxic collars in Texas. EPA concluded that the Texas Department of Agriculture was unlikely to develop any information which would differ from that being generated under the other two permits. The University of Wyoming also requested an experimental permit for use of 1080 in a program to control livestock predation. In the fall of 1980, the university asked EPA to authorize experimental programs with 1080 in balloons glued to the flanks of sheep and in single lethal dose drop baits. EPA asked the university to provide more information to support its request, but none has been submitted.

3. Recent Requests From the States and Livestock Groups for Permission to Use 1080

EPA has recently received a variety of requests for registration or emergency exemptions for the use of 1080 as a predacide. Three states, one federal agency, and two livestock associations have asked EPA approval for 1080 use in the toxic collar, large bait stations, and drop baits. These applications are summarized in Table III-1 and Table III-2.

The U.S. Department of the Interior has submitted an application for conditional registration under FIFRA §3(c)(7) of the toxic collar.* The product for which registration is sought is the collar currently being tested in experimental programs in Texas and New Mexico. The collar would be placed on sheep and other livestock in areas where coyote predation was expected.

The State of Wyoming has requested that EPA grant an emergency exemption from the registration requirements of FIFRA or alternatively a conditional registration for a 1080 product to use against coyotes preying on livestock. In both instances, Wyoming seeks to use 1080 in single lethal dose drop baits and large meat bait stations. Wyoming has also issued a state registration, under FIFRA §24(c), for 1080 use in single lethal dose

* FIFRA §3(c)(7) and the implementing regulations provide generally that a person may obtain registration for a pesticide which is intended for a use that is not authorized by any existing registration for that pesticide, so long as the applicant submits data pertaining to the safety of the new use and EPA finds that registration and use of the product will not significantly increase the risk of unreasonable adverse effects on the environment.

Table III-1. Applications for Section 18 Emergency Exemptions for use of 1080 as a Predacide.

Applicant	Delivery Mechanism	Target Species	Dose Rate	Density	Basis for Exemption	Special Restrictions
Montana Dept. of Livestock ID #: 81-MT-07 Date Submitted: 7-24-81	Single lethal drop bait	Coyotes, feral dogs	3.6 mg/1080 incorporated with 15 grams of ground or rendered lard, tallow or animal matter. A total of no more than 75 grams of 1080 will be used.	Up to 10 baits per square mile.	State claims available control methods inadequate to control severe predation problems.	°Livestock depredation must be documented by department agent before use is granted. °Dates of use; Sept. 1, 1981-August 31, 1982. °1080 will be used only by trained, certified government applicators under the supervision of the Montana Department Livestock.
Wyoming Dept. of Agriculture ID #: 81-WY-02 Date submitted: 7-28-81	Single lethal drop bait, meat baits	Wild canids (primarily coyotes and red foxes)	Drop baits- a maximum of 5mg of 1080 per bait. maximum of 1 pound. Meat baits- 1.6 grams of 1080 per 100 pounds of meat. maximum of 2 pounds.	Maximum density of 10 baits per square mile. Meat baits- one meat bait per 36 square miles.	State claims predation losses require chemical toxicants.	°Use only by qualified and certified applicators after losses are established. °Bait placement must be approved by program supervisor °Access roads and trails must be posted in English and Spanish. °No bait stations to be placed near residences, areas of intensive farming or recreational areas. °Records pertaining to bait location, monitoring, etc. to be kept by Department of Agriculture and certified applicator. °Bait stations to be completely destroyed at the end of the baiting season. °Dates of use; Sept. 1, 1981-April 30, 1982.

Table III-1. Applications for Section 18 Emergency Exemptions for use of 1080 as a Predacide.

Applicant	Delivery Mechanism	Target Species	Dose Rate	Density	Basis for Exemption	Special Restrictions
South Dakota Dept. of Ag. ID#: 82-SD-01 Date Submitted: 9-16-81	Single lethal drop bait, toxic collars	Coyote	Drop baits-will be composed of 15grams of lard, tallow or other animal tissue; baits will contain no more than 3.6 mg. of 1080	No more than 2 baits at one station and no more than 5 stations located in a section. (640 acres) No more than 10 collars will be placed on sheep at a given location.	Increase in landowner requests for assistance. Would control costs of viable animal damage control program	°Use by certified applicators only. °Baits/collars to be used only after coyote kill is verified °Warning signs will be posted at points of entrance to fields where baits are used. °Qualified ADC personnel will select bait sites. °Baits will be monitored at least every 7 days. °Baits and warning signs to be removed when predator is eliminated or within 30 days of placement.

Table III-2. Applications for Section 3 Registrations for use of 1080 as a Predacide.

Applicant	Delivery Mechanism	Target Species	Dose Rate	Density	Special Restrictions
USDI- Fish and Wildlife Service File Symbol: 6704-IL Date: 9-22-81	toxic collar	coyotes	one collar per animal (sheep or goat). 1.08% 1080		°restricted use pesticide
Wyoming Dept. of Agriculture File Symbol: 35978-G Date: 7-28-81	not specified	mammals	single dose		°restricted use pesticide °government agency use only

drop baits and large meat bait stations. EPA has informed Wyoming that this latter action is specifically prohibited by FIFRA, and therefore it has no legal effect.*

The Montana Department of Livestock and the South Dakota Department of Agriculture have also requested that EPA grant an emergency exemption under FIFRA §18 for products containing 1080 for use against coyotes and feral dogs which prey on livestock. Montana's product would consist of a single lethal dose of 1080 and would be applied only by state personnel. South Dakota proposes to use two delivery mechanisms, the 1080 toxic collar and single lethal dose baits. Under South Dakota's proposal, only certified applicators (individuals specially trained to use highly toxic pesticides) or people under their direct supervision could use the 1080 products.

The Montana Department of Agriculture has also notified EPA that it plans to issue a special local needs registration for use of 1080 as a predacide under §24(c) of FIFRA, but has also stated that it will not allow use of 1080 under this registration until EPA has approved either a federal registration or an emergency exemption for this use. The State of Colorado has submitted a similar request, asking EPA approval of a special local needs registration for use of 1080 in large bait stations and single lethal dose drop baits. EPA has notified both Montana and Colorado that FIFRA §24(c) would prohibit the state from issuing the special local needs registration described in their notices.

Finally, in the spring of 1981, EPA received a letter from the National Woolgrowers Association and the National Cattlemen's Association which claimed that there have been increasing losses from predation due to the unavailability of chemical controls such

* Section 24(c) of FIFRA authorizes states to "provide registration for additional uses of federally registered pesticides formulated for distribution and use within that State to meet special local needs . . . ." However, this section also provides that a state's authority does not extend to any use "if registration for such uses has . . . previously been denied, disapproved, or cancelled by the Administrator." (See also EPA's "24(c) regulations" at 46 Fed. Reg. 2008 [January 7, 1981]; to be codified at 40 CFR §§162.150 - .156.) Thus, Wyoming lacks authority to issue a registration for 1080 as a predacide.

as compound 1080. The two groups requested that EPA concur in the declaration of an emergency resulting from coyote predation on livestock in western states and that EPA allow emergency use of 1080 to control coyotes and feral dogs which prey on sheep and cattle. No formal application has been submitted.*

C. Public Hearings

Given the claims of ever increasing losses of sheep and cattle due to predation and the strong interest of certain states and livestock producers in the restoration of 1080 use, the Agency concluded that it would be useful to hold public hearings under FIFRA §21(b) to gather information--information which might be used to support a request for reconsideration of the 1972 cancellation order. Accordingly, EPA scheduled hearings in Denver, Colorado, for July 28 and 29 and in Washington, D.C., for July 31, 1981.

The public hearings attracted over 80 witnesses, including livestock ranchers, wildlife biologists, trappers, scientists, environmentalists, state officials, representatives of livestock associations, and representatives of animal welfare groups. The witnesses presented a diversity of viewpoints; some opposed use of 1080, while others favored its use in various forms. A panel of five federal employees from EPA and the Departments of Agriculture and Interior received both written and oral testimony. At the close of the hearings, the panel members prepared brief reports identifying the witnesses who provided information which appeared to be both new and potentially significant. Though

* This letter contains both a request for an emergency exemption under FIFRA §18 and a request that EPA concur with the Department of the Interior and other federal agencies in declaring, under the terms of Executive Order 11643, that an emergency exists which would justify using 1080 on public lands. Since no one may legally use 1080 under the Executive Order until EPA issues either a section 18 emergency exemption or a section 3 registration, EPA will not address the appropriateness of revising the Executive Order at this time.

cross-examination of witnesses by members of the public was not permitted, the panel members asked some of the witnesses to explain or clarify their comments and to provide references to support their comments.

E. Conclusion

The preceding review indicates that the Agency, in accordance with its regulations, has consistently demanded that proponents of 1080 use present substantial new evidence that would justify reconsideration of the 1972 cancellation order. In the past, proponents of 1080 use have failed to present significant new information. This review also indicates that EPA has issued experimental use permits for experimental programs which promised to generate relevant new data. In many cases, however, people requesting experimental use permits have been unwilling or unable to design satisfactory studies. Thus, only three experimental use permits have been issued for 1080 use.

In 1964, "The Leopold Report" noted a lack of scientific data in many areas relevant to the predator control controversy and urged further research. Seven years later "The Cain Report" expressed the same concerns, calling for more research. Now, nine years after "The Cain Report," EPA has received some new data. As a result of the studies performed under the experimental use permits and some laboratory research on wildlife toxicology, EPA now has more information on the environmental hazards of 1080. EPA has also received more information concerning the livestock loss rates due to predation in various states and localities. This information is discussed more fully in the next three sections of this document.

IV. SUMMARY OF LIVESTOCK DEATH LOSSES

The purpose of this section is to summarize and discuss the data concerning livestock losses to predators that were the basis of EPA's 1972 order cancelling the use of 1080 and the data which have become available since 1972. There are several research methods that have been used to gather, measure and evaluate livestock losses to predators. The most common methods are direct field studies and mail and interview surveys. Direct field studies are intense, biological studies conducted over small areas for the purpose of documenting causes of livestock death. Mail and interview surveys use questionnaires to determine loss levels and causes of death over large areas (i.e., states or regions). Other information which is not gathered using rigorous research methods but which provides useful insights into overall losses of livestock to predators, includes information provided by individual livestock producers, livestock producer organizations, various state agencies and universities. A significant amount of information of this type was presented during three days of informal public hearings held in late July, and it is summarized herein along with the scientific literature published since 1972.

As noted in the previous section, EPA based its 1972 decision primarily on "The Cain Report". That report found only limited scientific literature regarding livestock losses to predators. Based on "The Cain Report" and other information, the Agency found:

1. There are no reliable data as to the amount of predator control achieved by use of poisons.

2. There are no reliable data as to the loss of sheep that might occur without a predator control program using poisons or the real effect of such losses on the general economic health of the sheep industry.

3. Predator losses may be only a minor part of total losses.

4. Several non-chemical alternatives exist though they are more costly than poisons.

5. The federal government has committed itself to a research program for methods of controlling predators other than with poisons.

37 Fed. Reg. 5718, 5720. Since the 1972 order, several research studies and various surveys have been conducted which specifically address predation on livestock. Few of these studies (either before 1972 or after 1972) were conducted under similar conditions or over identical time periods. Due to variable conditions from study to study, it is difficult to compare predation rates over time.

A. The Cain Report

The Cain Commission discussed loss data from five sources:

Nielson and Curle (1970) - Utah only. Data collected for fiscal 1968-69. Reported ewe losses of about 2 percent, lamb losses of about 40 per 1,000 ewes for a total loss of about 61 ewes and lambs per 1,000 ewes.

Owen Morris' Estimates - Utah only. Data assembled from early 1940's to 1965. Reported 7-10 percent loss prior to late 1940's (and beginning of 1080 use) and 2-4 percent loss up until 1965.

Reynolds and Gustad (1971) - Colorado, Montana, Texas and Wyoming only. Data from USDA Crop and Livestock Reporting Service or USDA Statistical Reporting Service reports of predator losses in these states for 1966-69. Loss reports ranged from 3.6-7.9 percent.

U.S. Forest Service (USFS) Estimates - USFS records total livestock losses during the grazing season. Producers are asked to estimate proportion of losses to various causes. "The Cain Report" noted that predator losses for Utah (0.4-1.4 percent for the grazing season) were consistent with the estimates of Nielson and Curle (1970) and Morris for entire years.

USDA Statistical Reporting Service Estimates. Reports of losses to all causes. "The Cain Report" noted that these data place a "ceiling" on the numbers of losses attributed to predators. "The Cain Report" mentioned estimates for three individual states: Utah, usually 9-11 percent (range 7.9-14.9 percent); Idaho, usually 7-8 percent (range 6.1-16.1 percent); Wyoming, usually 8-9 percent (range 5.4-13.8 percent).

Although "The Cain Report" noted general agreement among the studies, it indicated that the reported loss estimates may exaggerate the actual predation loss rates for the following reasons: the scavenging of lambs which died due to malnutrition or birth defects might occasionally be reported as predator kills; the killing of weakened animals "that would have died anyway" (p. 45) could be attributed to predation and not other causes; and the "current heated predator control climate" (p. 45) caused possible exaggeration by ranchers of losses to predators. "The Cain Report" also noted the finding of Nielson and Curle (1970) that extremely high loss levels were suffered by only a small proportion of Utah producers, while the majority suffered losses of less than 100 lambs and ewes (combined) per 1,000 ewes.

Cain took the view that some loss to predation would be expected for any prey species. In the absence of predation, the impact of other factors causing mortality would be expected to increase (p. 52). While implying a belief that losses to predators represent a minor proportion of all sheep lost (e.g., p. 47 and

52), "The Cain Report" concluded that the available data on sheep losses to predation and other causes were too vague to strongly support any conclusion, adding:

> ... The ambiguity only points up the need for careful research to determine the true magnitude and nature of sheep losses and the effectiveness of predator control in reducing them. And it raises a serious question as to the benefit derived from control operations. (p. 52).

B. Sheep Loss Information Since 1972

The most comprehensive review of studies on livestock predation conducted since 1972 is the 1978 USDI Fish and Wildlife Service report entitled "Predator Damage in the West: A Study of Coyote Management Alternatives." Tables IV-1 and IV-2 are adapted from this report and include other information and studies not available in 1978 when the USDI report was completed. Table IV-1 provides a brief description of the characteristics of the loss studies conducted since 1972. Table IV-2 summarizes the sheep and goat losses reported in these studies.

1. Direct Field Studies

Direct field studies (also called biological studies) provide the most reliable method of estimating minimum and maximum livestock loss to predators. These studies are conducted by biologists who intensely search for dead animals and verify cause of death. Minimum losses to predators are the number of animals found and verified as predator killed. However, even with intense searches, not all lost sheep can be found. Maximum loss to predators then is the number of animals found and verified as to cause of death plus the number of unaccounted animals. Estimates of predation rates from studies of this type are usually somewhat lower than are

Table IV-1. Summary of Ewe, Lamb and Goat Loss Studies - 1972 to 1981

Study No.	Source	Location	Years	Predator Control	Husbandry Practices	Comments
1.	Shelton (1972)	Texas	1967-71	By experiment station staff	More protection than ranchers could afford	No herders. Research flocks with good records.
2.	Klebenow & McAdoo (1976)	Nevada	1973	Yes	Range lambing, range grazing	Migratory range with herders.
3.	Nass (1977)	Idaho	1973-75	Yes	Shed lambing, range grazing	Shed lambing operations with herders.
4.	Taylor _et al._ (1978)	Utah	1972-75	Yes	Mostly shed lamb, all range grazing	Herders and no herders. Typical range sheep operations.
5.	Tigner & Larson	Wyoming	1973-75	Yes	Range lambing, range grazing	Range lambing operations with herders.
6.	Brawley (1977)	Montana	1976	Control research by DWRC	Shed lambing, fenced pastures	No herders. High loss ranch with loss control experiments.
7.	Henne (1975,	Montana	1974	Partial	Shed lambing, fenced pastures	Study without herders and predator control.
8.	Munoz (1977)	Montana	1975	Partial	Shed lambing, fenced pastures	Study without herders or predator control.
9.	McAdoo & Klebenow (1978)	California	1976	No	Range grazing	Study with herders but no predator control.
10.	Delorenzo & Howard (1976)	New Mexico	1974-75	No	Fenced range	Study without herders or predator control.
11.	Robel _et al._ (1981)	Kansas	1975-76	Yes	Fall lambing	Mostly night confinement. Relationships between husbandry practices and losses were studied.

Table IV-1. Summary of Ewe, Lamb and Goat Loss Studies - 1972 to 1981 (Continued)

Study No.	Source	Location	Years	Predator Control	Husbandry Practices	Other
12.	Reynolds & Gustad (1971)	MT, WY, CO, TX	1966-69	Some ranches	All types	Herder and no herders. Economics of predation studied.
13.	Early *et al.* (1974a, b)	Idaho	1970-71 1972-73	Yes	Range grazing	Herders. Sample range sheep ranchers.
14.	Nesse *et al.* (1976)	California	1973	Yes	Fenced pastures	No herders. Monitored fiscal 1973 losses.
15.	Nesse *et al.* (1976)	California	1974	Yes	Fenced pastures and range	No herders. Monitored fiscal 1974 losses.
16.	Nesse *et al.* (1976)	California	1974	Some ranches	All types	Herder and no herders. State survey.
17.	deCalesta (1978)	Oregon	1976-77	Some ranches	Fenced pastures	No herders. Losses characterized.
18.	Gee *et al.* (1977)	Western U.S.	1974	Some ranches	All types	Herders and no herders. Survey of western sheep industry.
19.	Meduna (1977)	Kansas	1975-76	Only by 25% of ranchers	Fenced pastures	No herders; 80% of sheep penned at night. Relationships between husbandry practices and losses were studied.
20.	Walther *et al.* (1979)	Texas	1967-78	Yes	Various types	Herding practices not identified. State Survey.
21.	Terrill (1980)	33 States	1958-79	Yes	All types	Compilation of predator loss reports.

Table IV-2. Summary of Ewe, Lamb and Goat Losses to Predators - 1972 to 1981

Study No.	Type	All Causes		All Predation		Coyote Predation	
		Ewes	Lambs	Ewes	Lambs	Ewes	Lambs
		percent					
	Field studies with control						
1.	Sheep	[9.3][b)]		[3.4][b)]			
	Goats	[12.0]		[4.9]			
2.		[9.0]		0.1	6.5	0.1	5.9
3.	1973	6.8	11.3	2.5	3.1	2.3	2.9
	1974	5.8	15.2	1.0	3.1	0.9	2.9
	1975	10.1	11.6	0.8	1.3	0.7	1.2
4.	1972	—	—	0.0[c)]	7.0[c)]	0.0[c)]	7.0[c)]
	1973	—	—	0.0[c)]	4.7[c)]	0.0[c)]	3.9[c)]
	1974	—	—	0.0[c)]	5.8[c)]	0.0[c)]	5.5[c)]
	1975	—	—	0.0[c)]	2.9[c)]	0.0[c)]	2.6[c)]
5.		4.0	18.0	0.6	5.5	0.5	4.2
	Field studies with various levels of control or without control.						
6.	1977	6.8	26.5	1.5	13.3	1.2	12.9
7.	1975-76	6.8	7.9	0.9	0.9	0.7	0.7
8.		11.6	42.5	8.4	29.3	7.5	28.8
9.		12.8	30.9	8.1	24.4	8.1	24.2
10.		1.9[d)]	7.1[d)]	1.4[d)]	6.3[d)]	1.4[d)]	6.2[d]
11.	1974	4.3	34.2	0.0	15.6	0.0	12.1
	1975	6.8	18.1	0.9	12.1	0.9	12.1

Table IV-2. Summary of Ewe, Lamb and Goat Losses to Predators – 1972 to 1981 (Continued)

Study No.	Type	All Causes		All Predation		Coyote Predation	
		Ewes	Lambs	Ewes	Lambs	Ewes	Lamb
		percent					
	Questionnaire Surveys						
12.		[21.3][b]		[5.3][b]			
13.	1970-71	10.5	18.8	2.6	4.0	1.7	3.1
	1972-73	8.6	15.5	2.8	3.8	2.2	3.2
14.		5.7	8.4	0.1	0.9	0.1	0.8
15		7.3	5.9	0.4	1.1	0.3	0.7
16.		7.6	10.4	1.1	2.7	0.9	2.2
17.		6.5	11.4	2.0	4.7	1.6	3.8
18.		10.4	23.2	3.4	11.4	2.5	8.1
19.		6.8[c]	10.0	0.9[c]	1.1	0.7[c]	0.9
20.		[f]	[f]	[f]	[f]	[f]	
21.	1958	7.8	9.3		4.0		
	1979	7.3	13.7		6.5		

[a] Data adapted from USDI, 1978 for all studies with the exception of No's 11, 20, and 21. No two studies reported losses in the same way. Additional calculations were necessary to bring the data into a consistent format. These calculations were made by wildlife research biologists of the Section of Predator Damage, Denver Wildlife Research Center. Dashes are shown in the cells for which estimates are not available.
[b] Losses of ewes and lambs combined; data were not reported separately for ewes and lambs.
[c] Data include spring and summer only. Losses in fall and winter were negigible.
[d] Data for only 113 days in summer.
[e] Designated as "stock sheep" rather than ewes.
[f] Losses were reported as percent of total loss and not percent of total ewe and lamb inventory.

NOTE: Study numbers refer to Table IV-1.

predation rates reported in mail or interview surveys. Direct field studies are expensive and only a small fraction of the sheep industry has been sampled via this method. Due to the limited sample, it is not known to what extent predation rates recorded in direct field studies represent loss rates for the entire western sheep industry.

When interpreting the results of direct field studies (studies 1 through 11, Tables IV-1 and IV-2), it is necessary to appreciate the many factors affecting reported loss statistics. Predator control, for example, varies widely from place to place and can lead to misconceptions about the actual extent of "predator control" being practiced. In some of the studies, predator control was withheld or restricted on the cooperator's ranch, although some control may have been conducted on neighboring areas (USDI, 1978). In other studies, normal legal means of predator control were utilized (control) while in other studies some predator control methods were used (partial control).

Field studies conducted since 1972 with predator control in effect showed losses from all causes ranging from 4 to 10 percent for ewes and 11 to 18 percent for lambs. Losses attributed specifically to coyotes were 0 to 2.3 percent of ewes and 1.2 to 7 percent of lambs (Table IV-1, studies 1 through 5). Field studies with partial control or where predator control is practiced at varying degrees (studies 6 and 7) showed losses from all causes ranging from 6.8 percent of ewes to 26.5 percent of lambs. In these studies, losses attributed to coyotes ranged from 1.2 percent of ewes to 12.9 percent of lambs.

Several intensive field studies in which predator control was restricted (studies 8 through 11) were conducted since 1972. Two of the studies lasted two years, and the third study (study 10) was limited to one summer. In the studies covering the entire production year, predators killed 0 to 8.4 percent of the ewes and 12.1 to 29.3 percent of the lambs. These loss rates are generally higher than those recorded with predator control in effect (studies 1 through 5). However, other than the presence or absence of predator control, the small number of studies preclude further analyses of differences between the two groups.

In 1981, Robel et al. (study 11, Table IV-1) reported results from a 15-month field study conducted from June 1975 through August 1976 in a nine-county area of south central Kansas. They reported that death losses to canine predators comprised 16.8 and 12.5 percent of stock sheep and lamb losses, respectively. Annual losses to predators in the nine-county area were 0.9 percent of the stock sheep inventory and 0.9 percent of lambs. According to the authors, these losses were about one-fourth the estimated predator loss for Kansas as reported by USDA-ERS from mail survey data. Robel et al. used a system involving personal contact with all cooperating sheep producers coupled with monthly reporting. Robel believed that this system reduced the reliance on the producers' memory and thereby greatly increased the accuracy and reliability of their predator loss data.

2. Mail and Interview Surveys

Results from mail surveys are based on responses from a sample of producers to questions on production and marketing practices, predation problems and predator control. Interview surveys generally cover the same information but are based on information collected during personal question and answer sessions between ranchers and researchers. Surveys offer the advantages of covering a much larger sample size and a broader cross section of producers with predator losses than do single ranch biological studies.

Unless carefully designed, results from mail and interview surveys appear to have the greatest uncertainties and potential for bias. Producers generally devote less time to daily searches for missing sheep than do researchers involved in direct field studies. Dead livestock found by producers can be identified as predator killed, but the actual fate of missing animals is often uncertain.

Mail and interview surveys conducted since 1972 are summarized in Table IV-1 (studies 12 through 20). In most of these studies, predation rates were similar to predation rates in direct field studies where predator control was practiced (i.e., 0.1 to 2.5 percent of ewes and 0.7 to 8.1 percent of lambs).

One study however, reported higher losses than others but was much more comprehensive because it covered half of the sheep producers in the West. In this study, based on farmers and ranchers surveyed in 1974, Gee et al. (1977) (study 18) reported on "Sheep and Lamb Losses to Predators and Other Causes in the Western United States." They reported that rates of loss to coyotes varied considerably among farmers and ranchers. Some had minor or no losses to predators while others had very high losses. Overall losses approximated more than 8 percent of all lambs born and more than 2 percent of the inventory of adult sheep. USDI is in general agreement with these rates of loss estimating annual nationwide predation loss averages of 4 to 8 percent of lambs and 1 to 2.5 percent of ewes (Andrus, 1980).

The relatively high rates of predation reported by Gee et al. (1977) as compared with other studies during this period are not easily reconciled. In both California and Kansas, for example, USDA mail questionnaire surveys have generally reported predator loss rates that are higher than direct field studies that validate death loss (compare Nesse et al., 1976 and Robel et al., 1981). Regarding the reliability of the ERS estimates, Gee et al. (1977) wrote "... the total number and proportion of producers affected (without regard to loss level) by coyote predation are probably quite realistic, since most producers know whether or not coyotes are preying upon their herds. The numbers and percentages of sheep and lambs lost to coyotes and the number of producers with different levels of loss must be considered more cautiously since the degree of producer judgment is higher."

Terrill, 1980, estimated sheep and lamb losses to predators in the United States from 1958 through 1978. These estimates were based on available USDA statistics and other reports. As reported by Terrill, sheep and lamb losses averaged 4.61 percent of inventory plus lamb crop for the period 1958 through 1971. During this period, the loss rate increased 32 percent from a low of 4 percent in 1958 to the high of about 5.28 percent in 1971. During the next seven years from 1972 through 1978, the loss rate averaged 6.22 percent ranging from 5.65 percent in 1972 to 6.83 percent in 1978 for an increase of 35 percent over the 1958-71 annual average.

A survey of Texas producers also shows an increase in predation rates. Texas reported the results of a survey of sheep and goat producers, based on mail questionnaires sent in conjunction with the January 1, 1979, USDA Livestock Survey. Reported death losses of all sheep and lambs to predators comprised 58 percent of all deaths in 1978 compared to 25 percent in 1967. In 1978, coyotes were reported as the largest single cause of death comprising 24 percent of sheep and lamb deaths. Other leading causes were eagles 20 percent, bobcats 18 percent and weather 10 percent. In 1978, sheep losses to predators in Texas reported in the Texas survey, comprised about 30 percent of all sheep losses compared to 15 percent in 1967. As reported by Texas, predators caused 67 percent of all lamb losses in 1978 compared with 40 percent in 1967. Adult goat losses followed similar trends with 54 percent of total losses to predators in 1978 compared with 30 percent in 1967. About 79 percent of kid losses in 1978 were attributed to predators compared to 59 percent in 1967.

Finally, USDA statistical publications, based on producer surveys, report death loss from all causes of all sheep and lambs. On the national level, death loss to all causes has increased since compound 1080 was first available in the late 1940's. During the next three decades, death losses from all causes have steadily increased ranging from a low of about 13.1 percent in 1954 to a high of 16.7 percent in 1975 (Table IV-3).

In 1950, losses of adult sheep comprised about 60 percent of total sheep and lamb losses. During the next 22 years, the number of adult sheep losses (as a percent of all losses) steadily declined but remained at more than 50 percent of all losses. In 1972, lamb losses (on a percentage basis) were more than sheep losses for the first time.* In that year, about 51 percent of all

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* The cancellation of compound 1080 in 1972 would not have seriously affected lamb losses in 1972 since most compound 1080 use in that year would have been completed prior to the cancellation action.

death losses to all causes were lambs. In 1977, death losses reached a peak, comprising about 16.4 percent of stock sheep on hand January 1. Lamb losses accounted for more than 56 percent of total losses in 1977 (Table IV-3).

3. Other Information

In addition to direct field studies and mail and interview surveys, individual livestock producers, livestock producer organizations, state and local governments and other interested parties have provided information pertaining to livestock predation and comments regarding the need for compound 1080. This information was provided in testimony and written comments submitted to the Agency as the result of informal hearings held in late July. The following summarizes the information provided.

a. Livestock Producer Testimony and Comments

Livestock producers (primarily sheep producers) from 12 states provided information during the Agency's informal hearings. Producers with diverse production, management and predator control practices provided data describing livestock losses due to predation.

Because producers reported many categories of livestock loss information, the basis for comparing livestock losses (e.g., lambs lost as a percent of total lamb crop, lambs lost as a percent of total number of ewes, etc.) is not always consistent between each producer. In addition, livestock losses were often reported by producers as total losses to all causes rather than differentiating losses to specific cause. Producers generally indicated that coyotes were the primary cause of losses due to predation.

Arizona, Idaho, Oregon, and New Mexico livestock producers responded with information expressing their support for reregistration of compound 1080 for predator control. These producers

Table IV-3. Death Loss of Sheep and Lambs from all Causes, 1950 to 1978.

Year	All Sheep & Lambs on Hand, Jan. 1	Deaths from all Causes					Death Loss of all Sheep and Lambs as Pct. on Hand, Jan. 1.
		Sheep		Lambs		Total	
		(No.)	(%)	(No.)	(%)	(No.)	
1950	29,826	2,558	59.8	1,717	40.2	4,275	14.3
1951	39,633	2,495	59.1	1,725	40.9	4,220	13.8
1952	31,982	2,533	59.3	1,736	40.7	4,269	13.3
1953	31,900	2,494	58.4	1,778	41.6	4,272	13.6
1954	31,356	2,365	57.6	1,742	42.4	4,107	13.1
1955	31,582	2,455	57.9	1,788	42.1	4,243	13.8
1956	31,157	2,472	57.2	1,850	42.8	4,322	13.9
1957	30,654	2,493	57.3	1,860	42.7	4,353	14.2
1958	31,217	2,434	56.0	1,916	44.0	4,350	13.9
1959	32,606	2,529	55.7	2,010	44.3	4,539	13.9
1960	33,170	2,458	53.6	2,132	46.4	4,590	13.8
1961	32,725	2,437	54.2	2,062	45.8	4,499	13.7
1962	30,969	2,430	54.8	2,007	45.2	4,437	14.5
1963	29,176	2,268	54.6	1,889	45.4	4,157	14.2
1964	27,116	2,265	55.8	1,797	44.2	4,062	15.0
1965	25,127	2,199	56.2	1,711	43.8	3,910	15.6
1966	24,734	1,940	53.7	1,674	46.3	3,614	14.6
1967	23,953	1,980	54.6	1,649	45.4	3,629	15.2
1968	22,223	1,789	53.1	1,580	46.9	3,369	15.2
1969	21,350	1,826	54.0	1,556	46.0	3,382	15.8
1970	20,423	1,638	52.6	1,478	47.4	3,116	15.3
1971	19,731	1,482	50.6	1,446	49.4	2,928	14.8
1972	18,739	1,417	48.9	1,480	51.1	2,897	15.5
1973	17,641	1,386	49.0	1,441	51.0	2,827	16.0
1974	16,310	1,248	47.0	1,409	53.0	2,657	16.3
1975	14,515	1,081	44.6	1,343	55.4	2,424	16.7
1976	13,311	983	45.0	1,202	55.0	2,185	16.4
1977	12,766	910	43.5	1,181	56.5	2,091	16.4
1978	12,322	911	44.8	1,123	55.2	2,034	16.5

Source: USDA statistical Bulletin No. 522

also indicated that predation problems are increasing despite improved management practices and the use of legal predator control methods.

Colorado and Wyoming producers supplied the majority of responses emphasizing sheep losses due to predation. Various Colorado sheep producers reported pre-1972 losses of 0.4 to 2 percent of their lambs and post-1972 losses of 3 to 20 percent of their lamb crop, averaging approximately 11 percent annually. Wyoming producers indicated that before compound 1080 was used for predator control, annual lamb losses averaged 10 percent of the lamb crop. Annual lamb losses of 2 to 5 percent occurred when compound 1080 was available for predator control and increased to 5 to 50 percent (averaging approximately 21 percent) after compound 1080 was cancelled. Montana sheep producers reported annual lamb losses of 10 to 20 percent since 1972, averaging approximately 13 percent.

Responses from Kansas, Texas, Nebraska, South Dakota, and Utah were received from one to three producers in each state. Producers stated that sheep and lamb losses were generally increasing despite improved management practices and the use of legal predator control methods. A South Dakota producer indicated a 14 percent lamb loss in 1979, one Kansas producer lost 15 and 11 of his lambs and ewes, respectively in 1977, while a Texas producer reported a complete loss of kid goats and a 30 percent loss of adult goats to coyotes. Two individual livestock producers, Mary Wintch and John Hotchkiss, provided statistical data on trends in predation from their operations. The Wintch data included death losses from all causes with over half attributed to predators. These data are summarized as follows:

	Wintch Livestock Company	Hotchkiss Ranch
Year	Number of Lambs Lost as Percent of Lambs Docked	Number of Lambs Lost as Percent of Flock Size
1968	10.6	--
1969	0.6	--

Year	Wintch Livestock Company	Hotchkiss Ranch
1972	16.3	2.4
1973	13.5	3.0
1974	16.4	5.0
1975	--	6.0
1976	19.4	6.5
1977	28.2	7.0
1978	24.1	7.2
1979	9.4	7.6
1980	13.5	8.0

While limited data are presented prior to 1972, the reported data show that losses were generally lower prior to 1972 than in subsequent years and/or losses generally have increased during the 1970's.

In summary, the comments and testimony received by the Agency from individual livestock producers indicate that predation losses (primarily by coyotes) have increased since 1972. They indicate livestock losses have increased despite intensive management and uses of available predator control methods. According to livestock producers, losses to predation combined with adverse market forces create a situation that many livestock producers consider intolerable.

b. Producer Associations

Several livestock producer associations provided oral and written testimony and/or written comments regarding livestock losses to predators during informal hearings held in July. A brief tabular summary of this information follows.

NAME	DESCRIPTION OF LOSS DATA
California Wool Growers Association	1970 to 1980 - 33,553 sheep lost due to coyote predation.

NAME	DESCRIPTION OF LOSS DATA
Idaho Wool Growers Association	Same as provided by New Mexico Dept. of Agriculture.
Montana Wool Growers Association	Some producers suffer significant lamb losses while others do not.
New Mexico Farm Bureau	1980 state-wide survey - lamb losses due to coyote predation average 4 percent.
Oregon Sheep Growers Association	Livestock losses have increased each year since 1080 ban.
Utah Farm Bureau	Lamb losses since 1080 cancellation range from 8 to 20 percent.
Utah Wool Growers Association and Utah-Idaho Farmers Union	91.9 percent of all predator losses are due to coyotes. 1978 - 16 percent of all sheep and lamb losses due to predators. 1979 - 18 percent of all sheep and lamb losses due to predators. 1980 - 19 percent of all sheep and lamb losses due to predators.
Wyoming Stock Growers Associations	1974-1980- Total sheep numbers declined by 29.5 percent, total number of sheep lost to predators declined by 41.2 percent.

NAME	DESCRIPTION OF LOSS DATA
Wyoming Stock Growers Associations (con't)	1974 - 1.7 percent of total sheep numbers were lost to predators.
	1980 - 1.4 percent of total sheep numbers were lost to predators.
Wyoming Wool Growers Association	1965 to 1972 - 4.87-7.93 percent of all sheep and lambs were lost to predators.
	1972 to 1981 - 7.37-10.43 percent of all sheep and lambs were lost to predators.

c. State and Local Governments

Like producer associations, several state and local government agencies provided oral and written testimony and/or written comments regarding livestock losses to predators during informal hearings held in July. A brief tabular summary of this information follows.

NAME	DESCRIPTION OF LOSS DATA
Montana Dept. of Agriculture	Historic livestock losses due to coyotes - 4-8 percent.
	Decline in sheep numbers due to market factors and depredation.
	Factors affecting depredation - 1) size of operation, 2) location, 3) rangeland vs. farm flocks, and 4) vegetational differences.

NAME	DESCRIPTION OF LOSS DATA
Nevada Dept. of Agriculture	No loss data provided.
New Mexico Dept. of Agriculture	1974 survey - 8 and 2.5 percent of westwide lamb crop and adult herd lost to coyotes, respectively. 1980 - 4 percent of lambs lost to coyotes in New Mexico. Summary of several state surveys: Post-1972 livestock loss rates approximately double pre-1972 loss rates in Colorado, Montana, New Mexico, and Wyoming. Post-1972 livestock loss rates increased slightly in Idaho, South Dakota and New Mexico (mail questionnaires and personal interviews). Post-1972 loss rates in Texas indicate a "definite increase" in predation. Post-1972 loss rates in Nebraska "rose slightly" then declined.
Oregon Dept. of Agriculture	1980 livestock losses to predators Sheep - 4,300* Lambs - 10,300* *99 percent of losses due to coyotes

NAME	DESCRIPTION OF LOSS DATA
South Dakota Dept. of Game, Fish and Parks	See table below
Texas Dept. of Agriculture	See Texas Survey previously discussed in "Mail and Interview Survey Section"
Washington Dept. of Agriculture	1964-1972 - 3.6-5.5 percent of lambs lost due to coyotes. 1972-1979 - 7.5-20 percent lambs lost due to coyotes.
Wyoming, Campbell County-Predatory Animal Control Board	1972-1981 - Sheep population declined by approximately 52 percent due to predators.

South Dakota Dept. of Game, Fish and Parks:

Years	Sheep	
	No.	Percent Increase
1978-1979	306	--
1979-1980	476	55.5
1980-1981	688	44.5
1978-1981		124.8

d. Universities and Other Interested Parties

In addition to livestock producers, livestock producer associations and state and local government agencies, universities and other interested parties provided oral and written testimony and/or written comments regarding livestock losses to predators during informal hearings held in July. A brief tabular summary of this information follows.

NAME	DESCRIPTION OF LOSS DATA		
Oregon State University		Animal Nos.	Losses to predation
		(compared to baseline period)	
	Sheep		
(baseline period)	1967-1971	- declined	
	1972-1975	- (-)13.5%	(-)5.3%
	1976-1980	- (-) 6.5%	(-)27.1%
U.S. Dept. of Interior Bureau of Indian Affairs	Livestock losses due to coyotes and wild dogs have increased annually since 1972.		
International Association of Fish and Wildlife Agencies	Coyote is an important livestock and wildlife predator that has not been managed properly since 1080 ban.		
Wyoming Financial Institutions	Due to predator loss, banks are often reluctant to lend operating or start-up funds to sheep producers.		

4. Summary of Sheep Losses

Many studies of sheep loss to predators have been completed since 1972. Direct field assessments with normal predator control have shown predation of 0 to 2.5 percent of the ewes and 1.3 to 7 percent of the lambs annually. The majority of predation in different studies was attributed to coyotes.

Questionnaire surveys also show the coyote as the main predator. Predation losses are unequally distributed both geographically and among producers. Various local or regional surveys report annual predation loss at 0.1 to 2.8 percent of ewes and 0.9 to 4.7

percent of the lambs. The most comprehensive survey to date (Gee et al., 1977a) estimated total predation losses of 3.4 and 11.4 percent, respectively, of ewes and lambs in 15 western states in 1974. Some 2.5 percent of the ewes and 8.1 percent of the lambs were reportedly killed by coyotes. Limited comparisons with other studies suggest that these estimates are substantially higher than estimates from other sources (USDI, 1978).

According to USDI (1978), it is difficult to obtain precise overall estimates of sheep losses to predators. Each method of loss assessment has limitations and possible sources of bias. As reported by USDI (1978), losses to sheep producers in western states during 1972 averaged 4 to 8 percent of the lambs and 1 to 2.5 percent of the ewes. However, average loss rates do not adequately portray the nature of coyote depredation on sheep as losses are unequally distributed both geographically and among ranchers and producers (USDI, 1978). USDI concludes: "Truly comprehensive records of predation losses of sheep over time are lacking, but the available estimates point to higher predation rates in the early 1970's than the 1960's."

Livestock loss data presented by producers, producer associations, state and local government organizations, and other organizations present a diverse picture of the predation problem. Losses reported by individual producers are often substantially different from producer to producer and may vary considerably from loss data generated from surveys. The nature and diversity of reported losses tend to substantiate a conclusion that predation is often a producer-specific problem. In other words, many producers have no predation problems while others, despite their best efforts to control predators, suffer very significant losses of livestock.

C. Cattle and Calf Losses

Predators are a problem to cattle producers, but not to the extent experienced by sheep producers. Few field or biological surveys are available to evaluate the nature and extent of the problem under various husbandry or predator control practices.

USDA-ESCS (1976) conducted a comprehensive personal interview survey on the beef breeding industry in 1975 and as part of this survey included questions on cattle losses to predators. USDA-ESCS reported that predators killed less than one-tenth of one percent of the January 1, 1975 inventory of beef cattle (500 lbs. and over) in the survey populations. Highest losses were in the Southwest* and most predator losses were attributed to coyotes and dogs.

USDA-ESCS (1976) reported losses to coyotes in the western states ranging from 0.4 reported in the Great Plains* region to 0.8 percent in the Southwest. The highest loss to all predators, 1.1 percent, also occurs in the Southwest. Calves are particularly vulnerable to predators in the first 6 to 8 weeks of life but by weaning time, the probability of predation is virtually eliminated (USDI, 1978). As with sheep losses, losses of calves to coyotes and other predators are unequally distributed. In the three western regions, the proportions of producers reporting any losses to coyotes ranged from 14 percent in the Great Plains to 26 percent in the West. Two percent of respondents in the Southwest and one percent in the West reported losses to coyotes of more than five percent of calves born (USDI, 1978).

Losses of calves (less than 500 lbs.) to predators occur at a higher rate than losses of cattle but are minor compared to losses to other causes. By comparison, calf losses to theft, disease and other causes are substantially higher, ranging from 3.6 percent in the Southwest to 9.1 percent in the Great Plains region (USDA-ERS 1976).

USDA statistical publications based on producer surveys, report death loss from all causes to cattle and calves. Based on these data, on the national level, death loss of cattle and calves from all causes remained remarkably constant from 1950 to 1971. For this period, the death loss of all cattle and calves averaged 8.9

* See Figure IV-1.

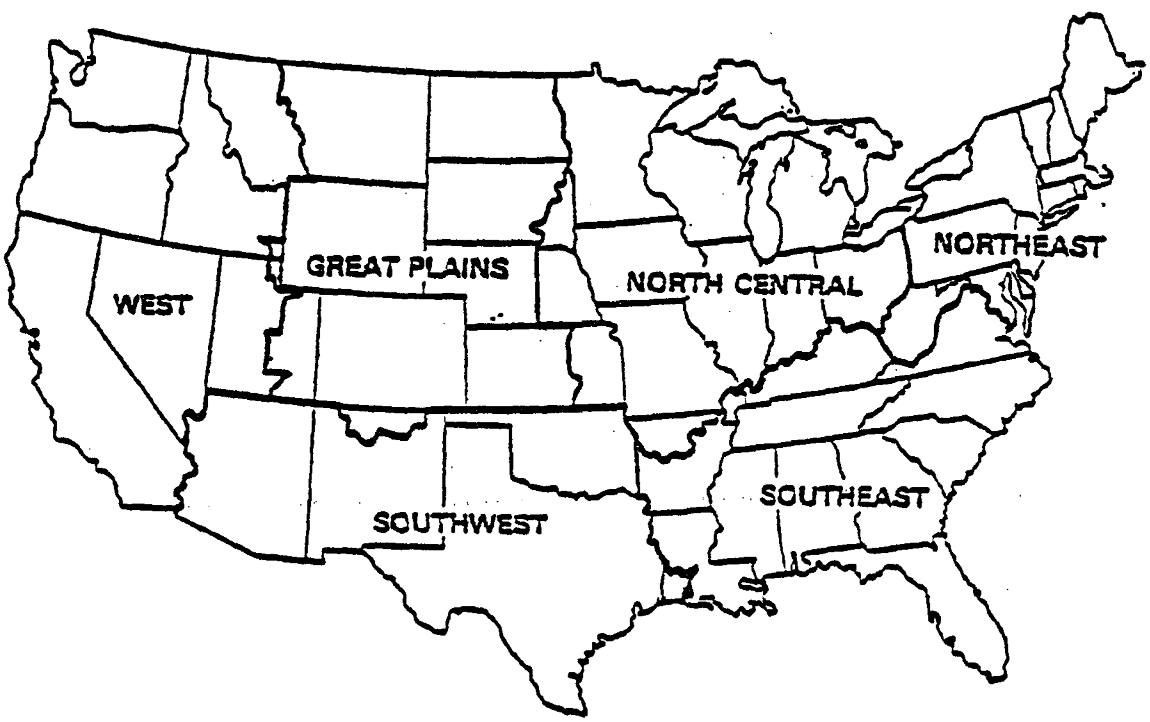

Figure IV-1. Livestock Production Regions of the United States percent,* ranging from a low of 8.4 percent in 1966 and 1968 to a high of 9.5 in 1950 (Table IV-4). From 1972 to 1980, the rate of death loss averaged 11.2 percent, an increase of over 20 percent from the average for the 1950-72 period.

In addition to the USDA-ESCS survey data and the USDA statistical publication, individual livestock producers, livestock producer organizations, state and local governments and other interested parties have provided information pertaining to livestock predation and comments regarding the need for compound 1080. This information was provided in testimony and written comments submitted to the Agency as the result of informal hearings held in late July. The following is a brief summary of the information provided regarding predator loss to cattle and calves.

NAME	DESCRIPTION OF LOSS DATA
Texas and Southwestern Cattle Raisers Associations	1973 survey of 87 percent respondents indicated problems with predators.
	1977 survey - 1.1 percent of all calves born are lost to predators; 2.0 percent of survey respondents reported calf losses of at least 5.0 percent to coyotes.
	Coyotes are known carriers and potential transmitters of brucellosis.
National Cattleman's Associates	1970 to 1980 - Requests for Animal Damage Control assistance in 16 western states increased 430 percent.

* Expressed as percentage of cows on hand January 1.

NAME	DESCRIPTION OF LOSS DATA
Oregon Department of Agriculture	1980 Livestock Losses To Predators

Type	No.
cattle	260*
calves	4,440
poultry	230
swine	14

* 99 percent of losses due to coyotes.

South Dakota Department of Game, Fish and Parks

Year	Calves No.	Calves Percent Increase
1978-79	11	--
1979-80	34	209.1
1980-81	24	- 29.4
1978-81		118.2

Oregon State University

	Cattle Animal Nos.	Cattle Loss to predators
(baseline period)	1967-71 - stable	--
	1972-75 - stable	doubled
	1976-80 - stable	same as baseline periods

Table IV-4. Death Loss of Cattle and Calves from all Causes 1950 to 1980.

Year	Cows[a] on Hand, Jan. 1 (million)	Death Loss from All Causes No. (000)	Death Loss from All Causes As Percent on Hand Jan. 1.
1950	39.25	3,742	9.5
1951	41.05	3,863	9.4
1952	43.84	4,034	9.2
1953	45.83	4,060	8.9
1954	46.03	4,063	8.8
1955	45.33	4,032	8.9
1956	43.94	3,912	8.9
1957	43.34	3,801	8.8
1958	42.63	3,810	8.9
1959	42.89	3,876	9.0
1960	43.59	4,100	9.4
1961	44.49	4,018	9.0
1962	45.65	4,125	9.0
1963	47.05	4,040	8.6
1964	48.23	4,232	8.8
1965	48.77	4,248	8.7
1966	47.97	4,049	8.4
1967	47.49	4,045	8.5
1968	47.67	4,012	8.4
1969	48.03	4,123	8.6
1970	48.78	4,297	8.8
1971	49.79	4,442	8.9
1972	50.58	5,126	10.1
1973	52.54	6,487	12.3
1974	54.47	6,110	11.2
1975	56.92	6,992	12.3
1976	54.97	5,190	9.4
1977	52.42	6,000	11.4
1978	49.75	5,680	11.4
1979	47.85	5,600	11.7
1980	47.87	5,400	11.3

a/ Inventory of cows and heifers that have calved.

Source: Data Resources, Inc. 1981.

V. EFFICACY OF 1080 AND ALTERNATIVE METHODS OF REDUCING PREDATION

A. Information on the Efficacy of 1080 and Alternatives Considered in 1972

In 1972, the U.S. Environmental Protection Agency followed the recommendations of "The Cain Report" and a petition by several conservation groups (Natural Resources Defense Council, et al., 1972) in banning the use of 1080 and three other toxic chemicals for the control of predatory mammals. The Administrator described the benefits of predator control toxicants, in general, as "speculative and ill-defined" (Ruckelshaus, 1972). He concluded that

> There is no reliable data as to the amount of predator control achieved by the use of these poisons.

and that

> There is no reliable data as to the loss of sheep that might occur without a predator control program using these poisons... (Ruckelshaus, 1972, p. 5720).

In recommending the cancellation of these chemicals, Cain et al. (1972) concluded that effective resolution of local predation problems could be achieved by use of methods then available (shooting, denning, and "the use of more humane traps") (p. 111) or by use of procedures that would be developed through research ("truly specific poisons," repellents, reproductive inhibitors, live trapping, transplanting, "basic ecological mechanisms") (p. 111). In addition, the report recommended the use of extension programs

> to encourage livestock producers to solve their

> own problems by accepted methods directed toward specific marauding animals, especially near lambing grounds and closed pastures.
>
> ... Extension should not be concerned only with control; there is a need for assistance and encouragement in the use of better husbandry and management practices ... (p. 111).

Many of these conclusions of the Cain Commission were echoed by persons (cf. Klataske, 1981; Wentz, 1981) testifying at the information gathering hearings in opposition to reinstatement of the use of 1080 as a predacide.

The following three sections discuss the use patterns which have been proposed for the reintroduction of 1080 as a predacide. Subsequent sections present discussions of alternative methods for controlling predation and lists of husbandry practices which have been found to affect livestock losses. As Cain et al. (1972) had concluded that these alternative control practices (whether in use then or projected for the future) and husbandry practices could provide all of the livestock protection needed, discussions center upon new approaches and recent findings or interpretations of old data which contradict or define the limits of this conclusion.

As mentioned in Section III, in reaching the decision to suspend registrations for chemical practices (Ruckelshaus, 1972), the Administrator used "The Cain Report" (Cain et al., 1972), "The Leopold Report" (Leopold et al., 1972) and the Natural Resources Defense Council et al. (1971) petition as major sources of information. Table V-1 summarizes the conclusions expressed in these documents or in the Administrator's notice of suspension concerning 1080 use patterns and alternative control methods. In addition, Table V-1 notes whether new data have become available since 1972 on the various methods and whether the data may warrant any re-evaluation of the conclusions reached in 1972. In interpreting Table V-1 and for the

Table V-1. 1972 Assessments of Methods for Controlling Livestock Predation and Additional Information Affecting Current Assessments of These Methods.

Method	1972 Assessment	New Data? (post 1972)	Areas for Possible Reassessment
1080			
Toxic collar	None	Yes	Efficacy Offending animal selectivity Safety
Bait station	Effective in local population reduction[1,2] "... no reliable data" on benefits[3] "Fair" for troubleshooting[1] "Very good" as economical method[1] Misused (dosing, density, persons applying)[1,2,4] Wildlife hazard[1,3,4] Endangered species hazard[3,4] Secondary poisoning[1,3,4] Hazard to humans[1,3]	No	No new experimental data on method Robinson (1948) data re-examined
Single lethal baits	Less selective than carcass stations when baits are broadcast[1]	Yes	No data on use of 1080 in single lethal baits to control coyotes New data are on selectivity of non-lethal baits
Sodium Cyanide			
M-44 or coyote getter	Effective as prophylactic tool[1] Poor troubleshooting tool[1] "Good" as economical method[1] Fairly specific for offending animal[2] Humane[1] Lack of environmental impact[1] Not selective[1,2,3] Wildlife hazard[3] Human hazard[1,3,4] Misused[3]	Yes (M-44 only)	Selectivity and safety limitations of M-44 device Efficacy

Table V-1. 1972 Assessments of Methods for Controlling Livestock Predation and Additional Information Affecting Current Assessments of These Methods.

Method	1972 Assessment	New Data? (post 1972)	Areas for Possible Reassessment
Other Chemical Methods			
Repellents (no specific compounds mentioned)	"Poor" prophylactic tools[1] "Very good" troubleshooting tools[1] Presumed safety, selectivity for offending target animals[1] Questionable economy, environmental impacts[1]	Yes	None Agents tried have not proven to be effective
Reproductive inhibitors (no specific compounds mentioned)	"Very good" for safety, humaneness[1] "Good" for prophylactic effects, lack of environmental impacts[1] "Poor" for offending animal selectivity[1] "Fair" for target species selectivity[1] Questionable economy (thought to be "Good")[1]	No	None (no new research)
Aversive conditioner (lithium choloride)	None	Yes	Efficacy Offending animal selectivity Limitations Safety
Mechanical Methods			
Aerial shooting	"Very good" troubleshooting tool[1] "Fair" prophylactic tool[1] "Good" selectivity for target species[1] "Fair" selectivity for offending animal[1] Questionable humaneness[1] "Very good" safety to man and livestock, lack of environmental impact[1] "Poor" as economical method[1]	Yes	Use greater than projected in 1972 Costs have risen greatly

Table V-1. 1972 Assessments of Methods for Controlling Livestock Predation and Additional Information Affecting Current Assessments of These Methods.

Method	1972 Assessment	New Data? (post 1972)	Areas for Possible Reassessment
Ground shooting	"Good" for troubleshooting, target species selectivity, offending animal specificity[1,2] "Very good" for safety to man and livestock, lack of environmental impact[1] "Poor" as prophylactic method[1] "Fair" as economical method[1] "Questionable humaneness[1]	Yes	None
Denning	"Good" for troubleshooting, target species selectivity, offending animal specificity[1] "Very good" safety to man and livestock, lack of environmental impact[1] "Poor" as prophylactic tool[1] "Fair" as economical method[1] Questionable humaneness[1]	Yes	Effects on losses to coyotes Impacts of Andrus' (1979) policy change
Steel traps	"Good" for troubleshooting[1] Not very selective[1,2] "Fair" as prophylactic tool[1] Humane when properly used[1] "Good" as economical method[1] "Fair" in offending animal specificity[1]	Yes	Designs Methods of use Selectivity Economics
Snares	None	Yes	Selectivity Economics Utility

References

1. Cain *et al.*, 1972.
2. Leopold *et al.*, 1964.
3. Natural Resources Defense Council, Inc., *et al.*, 1971.
4. Ruckelshaus, 1972.

discussions which follow, the reader should note that the term "prophylactic" refers to attempts to reduce the incidence of predation by reducing the predator population in a general area. The terms "troubleshooting" and "corrective" control refer to attempts to reduce predation by removing the specific individual predator(s) responsible for the damage.

B. Efficacy of 1080

1. Bait Stations

The most common method of use of compound 1080 prior to its being banned as a predacide was in the impregnated bait station. Large portions (50-100 lbs.) of animal carcasses (generally horses or sheep) were given multiple injections of a sodium fluoroacetate solution at closely spaced intervals. These carcasses were then placed on rangeland in efforts to reduce coyote populations. While this use pattern was implemented without being subject to intensive quantitative investigations of its efficacy and safety (cf. Balser, 1974), Robinson(1948, 1953) reviewed the method, developing a set of use guidelines which he believed would minimize hazards to non-target species' populations while, at the same time, providing effective coyote control. These guidelines have been adopted with few modifications by several groups which have been concerned with reinstatement of this use pattern since 1972 (e.g., ASTM, 1976; Wyoming Department of Agriculture, 1977). This section discusses the elements of the use guidelines which may affect the effectiveness of this use pattern.

According to Robinson's (1948) scheme, 1080-treated carcasses would be placed at densities of no more than one station per 36 square miles.* Due to the extensive home ranges of coyotes, such placement densities were believed to provide effective target species exposure. The baits were to be deployed

* One bait per township section.

during the winter and early spring when conditions would favor scavenging by coyotes, preservation of the freshness of the bait and, therefore, the "drawing" power of the carcass. Kill of coyotes at this time of year would, according to Robinson (1948), provide efficient population reduction by taking coyotes during their own reproductive season. Coyote reduction at this time was also thought to benefit the sheep maximally since it would be achieved prior to the lambing season and the movement of sheep bands into the higher range areas.

Prior to the 1972 cancellation, baits were dosed at a rate of 1.6 grams of 1080 per 45 kilograms (100 lbs.) of eviscerated livestock carcass. The ASTM (1976) recommendations for use of 1080 in bait stations direct a similar dose level. These guidelines, however, call for placement of stations at an average of one per township (36 square miles) but state that "in some areas, more frequent placement may be required" (ASTM, 1976, p. 11). Proposed state registrations for this use pattern (e.g., Wyoming, 1981) generally follow the ASTM directions (See Table III-1). Connolly (1981) has speculated that the dosage level for bait stations could be reduced without diminishing effectiveness.

The perceptions of the EPA Administrator and the authors of the reference documents given major attention in 1972 concerning this use pattern are summarized in Table V-1. The method was perceived to be effective in reducing local coyote populations, but Robinson's (1948) data suggesting that these reductions in predator densities markedly reduced lamb losses to predators apparently were not accepted.* The prevailing viewpoint in the documents given primary weight in 1972 (Cain *et al.*, 1972; Leopold *et al.*, 1964; Natural Resources Defense Council *et al.*, 1971) was that any possible benefits derived from this

* "The Cain Report" did discuss non-target hazards of 1080 and thallium sulfate that were noted by Robinson (1948), indicating that the panel was aware of the report. "The Cain Report" did contain an analyis by Wagner, one of the commission members (cf. Wagner, 1972; 1975), which purported to show some depressent effects on coyote numbers during the period of operational use of 1080 in western states. The impacts of these possible effects (see below) on total livestock losses were not found to be clear-cut. (See also the testimony of Bourret, 1981.)

use pattern were outweighed by ethical considerations (e.g., "humaneness") and hazards to man, endangered species and other wildlife (see Table V-1 and Section VI). Patterns of misuse noted for this use pattern included excessive dosing of carcasses, placement of carcasses at densities exceeding Robinson's guidelines, placement by unqualified or unauthorized personnel and failure to collect baits in the spring (see Table V-1 and Section VI).

The validity of Robinson's conclusions concerning the methods for safe and effective deployment of 1080 bait stations has not been tested in a detailed, quantitative manner. Leopold *et al*. (1964) accepted the logic of placing stations at one per 36 square miles as a means for controlling coyotes while not seriously disturbing non-target populations but did not cite any supporting data.

By using data on total known takes in the federal program for animal damage control and on manpower used in these programs, Wagner (1972) has developed an index which he believes is an approximate reflector of population levels for various species of predators. Using this index, Wagner has assessed the effects of the use of 1080 on predator populations. Because Wagner has revised his original assessment of the effects of coyote populations on sheep losses (Wagner, 1975), his original and subsequent evaluations are discussed at length.

By dividing the total number of coyotes known to be taken in the federal control program in a given state in a given year by the number of man-years expended in the program in the same state for the same year, Wagner derived the statistic "Coyotes Killed per Man-year of Effort." When coyote numbers were high, Wagner reasoned, these animals would be more easily taken than in years when their numbers were low. Wagner felt that, in the absence of thorough analysis of the control program's effects, this measure of the program's efficiency could "provisionally be used to indicate changes in the populations of coyotes and other carnivorous mammals" (Wagner, 1972, p. 9).

Wagner assembled data from the 1930's until 1970 or 1971, depending upon the state in question. Although data were missing for some years in some states, a fairly continuous series of values was assembled. Wagner divided this series into a "pre-1080" period and a "1080" period. The pre-1080 period ran from the earliest available record for a state until the year before 1080 (along with the "Coyote Getter"--see discussion of M-44 device) was introduced for operational use in the state.* The 1080 period extended from the year of 1080 introduction onward. Since Wagner's data were originally assembled for inclusion in "The Cain Report," he reported no data subsequent to the banning of 1080 as a predacide. USDI (1979a) has reported data on "Coyotes Killed per Man-Year of Effort" for the years since 1972, thus adding a "post-1080" period to this "accidental" experiment.

Analysis of the figures on coyotes killed/man-year reported by Wagner (1972) for eight western states and supplemented by USDI (1979a) for seven of these states indicates two general patterns of results:

1. Coyotes/man-year sharply declined slightly before or after the onset of the 1080 period, remained depressed during the 1080 period (1948 or 1949 to 1972) and increased during the post-1080 period (1973 to the present). These trends were seen in four northerly, mountainous states: Idaho, Montana, Utah and Wyoming.

2. Coyotes/man-year declined after the introduction of 1080, but these declines did not persist. Changes in the index in Arizona, Colorado, New Mexico, and Texas appeared to be more closely associated with cyclical phenomena independent

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* In the states for which Wagner compiled data, 1080 was introduced as an operational tool in 1948, 1949 or 1950.

of changes in control methods used. In the three states (Arizona, New Mexico and Texas) for which post-1080 data were reported by USDI (1979a) these cyclical fluctuations appear to have continued following the banning of 1080.

Wagner (1972) attributed the differences between the more northerly and more southerly states in the response of the measure "Coyotes Killed Per Man-Year of Effort" to a perception that 1080 was more effective in the northern states and to information that, perhaps as a consequence of that perception, more 1080 was used in the northern states than in the southern ones. According to this interpretation, the data on coyotes/man-year from these eight states support the notions that the use of 1080 can suppress coyote populations and that the degree of coyote population suppression achieved is proportional to the amount of 1080 used. Wagner (1975) stated that he believed that reductions in coyote populations were correlated with reductions in sheep losses.

Because these data provide much of the available quantitative support for the efficacy of the 1080 bait station as a prophylactic control agent and, in conjunction with some surveys of sheep losses, support for the general effectiveness of prophylactic control, Wagner's interpretations merit critical review. It should first be noted that the changes in coyotes/man-year noted by Wagner (1972) are corroborated in certain areas of certain states by trapline surveys (Linhart and Robinson, 1972) and by numbers of coyotes bountied (Wagner, 1972).

Several factors could operate to make the index "Coyotes Killed per Man-Year of Effort" misrepresentative of population levels or of the efficacy of 1080 bait stations. Such confounding factors could include the contributions of other methods to the total number of coyotes killed and differing contributions of various methods to the coyotes/ man-year index, either through different killing efficiencies or different efficiencies of having kills detected.

The data on coyotes/man-year are composites of the efficiencies of all methods used. Methods which have known takes of relatively large numbers of coyotes or which involve expenditures of relatively large amounts of employees' time exert major influences on this composite measure. The methods used over the periods covered by the Wagner (1972) and the USDI (1979a) data include traps, snares, M-44's, "Coyote Getters," gunning (from ground or air), denning, and toxic baits laced with strychnine, thallium sulfate or 1080.* The victims taken are readily located and, therefore, readily tallied for traps, snares, shooting and denning. For quick-acting toxicants such as sodium cyanide (in the "getter" or the M-44) and strychnine, a larger proportion of victims would be expected to be located than for slow-acting poisons such as thallium and 1080.** Over their periods of use, the contributions to the total known kill of coyotes and to the total actual kill of coyotes would be very similar for some methods and very different for others.

The different methods also vary in the number of known kills (or takes) per man-year of use (USDI, 1978). For example, in fiscal year 1976, the composite efficiency of the U.S. Fish and Wildlife Services' animal damage control program was 204.5 coyotes taken per man-year of effort. Coyotes/man-year values for individual techniques ranged from highs of 989.4 and 426.2 for gunning from helicopters and fixed wing aircraft, respectively, to lows of 70.3 for snares and 113.5 for sodium cyanide in the M-44 (USDI, 1978). For fiscal year 1976, denning, hunting with dogs, ground shooting and aerial shooting produced coyotes/man year values above the composite efficiency while traps, M-44's and snares had efficiencies below this figure. There are no

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* Although the mix of methods used by USDI personnel varied over the years, Wagner (1972) assumed that, with the exception of 1080, the various methods "each compensated for the other in its respective period of use" (p. 10).

** The difficulty of locating coyotes believed to have been poisoned by 1080 has been mentioned and discussed in many sources (e.g., Robinson, 1948; Hegdal <u>et al</u>., 1978; Connolly, 1980).

known data giving coyotes/man-year values for use of the 1080 bait station. If such data were available, Wagner's (1972) conclusions could be assessed more accurately.

Since animals killed by 1080 frequently are not located, it is possible that a low known coyotes/man-year value was obtained for use of 1080. Since cancellation of 1080 was followed by an increase in the use of aerial gunning, the apparent increase in coyote populations as measured by "Coyotes Killed per Man-Year of Effort" may merely reflect the influence that changing control methods has on this index. The same effect may have operated between the "pre-1080" and "1080" periods as well. It is note-worthy that the greatest and most enduring depressions in the index following the introduction of 1080 as an operational tool occurred in the states which used the most 1080. This finding is consistent with the interpretation expressed in this paragraph as well as with that of Wagner (1972).

Although Wagner's (1972; 1975) interpretations of his data, as supplemented by USDI (1979), may be correct, the data of Robinson (1948) provide the clearest support for the effectiveness of 1080 bait stations in reducing predation loss. Although Robinson's data were limited in validity by his use of year-to-year comparisons of loss figures obtained through interviews with producers, the local reductions in losses to predators reported were of such magnitudes (85, 98 and 99 percent) that it is difficult to conclude that subtle biases produced all of the apparent effects. As noted above, these data were known to the Cain Commission but were not discussed in the report's section on coyote control and sheep losses.

Lynch and Nass (1981) have recently summarized loss data on national forest service lands from the years 1960 to 1978. Percent loss was significantly inversely correlated with numbers of 1080 stations used (1960-1972), but percent loss was also significantly inversely correlated with the numbers of sheep grazed.

The degree of relief from predation which would result from reinstitution of this use pattern is difficult to predict. Despite Robinson's (1948) data, the benefits of the old registration have been hotly contested. Allegations of misuse and excessive secondary coyote kills by 1080 used in rodenticide programs (e.g., Natural Resources Defense Council et al., 1972) suggest that more coyotes may have been taken by 1080 prior to 1972 than would be taken under a reinstituted and tightly controlled registration of this use pattern. The use of 1080 bait stations in Wyoming in 1975-1977 (cf. testimonies of Crosby, 1981; Bourret, 1981; and Strom, 1981) was apparently not accompanied by careful monitoring of effectiveness of the baits in controlling coyotes or reducing livestock losses.

2. Toxic Collar

The toxic collar was developed by Mr. Roy McBride, of Alpine, Texas, in the early 1970's as a way of delivering toxic material to coyotes which prey upon sheep (Connolly, 1980). The first collars contained sodium fluoroacetate (1080) in vessels positioned in the throat region, a common locus of attack for coyotes preying upon sheep (Timm and Connolly, 1977). A coyote attacking collared sheep would, according to toxic collar theory, inadvertently rupture the collar, causing toxicant to enter the mouth. Since coyotes are extremely sensitive to 1080 (LD_{50} about 0.12 mg/kg body weight--Connolly, 1980), even a small amount of sufficiently concentrated 1080 solution can be fatal. With the cancellation of 1080 as a predacide in 1972, domestic development of the 1080 toxic collar stopped. The use of 1080 in the toxic collar was not mentioned in the decision to suspend registration of 1080 as a predacide.

Experiments with toxic collars were begun in 1974 by the Fish and Wildlife Service, USDI (Connolly, 1980). Because it delivers toxicant only to animals "guilty" of attacking livestock, the collar was perceived as a mechanism for "discriminating against animals actually doing damage," the type of predator control recommended by the Cain commission (Cain et al., 1972, p. 6).* Fish and Wildlife Service field researchers used sodium cyanide (NaCN) in 1975, diphacinone (DPN) in 1976, and have used

* The Cain Commission did not favor the use of toxicants for such "corrective" control, however.

1080 from 1978 to the present. In 1979, field trials were expanded to include goats.

Following the directive of the Secretary of the Interior to halt his department's "research or development of potential uses of Compound 1080" (Andrus, 1979), other parties sought experimental use permits for the testing of the 1080 toxic collar. Two permits have been granted: one to the Texas Agricultural Experiment Station (TAES), Texas A&M University; and the other to the New Mexico Department of Agriculture (NMDA). The USDI permit for the 1080 collar has been renewed, but the only field studies being conducted under it are several trials on mohair goats in Texas in cooperation with the TAES and one trial in Idaho where collars have been used on sheep since 1978. The toxic collars being used are manufactured by Mr. McBride, who also carried out field trials in Texas in 1978 under contract with USDI.

Toxicants Used in Collars. The USDI's experiments with neck collars for sheep began in 1974 with NaCN. Over the first three years of research, the compounds screened with captive coyotes in one-hectare enclosures included NaCN, DPN, mandelonitrile, 4-aminopyridine, phosphamidon, and 1080 (Connolly et al., 1978). Three of these compounds, NaCN, DPN and 1080, have been tested for effectiveness in the field (Connolly et al., 1978; USDI, 1979b; Connolly, 1980). At present, methomyl is being screened for use in toxic collars (Connolly, 1981).

Collar Designs. During the course of experimental study of this method of coyote control, several different collar designs have been developed. An early design tested by USDI was a bulky polyvinylchloride (PVC) collar which included 10 packets each capable of holding 50 ml of liquid (Connolly et al., 1978). This design was used in the initial NaCN field trials. Modifications of this design included reducing the numbers of packets, altering the thickness of the packets, substituting other materials (e.g., different plastics, rubber) for PVC, altering fill valve design, and shifting from nylon to velcro straps for attaching collars to animals. Collar color was changed from white to black. The major reasons for design changes were the needs to:

1) contain the toxicant adequately prior to attack; 2) minimize chances that collars would be lost or displaced prior to attack; and 3) maximize chances that attacking coyotes would be poisoned (i.e., collar designs should neither repel coyotes nor cause them "inadvertently" to miss or fail to puncture the collar or to receive a sublethal dose). Some design modifications have also served to promote safe use of the collar both for the person handling it and the sheep or goat wearing it (Connolly et al., 1978; USDI, 1979b).

The design currently being tested with 1080 consists of a one-piece black rubber body which is fastened around the neck of a sheep or goat by means of two Velcro or elastic straps. The body is divided into two reservoirs. The reservoirs are loaded with toxicant by hypodermic injection. Two sizes of collars of this design are now being used: a smaller size with reservoir capacities of about 15 ml (30 ml per collar), and a larger size with reservoir capacities of 25-30 ml (50-60 ml per collar, Connolly, 1980). The larger size is used on larger lambs and kids and, occasionally, on adult sheep or goats.

Methods of Collar Use. Because of expense, labor requirements and, in some cases, safety considerations (NaCN), researchers have not equipped all animals in a given livestock operation with toxic collars. Instead, researchers have attempted to direct coyote predation toward small numbers of animals which have been collared and placed away from the much larger numbers which have not. In order to influence the coyote's selection of victims, biologists have placed collared animals in regions where predation has occurred in the recent past and have moved most of the uncollared livestock to other locations which were felt to be safer from coyotes.

In USDI's NaCN trials, researchers attempted to direct predation toward individual collared lambs tethered at points along "routes habitually traveled by sheep-killing coyotes" (Connolly et al., 1978, p. 198). This approach had led to collar punctures and coyote kills in pen tests but proved to be unsuccessful in the field. The approach failed not only because relatively few attacks were directed at the tethered lambs, but also because the coyotes that did puncture NaCN collars apparently were not killed.*

Despite the apparent failure to kill coyotes, predation rates "dropped substantially" during the NaCN field trails. The researchers (Connolly et al., 1978) attributed these declines to disturbance caused by increased human activity in the test areas.

Following the NaCN trials, flocks were manipulated in different ways in attempts to direct predation toward collared lambs. Small flocks (up to 10 animals) of collared lambs were placed in pastures either prior to the arrival of the main flocks or after the main flocks had been relocated in areas that were presumed to be safe. These procedures were used for most of the DPN trials (Connolly et al., 1978). Collars were punctured in the DPN field trials, and in some cases, declines in predation were noted after collars were broken. The likelihood that collared animals would be attacked was strongly affected by the degree of separation of the main flock from the target flock.

USDI abandoned the use of DPN in the toxic collar because its slow, anticoagulant killing action permitted lethally dosed coyotes to kill sheep for several days after they had attacked collared sheep. Some apparently healthy coyotes shot from aircraft in the vicinity of the DPN field trails proved to have DPN residues in their tissues (Connolly, 1979). Some of these aerial gunning victims would probably have died from DPN poisoning had they not been shot first.**

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* With a fast-acting toxicant such as NaCN, the coyote carcass would be expected to be found near the site of attack. No coyote carcasses were found in the NaCN field trails even though eight collars were bitten.

** These data also show that at least some of the coyotes taken by aerial gunning are "offending" animals in livestock predation. That these coyotes could have been dosed through scavenging on sheep carcasses was unlikely because of the rather rapid post-mortem clean-up operations used by the researchers in the DPN field trials (USDI, 1979b; Connolly, et al., 1978).

In the 1080 trials (1978 to the present), the sizes of target sheep flocks have been expanded to include more lambs and ewes than in the earlier trials. In the 1978 trials (USDI, 1979b), numbers of collared lambs in target flocks ranged from 7 to 38, while the total number of animals in these flocks ranged from 7 to 70. The first goat trial, run in Texas in 1978, had a target herd of 80 animals, 20 of which wore collars. Target flocks used in trials since 1978 have tended to be of 40 or more animals, with 40 percent or more of the animals being collared young. Adult animals are occasionally collared, especially on trials which use goats as the livestock species to be protected.

USDI's field trials with 1080 collars have produced three major types of results. In one type of outcome, predation ceased after one or two collars were punctured. While it is tempting to conclude that such trials are clear demonstrations of effective control, there have been other trials in which predation stopped in the absence of punctured collars. This second type of result, which was also encountered in the diphacinone trials (Connolly et al., 1978), has been attributed to the removal of the problem coyotes by other means (Connolly, 1980; USDI, 1979b).* In the third type of finding, killings continue even after a few collars are broken. In these trials, predation rate often has been reduced after additional collars were broken and coyotes were taken by other means as well. In these situations, the collar was used as a tool in a predator control arsenal. Even in these cases, however, the action of the collar was corrective because all coyotes taken with it had demonstrated an interest in attacking livestock. The collar has not accomplished the total corrective job in situations in which there were some predators that did not attack the throat, whether these other predators were coyotes, dogs, or some other species. (Connolly, 1980; 1979b).

* In field trials, it generally has not proven to be possible to eliminate all methods of control other than the one under study. The fact that coyotes range over vast areas and are thus subject to interaction with the interests of many different humans is a major reason why the elimination of other types of control is so difficult to achieve.

The collar's selectivity for offending coyotes is its major advantage. This method is labor intensive to use and can be very costly when material and labor costs are included (especially when one considers that the costs of the "sacrificial" lambs or kids must be borne by the rancher involved with the use of the collar). It is believed by some (Texas Sheep and Goat Raisers Association, Appendix G, Connolly, 1980) that ranchers must be permitted to apply collars if they are to be used efficiently. According to this argument, responses to loss situations would be too slow if ranchers were forced to delay collar application until times suited to the schedules of local trappers or other professional applicators.

The collar is expected to be most useful in farm flock and fenced pasture situations which facilitate the manipulation and segregation of target and non-target flocks (USDI, 1979b; Connolly, 1980). It is unlikely that the collar can be used successfully in typical range operations.

If the collar is introduced for operational use, an accounting and recovery system may be useful. A system under which ranchers rent (with deposit) collars from government agencies may provide sufficient incentives to insure that excess collars are returned and that searches for lost collars are conducted.

3. Single Lethal Baits

The extent to which this method was used prior to 1972 for delivering 1080 to coyotes and other species is not known. A somewhat similar scheme was used to deliver strychnine, but single lethal or "drop" baits laced with 1080 received very little mention in the primary resource documents used by the EPA in 1972 (See Table V-1).

The concept of the single lethal bait is to place coyote-attractive materials that are laced with enough 1080 to kill one coyote. In theory, the coyote would consume the entire bait and would be fatally poisoned (with virtual certainty). The amount of 1080 in the bait would be carefully controlled so that the hazards to species less sensitive to 1080 (or larger) than the coyote would be reduced. The preparer of such baits, then, would be expected to be very careful to avoid overdosing or underdosing baits. Sublethally dosed coyotes would be expected to become bait shy (see section [C.3] on aversive conditioning agents).

Bait materials proposed for use are animal products such as "ground or rendered lard, tallow or other fats" (ASTM, 1976, p.7). These materials are expected to remain stable in cool weather but would melt at warmer temperatures. Warm weather is expected to destroy the baits, leading to the removal and degradation of the 1080 by plants and bacteria, respectively (ASTM, 1976).

Two methods of preparation of single lethal baits have been described (ASTM, 1976). In one method, 1080 concentrate would be mixed directly with melted bait material. The mixture would then be subdivided into 10-15 gram portions. In the second method, pellets or capsules containing a single lethal dose for the intended target species would be inserted into "preformed solid baits" (ASTM, 1976, p.9). The amounts of 1080 to be used in preparing single lethal dose baits have been listed as 5 mg for coyotes, 3 mg for red foxes, and 2 mg for gray foxes (ASTM, 1976). The levels listed by ASTM for coyotes and red foxes have been proposed by Wyoming (1981) and Colorado (1981) in their applications for Section 24(c) "Special Local Need" registrations. In its registration application, Montana (1981) proposes to use 3.6 mg doses for coyotes. (See Table III-1).

In use, single lethal baits are to be placed near "established draw stations" (intentionally placed animal carcasses) or near "preferred travel routes in suitable locations for the target animals to find them" (ASTM, 1976, p.13). The number of baits to be placed in one location is left to the discretion of the applicator, who is expected to weigh various local factors such as perceived densities of target and non-target species in determining the proper number of baits to be placed. Bait densities proposed in applications for registration of this use are summarized in Table III-1.

Various procedures have been recommended for discouraging bait take by non-target species and encouraging the take by target species. Some of these procedures include covering baits with stones, cowchips, or other objects (ASTM, 1976), burying baits or elevating them (Linhart et al., 1968; Tigner et al., 1981). Fish meal or other attractants have been added to baits to attract coyotes (Tigner et al., 1981). Sonic emitters have been tested as alternative "draw stations" to livestock carcasses (Tigner et al., 1981).

The usefulness of these measures in reducing take by non-target species is discussed in Section VI. Of interest here is the observation that a bait taken by a non-target organism is a bait not available for consumption by the target species. Experiments with drop baits that did not contain 1080 (Linhart et al., 1968; Tigner et al., 1981) have indicated that many baits may be taken by non-target species and that relatively few of the coyotes collected from baited areas actually consume these baits.

While the information gathering hearings elicited much testimony regarding the efficacy and safety of single lethal dose drop baits, very little was offered in the way of evidence. Glosser's (1981) information concerning the baiting of feral dogs in Guam is not relevant to the baiting of coyotes in the western U.S. Data supporting the ASTM (1976) procedures for using single lethal dose baits were not presented. The Agency possesses no data on the efficacy of 1080 single lethal dose baits from either laboratory or field testing. This lack of data restricts the Agency's ability to assess the possible benefits of this delivery mechanism.

Information currently available does not indicate whether effective and selective delivery is possible through use of drop baits. The value of any future field research conducted in this area would be enhanced by data on densities of species of concern in the test areas. In the absence of such data, a result showing that coyotes accounted for nearly all of the baits taken in an area could mean either that a selective baiting procedure had been developed or that the non-target species which might be attracted to the bait placements used were simply not present in the study area.

C. Other Chemical Methods

1. Sodium Cyanide

Prior to the cancellation decision of 1972, the primary mechanism for the delivery of sodium cyanide to coyotes was the "Humane Coyote Getter." This device was embedded vertically in the ground. When a coyote or other animal tugged on a meat lure attached to the exposed end of the "getter," a gunpowder explosion was triggered, forcing a cyanide capsule into the mouth and producing a rapid death. In the M-44 device, a spring ejector is substituted for the gunpowder mechanism. Although the M-44 device was developed prior to the cancellation of sodium cyanide as a predacide, the negative perceptions of the use pattern in 1972 (Table V-1) were based primarily on the use of the "getter."

Following cancellation of this use, various state and federal agencies petitioned the EPA for experimental use of sodium cyanide in the M-44. The use pattern was ultimately registered (Table V-1). The "significant new evidence" supporting the registration of sodium cyanide in the M-44 included the documentation of a greater degree of selectivity for target species than had been attributed to the use of the "getter" and the M-44 in 1972. Nearly three-fourths to all of the animals known to have been taken with the M-44 in various campaigns have been coyotes, with canid species (coyote, fox, feral dog) comprising 89 percent or more of the total known take (Beasom, 1974; USDI, 1978, 1979a).

Reports of limitations and failures of the M-44 device have been mentioned in recent publications (USDI, 1978) and at the information gathering hearings (e.g., Levinston, 1981; Barron, 1981; Wade, 1981). Major limitations cited are the 26 use conditions attached to the registration (USDI, 1978; Rost, 1981; Wade, 1981) and the inapplicability of the method in winter in the northern states (Hibbard, 1981; Madsen, 1981; Uhalde, 1981). Caking of cyanide in the capsules has been cited as a reason why some animals discharging the M-44 devices are not killed. Mechanical failures noted include jamming of devices by dirt and corrosion.

Despite these problems, some individuals are now using the M-44 effectively. The USDI animal damage control program is now engaged in efforts to improve the reliability of this tool.

2. Repellents and Reproductive Inhibitors

Cain *et al*. (1972) placed great faith in the notion that effective chemical repellents and/or reproductive inhibitors could be developed which would provide effective solutions to many predator problems. The effects attributed to these methods were apparently theoretical because specific compounds were not mentioned. At the information gathering hearings, Havens (1981) recommended these approaches. Hodder (1981) discussed a "repellent" product applied to sheep but did not disclose its composition. Uhalde (1981) reported an inability to find an effective repellent.

Research reported on both methods before and after 1972 has yielded generally disappointing results. For example, trials using diethyl stilbestrol (DES) in drop baits as a sterilant for coyotes did not produce a technique that could be used operationally to suppress reproduction in this species (Linhart *et al*., 1968). Experiments with repellents have failed to identify chemicals which are consistently repellent to coyotes and do not harm sheep (Lehner *et al*., 1976).

3. Aversive Conditioning Agents

The area of non-lethal chemical control of predation which has received the greatest amount of research attention since

1972 is the development of conditioned aversions to prey. Presently, there are no chemicals registered for this use. At the information gathering hearings, however, representatives of several conservation and wildlife groups expressed support for the use of lithium chloride as an aversive agent (e.g., Armentrout, 1981; Atkins, 1981; Dungan, 1981; Scott, 1981; Stevens, 1981). Because of this interest and the extensive amount of recent experimentation on this approach, aversive conditioning of coyotes is discussed at length.

When an animal becomes ill following the ingestion of any substance, the animal may subsequently be reluctant to eat that substance again. Particularly strong conditioned food aversions result when the ingested substance is new to the animal, when the substance has a distinctive flavor, and when the (apparent) physical discomfort following ingestion is severe (Garcia et al., 1974). It is not necessary to the development of conditioned food aversions that the ingested material actually be responsible for the internal malaise, as long as the discomfort follows ingestion in time.*

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* The circumstances under which the formation of a conditioned food aversion has survival value, however, arise when the ingested material is also the source of the illness inducing factors. By correctly mentally linking the effect (illness) with the flavor (for mammals, taste stimuli seem to be more important in this regard than odors), the animal is able to avoid future poisonings by the same ingested substance or mixture of substances. While the animals use the conditioned food aversions to their advantage in dealing with toxic materials, the prime mover behind the elaboration of the process has probably been the development of toxic "defensive" chemicals by plant communities. Such toxic plant secondary compounds include some widely known and used pesticidal agents (e.g., pyrethrins, rotenone, red squill, sodium fluoroacetate, strychnine, etc.) and drugs (e.g., caffeine, atropine, opium, quinine, etc.).

That mammalian pests can form conditioned aversions to toxicants placed by man in control efforts is common experience and has given rise to the term "bait shyness." This built-in defense mechanism is of little value to the animal, however, if it has consumed a lethal dose before symptoms are detected. For this reason, animals tend to be cautious in sampling new foods. Nevertheless, many animals are fatally poisoned in pest control programs or by naturally occurring toxicants. Consumption of toxic plants can be a significant mortality factor in sheep and goat raising in the U.S. (Gee et al., 1977; Walther et al., 1979). Livestock eating Australian or African plants containing 1080 are often fatally poisoned (Aplin, undated; Pattison, 1959).

In recent years, there have been several attempts to exploit the conditioned aversion phenomenon for man's benefit in animal damage management (cf., Rogers, 1978). Such endeavors are complicated by the additional variables encountered when moving from the laboratory to the field and by the fact that it is frequently necessary to break animals of established feeding habits (as opposed to conditioning them not to eat a new food) in pest control applications. Nevertheless, there have been some reports of success in influencing the depredatory activities of vertebrate animals through use of the conditioned aversion phenomenon. The trials involving coyote's selection of prey are reviewed below.

The appeal of exploiting the conditioned food aversion process to resolve the coyote-sheep problem is that a successful program would spare both prey and predator (Garcia *et al*., 1974). Initial studies by Gustavson *et al*.(1974, 1976) demonstrated the conditioned aversion phenomenon in coyotes. Four coyotes fed fresh hamburger laced with lithium chloride, a mild toxin, became ill (vomited). Four days later, these animals refused to eat untainted fresh hamburger (Gustavson *et al*., 1974). One of three coyotes fed a bait composed of lithium treated lamb meat wrapped in a woolly hide failed to attack a live lamb four days later even though all three had killed lambs two days prior to the exposure to the lithium bait. The two coyotes that had continued to kill lambs were given a second experience with a lithium-laced lamb bait followed by an intraperitoneal injection of LiCl. These animals refused to attack live lambs presented four days after the second LiCl treatment. Results obtained with three coyotes trained to avoid rabbit meat were essentially similar to the lamb trials: two animals required two treatments before refusing to attack live rabbits. The third refused to attack after one treatment. The aversive conditioning did not appear to be permanent for the coyotes conditioned with LiCl after eating rabbit flesh (Gustavson *et al*., 1974).

In a second series of experiments, Gustavson *et al*. (1976) reported the conditioning of six coyotes to avoid eating rabbits after experience with rabbit carcasses or "rabbit-bait" packages laced with LiCl. Five of these animals required two experiences with tainted meat. One of these five continued to kill rabbits introduced into her cage but did not eat them.

Gustavson et al. (1976) also reported results of field trials in which they attempted to reduce predation by using lithium-laced baits. The first baits were composed of dog food mixed with LiCl and wrapped in sheep hides. Subsequently, sheep carcasses were injected or sprayed with LiCl and moved to bait station areas or allowed to remain in the spot where the sheep had been found dead. Feeding on these baits appeared to stop in March (dog food) and April (sheep carcasses) after about two and three months of exposure, respectively. Losses for the study season were compared with the cooperating rancher's loss records for the three previous years (1972-1974). The authors noted considerable disagreement between themselves and the rancher in sheep losses attributed to coyote predation. Using the rancher's records, Gustavson et al. (1976) calculated a predation rate of 30 percent lower than the average for the previous three years. Using their own records, the authors estimated a 60 percent reduction in losses to coyotes.

Other field trials in which successful application of conditioned aversions to reduce sheep losses to coyotes have been reported by Stream (1976a), Ellins et al. (1977), and Gustavson et al. (1977). Procedures used in these studies were generally similar to those employed by Gustavson et al. (1976) in that LiCl was the agent used to induce illness and that the LiCl was presented in baits consisting of sheep meat wrapped in sheep hide, injected carcasses of sheep which died on the range, and dog food wrapped in sheep hide. These studies were undertaken in Washington (state), California, and Saskatchewan. The Saskatchewan data came from rancher use studies involving 19 herds comprising nearly 22,000 sheep and lambs, and a total combined land area of nearly 140 square miles (Gustavson et al., 1976). Overall, losses to coyotes were reported to be 66 percent lower in the year that LiCl was used (1976) than they had been in the previous years. Losses were reported to have been reduced for 14 herds, with loss reductions exceeding 80 percent for nine of these. Losses were reported to have increased for two herds (6 percent and 40 percent), while one herd reportedly suffered no losses in either year and two more herds lacked loss estimate data for 1975.

Despite these reported successes of conditioned food aversion approaches to resolving sheep predation problems, the usefulness of this technique and the validity of the data reported above have been questioned. Bekoff (1975) criticized the conclusions of the authors (Gustavson et al., 1974) of the original demonstration of conditioned aversion in captive coyotes on the grounds that transfer of training from bait to live prey was established only with difficulty (two of three subjects required ingestion of two lithium laced baits plus a LiCl injection). Sterner and Shumaker (1978) noted a lack of appropriate controls and detailed reporting of procedures in studies reporting successful application of LiCl to reduce livestock predation by coyotes. Conover et al. (1977), Lehner and Horn (1977), Burns (1977), Burns and Connolly (1980), and Griffiths (1978) have all reported problems with transferring conditioned food aversions from treated baits to live prey. In three of these studies (Conover et al., 1977; Burns, 1977; Griffiths, 1978), researhers encountered difficulty in attaining even distributions of LiCl in injected carcasses and observed that coyotes learned to avoid treated spots in feeding on such baits.* Conover et al. (1977) provided their coyotes with intense preconditioning experience with live and untainted dead prey, procedures which would be expected to enhance the selectivity of any aversions established but which also represent a closer approximation of the situation encountered in the field by the reseacher attempting to break predators of established feeding habits. The studies with

* Similar problems of toxicant distribution have been mentioned for the injection of carcasses with 1080 solution (e.g., Natural Resources Defense Council et al., 1971)

captive animals agree that it is possible to establish some sort of conditioned food aversion in coyotes, but the permanence of such aversions is debated (Lehner and Horn, 1977), as is their applicability in field situations (Burns and Connolly, 1980).

Griffiths et al. (1978) reviewed prior research with LiCl as an aversive agent for regulating predation by coyotes. Their paper includes a detailed critique of the "positive" field results reported by Gustavson et al. (1976), Stream (1976a), and Ellins et al. (1977). Their review illustrates the need for caution in interpreting the results of all predator loss studies.

Griffiths et al. (1978) noted some factors in the data from the field trials in Washington (Honn Ranch) which Gustavson et al. (1976) and Stream (1976a) did not take into account in their discussions of results, although Stream (1976b) later reassessed his data. Griffiths et al. (1978) noted that although it was true that fewer lambs were killed and that the rates of lambs killed per week were lower in 1975 and 1976 than in 1972, 1973 and 1974, it was also true that the total numbers of lambs grazed were much lower in 1975 and 1976 than in the years prior to 1974. The percents of lambs lost in 1975 and 1976 were higher than the values obtained in any of the years from 1970 through 1974. Griffiths et al. (1978) also noted a significant negative correlation between the rates of lambs and ewes killed per week and the numbers of coyotes removed by the local trapper for the years 1970-76. Changes in husbandry practices, addition of fencing, and the use of other control methods concurrently with the LiCl trials were noted as other factors confounding the Honn Ranch data.

In the Ellins et al. (1977) study (Antelope Valley, California), Griffiths et al. (1978) noted the following weaknesses: absence of comparable loss data from other regions or other years (in which LiCl was not used); absence of information concerning concurrent use of other coyote control methods in study area; and inadequate explanation for the continued take of LiCl baits after killing of lambs had ceased. Griffiths et al. (1978) also speculated that other control methods (e.g., traps, snares, shooting, 1080 injections in fresh kills) may have been used along with LiCl in some of the study areas in Saskatchewan (studied by Gustavson et al., 1976). The reviewers acknowledge a possibility that LiCl used alone may have produced loss reductions in some of the Saskatchewan study sites, pointing toward a need for more tightly designed and controlled studies of LiCl in the field. The authors of a field study conducted recently in Alberta (Bourne and Dorance, 1981) have concluded that LiCl baits did not reduce coyote predation on sheep. In this study, the effects of LiCltreated and placebo baits were compared.

Griffiths et al. (1978) indicated that the development of an effective bait (i.e., one not subject to uneven toxicant distribution) and the determination of the rate of extinction of an acquired aversion are essential for the assessment of the conditioned aversion approach as a predation control tool. These authors also noted that field trials of LiCl induced aversions, like those of any other method:

> . . . must not only demonstrate that predation would have occurred in the absence of the treatment, but also, that any observed reduction in predation resulted from the experimental treatment and not from other causes. (Griffiths et al., 1978, p.193)

These performance criteria also have not been met in studies of other predator control methods. The criteria usually "settled for" with lethal and/or capture methods are the demonstration that the method will kill (or capture) coyotes and the compilations of data which indicate the degree of selectivity of the method for target organisms (variously defined as "offending" animals, coyotes, canids, carnivores, etc.--cf., Cain et al., 1972; USDI, 1978, 1979a; Connolly, 1980). With a method which does not capture or provide readily located victims, application of the more stringent criteria of Griffiths et al. (1978) is needed in order to draw any inferences concerning the usefulness of the method.

D. Mechanical Control Methods

The Cain Commission (Cain et al., 1972), the conservation groups petitioning the EPA in 1972 (Natural Resources Defense Council et al., 1971) and, ultimately, the Administrator of EPA (Ruckelshaus, 1972) were in agreement that methods available as alternatives to the use of toxicants were sufficient to control predator damage to livestock. The Administrator noted:

> For the maintenance of predator control programs, especially in the sheep industry, effective non-chemical alternatives exist, including denning, shooting, and trapping, methods that have long been available and effective, though more costly than poisons. (Ruckelshaus, 1972, p. 5720)

Table V-1 summarizes the assessments of these methods which appeared in the major support documents reviewed by the Agency in 1972. Studies of these methods have indicated some support for these conclusions as well as some contradictions and some areas which merit further investigation.

1. Aerial Gunning

Cain et al. (1972) recommended that this practice be limited to "authorized biologists of the appropriate Federal and State Agencies" (p.9). The commission did not believe that the method would be used very often. Since 1972, however, aerial shooting has accounted for a substantial proportion of the total known coyote take by the USDI Animal Damage Control (ADC) Program. In 1976, for example, more than one third of the coyotes known to have been taken in the ADC program were shot from aircraft (USDI, 1978). The method is costly on a per-hour basis with costs increaing sharply in recent years (Glosser, 1981; Treat, 1981;

Koch, 1981) Although the take/man year of effort tends to be high on the average (USDI, 1978), the productivity of aerial gunning of coyotes can vary considerably from region to region and season to season (Anderson et al., 1974a, b). In brushy areas, for example, locating coyotes from the air can be difficult.

Aerial gunning is practiced in areas where livestock damage is occurring. Diphacinone residues (from the DPN toxic collar trials) were found in several coyotes shot from aircraft, indicating that "offending" coyotes are taken by this method (Connolly, et al., 1980).

2. Ground Shooting

Animals shot from the ground may be lured into open areas by use of calls or dogs or they may simply be hunted. Although the USDI's (1978) assessments of ground shooting are at variance with those of Cain et al. (1972-see Table V-1), there has been very little new information developed on ground shooting since the toxicant ban.

3. Denning

In this method, coyote dens and their occupants are destroyed. The method can only be used during the spring months when dens are used. The theory behind denning is that not only are coyote pups killed, but also the need for the adults to obtain large amounts of food is removed (Young and Dobyns, 1945). As a result, a pair not taken may decrease its rate of predation or stop taking livestock entirely when its pups are taken through denning (USDI, 1978). Although Cain et al. (1972) favored this method as an effective troubleshooting tool, denning is no longer practiced by ADC personnel following a directive from the Secretary of the Interior (Andrus, 1979).

4. Traps

The steel leg-hold trap is the most widely used coyote trap.

It usually is not lethal to its victim, although target animals captured are generally destroyed. Non-target species are frequently caught in these traps, but selectivity for target species reportedly can be improved by selecting the proper type of set and scent (USDI, 1978; Boddicker, 1981). Efficient, selective use of steel leg-hold traps requires special skills and experience. Reports of total takes of animals (e.g., USDI, 1978, p.79) do not accurately reflect the selectivity of the method since different species may be targeted in different trapping situations. Recent work by USDI personnel has been directed toward improving humaneness and selectivity by using tranquilizer tabs and pan tension devices.

Traps are useful in corrective situations, but the time and labor needed for their deployment renders them inefficient in prophylactic control operations. Cain et al. (1972) and the conservation groups (Natural Resources Defense Council, 1971) believed that extension programs could be used West-wide for training livestock producers in the proper use of steel leg-hold traps, thus placing much of the manpower burden for predator control on the producer himself. Such a system has been reported to be successful in Kansas (Henderson, 1972; Robel, 1981). Boddicker (1981) doubts that this approach can be successfully applied as the only predator control system in the more mountainous states.

5. Neck-Snares

Neck snares were not discussed in the support documents used by EPA in 1972. Snares are loops of wire used to choke target animals as they pass through restricted areas such as habitual places of travel through or under fencing. Non-target animals are sometimes taken by snares. Careful selection of sites and knowledge of the animals in the area can improve selectivity (USDI, 1978). The effectiveness and selectivity of neck snares in Texas has recently been reported by Guthery and Beasom (1978). These authors believe that snares can be effective in prophylactic control programs in areas in which woven-wire fencing is used extensively. In other areas, snares may be "poor" in population reduction efficiency and in cost per coyote taken (USDI, 1978).

E. Livestock Husbandry Practices

In recommending expanded extension programs to enable sheep producers to resolve their problems with predators, Cain *et al.* (1972) suggested that these programs should encourage "the use of better husbandry and management practices" (p. 111) as well as instructing producers in mechanical control techniques. Since the toxicant ban, there has been considerable public debate over management practices (for examples, the 1978 Animal Damage Control Policy Study hearings and the 1981 EPA information gathering hearings). Opponents of the use of 1080 for predator control generally urge livestock producers to practice better husbandry (cf. Atkins, 1981; Hoff, 1981). Proponents of reintroduction of 1080 argue that producers are now practicing all of the known antipredation husbandry techniques suitable to their types of operations which are economically and logistically feasible (cf. Helle, 1981; Hibbard,1981). Support for both sides' contentions and, consequently, illustration of the bind in which the livestock producer may find himself, is found in the work of Faulkner and Tigner (1977). These researchers found that the practice of shed lambing consistently increased the number of lambs per 100 ewes that survived until docking over the docking percent obtained for lambs born on the open range to ewes from the same flocks. For the areas and types of operations studied, however, shed lambing for entire bands of sheep is prohibitively expensive (Faulkner and Tigner, 1977).

Nass (1980a, b) has recently reviewed the various husbandry practices thought to reduce predation (Table V-2) and has identified the types of operations on which these practices could be used (Table V-3). Most of these practices are fairly traditional in American sheep raising although new data are being gathered on their utilities. The use of dogs to guard sheep flocks is

Table V-2

Husbandry Practice Tradeoffs

Husbandry Practice	Advantages	Disadvantages
Confinement raising of sheep	May reduce predation Problems easily seen	More disease problems Higher feed costs
Confinement raising of lambs	May reduce predation Gain weight faster	More disease problems Higher feed costs
Confinement at night	May reduce predation Problems easily seen	Limits grazing time More labor involved
Selective use of pastures	May reduce predation	May waste forage Possible reduction of sheep numbers
Check sheep daily	May reduce predation Problems easily seen	More labor involved Overhead increased
Additional herders	May reduce predation	Higher costs
Herders in large pastures	May reduce predation Problems easily seen	Higher costs
Close herding	May reduce predation Problems easily seen	Soil compaction and erosion Vegetative compaction
Shed lambing	Increased lamb survival Predation reduced	Disease increased More labor required Initial cost high
Carrion disposal	May reduce predation	More labor involved
Keep flock healthy	More lambs marketed Possible less predation	May increase feed costs More labor required
Change lambing dates	Lambs absent in critical periods	May not fit labor pattern Forage may not be available
Shorten lambing period	Reduce small lamb exposure Uniform marketing improved	Intensive labor requirements Sheds may be too small
Improved fencing	May reduce predation Better grazing distribution Limits predator access	Initial costs higher Higher costs to maintain

Table V-2 (Continued)

Husbandry Practice Tradeoffs

Husbandry Practice	Advantages	Disadvantages
Truck sheep instead of trail	May reduce predation Less small lamb mortality	Costs are high Extra feed may be required
Related Predation Reduction Practices		
Lighted corrals	May reduce predation Easier to check on sheep	Increased costs
Bells on sheep	May reduce predation	Cost of bells and collars Labor increased Questionable efficacy
Guarding dogs present	May reduce coyote predation	May increase dog predation Costs increased
Electric fencing	Reduces predation Keeps stock from straying	Costs higher High costs to maintain

From Nass, 1980b.

Table V-3

A List of Livestock Husbandry Practices that May Reduce Predation

Husbandry Practice	Farm Flock	Large Pasture	Range
	Applicable Application		
Confinement raising of sheep	X	X	
Confinement raising of lambs	X	X	X
Confinement at night	X		
Selective use of pastures	X	X	X
Check sheep daily	X	X	X
Additional herders			X
Herders in large pastures		X(?)	
Close herding			X
Shed lambing	X	X	X
Carrion disposal	X	X	
Keep flock healthy	X	X	X
Change lambing dates	X	X	X
Shorten lambing period	X	X	X
Improved fencing	X	X	
Truck sheep instead of trail		X	X
Related Predator Reduction Practices			
Lighted corrals	X		
Bells on sheep	X	X	X
Guarding dogs present	X	X(?)	X
Electric fencing	X	X	

From Nass, 1980b.

relatively new in this country. This practice is reviewed briefly below.

1. Guard Dogs

Interest in the use of dogs to protect sheep from predation has increased greatly in the U.S. in recent years. Spurred by government and university research, this approach has apparently been effective in reducing predation on certain operations (Coppinger, 1980; Green and Woodruff, 1980). Some opponents to the reintroduction of 1080 as a predacide favor the use of guard dogs (e.g. Atkins, 1981; Stevens 1981).

The breeds of dogs which researchers, ranchers and farmers have evaluated as livestock protectors are types which are used in Europe and Asia to protect sheep. These breeds include Komondor, Kuvasz, Great Pyrenees, Anatolian Shepherd, Ovcharka, Maremma, Sar Planinetz, and Karabash (Coppinger, 1980; Green et al., 1980). The breeds which can be used effectively as livestock guard dogs differ behaviorally from the sheep herding breeds. While herding, dogs frequently direct elements of hunting behavior sequences (e.g., stalking) toward the sheep, guard dogs' responses to their charges tend to be more filial (Coppinger, 1980)

Socialization of dogs to sheep (or other livestock) is an essential element in the development of guard dogs. A properly socialized guard dog will exhibit the following behaviors necessary for livestock protection: "nonaggression toward the sheep, attentiveness to the sheep ('following instinct'), and defense of the sheep" (Coppinger, 1980). Proper socialization includes exposure to livestock and livestock operations at an early age and some general training in obedience and for the elimination of undesirable behaviors such as the harassing of livestock (Green and Woodruff, 1980). Using dogs that were probably too old for complete socialization toward sheep, Linhart et al. (1979) reported some harassment of sheep by guard dogs. Nevertheless, coyote predation on sheep appeared to have been suppressed in this study by the presence of dogs (Komondorok).

Even when conditions are optimal for socialization and training, not all individuals of the sheep guarding breeds actually become effective livestock protectors (Green and Woodruff, 1980). The use of dogs may not be appropriate for all situations or for all producers (Green and Woodruff, 1980). For example, at the information gathering hearings, Popoulas (1981) and Howard (1981a) reported lack of success in using guard dogs. Green et al. (1980) have recently summarized some of the economic factors involved with the use of guard dogs, an historically old practice that has only recently been promoted in this country. The producer must spend a considerable sum of money to acquire and feed a dog and this dog must be conditioned to the livestock operation. Whether the dog "pays for itself" is determined by the amount of relief from predation which can be attributed to the presence of the dog.*

F. Effects of Coyote Control on Livestock Losses

Beyond the question of whether an individual method kills, repels or captures coyotes lies the question of the value of coyote control in reducing losses of livestock. The primary reference documents used by the Agency in 1972 (Natural Resources Defense Council, 1972; Leopold, 1964; Cain et al., 1972) and the Administrator himself questioned the benefits derived from the use of predacides (Ruckelshaus, 1972).

Since 1972, the percents of sheep and goats taken by coyotes and/or other predators have been estimated in many publications. While there is much variation among studies in loss estimates, in methods of estimation, and in other relevant areas, lower estimates are usually reported for areas in which predator control has been practiced than where no control measures were used (cf. Section IV; USDI, 1978; Nass, 1980c).

* Dogs working in areas where 1080 baits were placed would probably be killed if they consumed baits. Any program for reintroduction of 1080 baits should provide for protection of herd and guard dogs.

The exact relationship between coyote control and the loss of livestock to coyotes is not defined. The Cain Commission opposed the idea of obtaining relief from livestock damage through campaigns designed to achieve general suppression of coyote populations. The Cain Commission stated that localized loss problems could be resolved by selective removal of the individual ("offending") animals responsible for the damage. Proponents of predator control have stated that individuals engaged in predator control must have a large variety of control methods at their disposal to meet the demands of the variety of circumstances which arise (Grieb, 1981; Beck, 1981). One such circumstance is said to be the situation in which local coyote population reduction or extermination is the most efficient (or best, or only) way to stop predation on livestock. Another problem situation is said to arise when coyote predation cannot be stopped by the use of the control techniques now available.*

Despite the controversy stirred by the topic of coyote control, there are several areas of tacit agreement among nearly all parties. The first is that in the absence of coyotes, there are no livestock lost to coyotes. Although some, including Cain et al. (1972), have argued that many lambs lost to coyotes would have been lost to other causes, the seemingly trivial point that no coyotes present means no loss to coyotes gives rise to the second area of tacit agreement: that coyote predation on livestock is in some way related to coyote density. The way(s) in which livestock loss may be related to coyote density are not known and have not been subject to a great deal of research or theoretical modeling. The third area of tacit agreement is that by killing, repelling or mitigating the offending coyotes, one can stop predation by coyotes. The unanswered questions in this area involve the most efficient way(s) of controlling offending

* Many of those who believe that currently available methods are not sufficiently effective believe that effective control of coyote predation on livestock could be achieved by the addition of 1080 to the control agent's arsenal (e.g., Bowns, 1981; Beck, 1981; Grieb, 1981; Meike, 1981).

coyotes and the changes in the behavior of surviving coyotes which are precipitated by removal of offending (or other) coyotes.

At the information gathering hearings some opponents of predator control (e.g., Morris, 1981; Ryden, 1981; Strojny, 1981) have argued that disturbing coyote population through predator control efforts actually increases predation through a variety of effects including stimulation of coyote reproduction (both in percent of females reproducing and in average litter size per whelping bitch), and stimulation of immigration by opportunistic coyotes which would be more likely than the former residents to select livestock as prey. Where toxic baits are used, Ryden (1981) argued that coyotes with a tendency to feed on carrion would selectively be removed from the local population, while the more strictly predacious conspecifics would survive. While there is no clearcut evidence to support many of these contentions, Knowlton (1972) has reported greater average numbers of uterine swellings in female coyotes captured in areas where predator control efforts were intense than in females from areas not subjected to extensive control programs. That high, stable populations of coyotes can exist in the same area as livestock operations without significant amounts of losses may be questioned since these carnivores would be required to exist on available supplies of natural live prey and carrion, both of which are subject to seasonal and other cyclical fluctuations in availability. As support for the contention that such coexistence is possible, Ryden (1981) cited lower levels of sheep and lamb losses in Kansas than in Wyoming despite the higher coyote index in Kansas. The validity of such a comparison may be questioned, however, due to difference between the two states in climate, topography, predominant types of livestock operations and habits of natural prey (cf. Boddicker's [1981] distinction between conditions in Kansas and Colorado).

While there is some agreement that not all coyotes living close to ranch or farm operations will prey upon livestock, the proportion of coyotes living under such conditions that are (or may become) livestock predators is not known.* The Cain Commission and many of the representatives of conservation groups testifying at the information gathering hearings (cf., Armentrout, 1981; Wentz, 1981; Reed, 1981) have implied that only a small proportion of local populations of coyotes prey upon livestock. Robel (1981) has recently stated that removal of one to three coyotes resolved predation problems for about 40 percent of the cooperators in a recent study.

Although some of the field studies (Connolly, 1980; Connolly et al., 1978; USDI, 1979b) conducted with the toxic collar appear to support the notion that removing a few offending animals can resolve coyote predation problems, these data are subject to other interpretations. The observation that losses stopped after a few collars were punctured is also consistent with the theory that a few immigrants had been removed from a previously coyote-free area.**

When predation stops after collars are used in conjunction with other methods, one cannot be sure whether the collar contributed by taking the "true" offending animals or by serving as the "last straw" in a general population reduction effort. For example, the toxic collar has been tested for two years near Meridian, Texas, on several goat ranches which are managed by one individual. From July 1979 through June 1981, thirty-six punctures of collars have been confirmed or appear to have occurred (Howard, 1981b). During that same period, 266 coyotes

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* The percent of coyotes that are "offenders" is probably not a stable value. The proportion could vary considerably from one situation to another. Althoff and Gipson (1981) recently reported that 3 of 19 radio collared coyotes (from 2 of 8 "families") known to range within 5 km of two Nebraska turkey operations were known to have killed turkeys. However, known home ranges for these animals showed that only one family's range overlapped the production sites extensively. Untagged coyotes were also believed to be involved in predation, leaving uncertain the estimate of the percent of offenders among the local coyote population.

** The same interpretation could be applied to explain the observations reported by Robel (1981; Robel et al., 1981) unless it were known that coyotes remained in the damage area after "offending animal" control had stopped livestock losses.

are known to have been taken by other control methods used on or near the properties where the livestock (principally angora goats) have been run. While this effort has led to significant reduction in rates of loss to coyotes, the data do not indicate the relative contribution of the various methods to the reduction of predation. Since the coyotes taken by the collar were clearly predators on livestock, at least 12 percent of the total number taken were offending animals. It is also possible, however, that all coyotes taken had preyed upon livestock at least once.

If it can be shown that nearly all coyotes living in proximity to livestock operations are (or can be expected to be) significant predators on livestock, predator population supression may provide an efficient way of reducing predation. A simulation model developed by Connolly and Longhurst (1975) suggests that coyote extermination over large geographical areas would require massive effort,* given the apparent capacity of the species to intensify its reproductive effort in response to control programs. If future studies show that offending coyotes constitute a small (and relatively constant) portion of coyote populations, prophylactic control programs would not be efficient (or necessary) for resolving predator problems. Since two of the proposed uses of 1080 (bait stations and single lethal dose baits) are primarily sought for purposes of population suppression, the usefulness of such approaches in reducing predation depends directly upon the proportion of the local coyote population which preys upon livestock.

The timing of predator control may also affect its efficacy in reducing livestock loss. The notion that control is most effective when practiced just before or during the coyote's reproductive season dates back at least as far as Robinson's (1948) report and has recently been reiterated by Dorrance (1980)

* The cost of such an effort would depend upon the methods used to achieve control. The use of toxic baits is reportedly much more economical than mechanical control methods (cf., Boddicker, 1981; Bourret,1981)

who studied the use of toxicants by livestock producers in Alberta.* It is possible that the loss of 1080 bait stations and, more recently, denning from the ADC program's arsenal have hindered federal efforts at disrupting coyote reproduction in high loss areas. If this is true, the reported higher livestock loss levels and higher takes of coyotes in the post 1972 period may not be irreconcilable.** Inappropriately timed efforts may have led to a need to take more coyotes.

The period (1972 to the present) since the cancellation of uses of 1080 as a predacide has seen an unprecedented research effort directed toward various aspects of coyote predation on livestock. Most of this research, however, has either documented the existence of predation problems or demonstrated the utilities and limitations of control and management methods which do not involve the use of 1080. Much of this new information has been reviewed in this section. The toxic collar is the only proposed use of 1080 for which a significant amount of data pertinent to the prevention of coyote predation on livestock have been generated (e.g., Connolly, 1980; USDI, 1979b).

Prior to the 1972 cancellations of predator control toxicants, little effort was expended to document the effectiveness of predacides through careful research (Balser, 1974). To date, there have been no sound research data published which demonstrate the effectiveness of 1080 single dose drop baits in controlling coyotes in the U.S. The effectiveness data (Robinson, 1948), along with an attempt to derive effectiveness data from total coyote takes and manpower data (Wagner, 1972), for the 1080 bait station have been reviewed in this section. On the basis of

* Dorrance suggested that strychnine baits could be used most efficiently in Alberta if they were applied only in March and April. These late applications would, according to Dorrance, disrupt the reproductive process while at the same time taking advantage of winter mortality in coyotes and exposing non-target animals to toxic baits for shorter periods of time.

** The proportion of the coyotes actually killed in the ADC program by toxicants used prior to 1972 that was included in the program's reported totals of animals taken is not known, however.

what little evidence is available for these methods, it is possible only to speculate concerning the effects that their introduction would have on the level of coyote predation on domestic livestock.

The results of the toxic collar research indicate that the method can be used successfully by biologists as a corrective tool to remove coyotes that attack sheep or goats in the throat region. In some situations, the collar may do the complete job of eliminating predation, but other methods of control are often needed. The method would probably be of little value on range operations or in other situations in which it is difficult to direct predation. Addition of this method to the predator control arsenal could help some family farm and/or fenced pasture operators to stay in the sheep or goat business. Whether this would occur would depend upon whether the use were registered and whether it would prove to be possible to set up efficient systems for training ranchers to use collars effectively and for keeping track of the fate of individual 1080 collars.

From the testimony at the information gathering hearings, it is apparent that many livestock producers perceive currently available mechanisms for controlling coyotes to be insufficient or impractical for all damage situations. Although other influences have contributed, it is evident that animal losses to predators is seen as a major factor in the decline of the sheep industry in the U.S. To the extent that any new approaches to the coyote problem would be sufficiently effective to enable individual producers to stay in business, the methods would help industry. Inexpensive, efficient and safe means of reducing damage are needed to augment (or partially replace) control methods currently used. Reintroduction of 1080 as a predacide might fill this need, but the efficacy of the proposed uses has not been fully established (see Section VI for discussions of safety of proposed uses).

VI. HAZARDS TO NON-TARGET WILDLIFE AND HUMANS

A. Hazards to Wildlife

1. Information on Non-Target Hazards of 1080 Used in 1972 Decision

One of the primary reasons for suspending and cancelling the use of 1080 to control predators was the hazards it posed to non-target wildlife. The Agency found that 1080 was extremely toxic to all species and that indiscriminate baiting with 1080 over wide remote areas posed two hazards to non-target animals: 1) primary poisonings of non-target animals that feed on baits placed for target species and 2) secondary poisonings of non-target animals that scavenge remains of poisoned animals. The order cancelling the use of 1080 to control predators indicated that while the impacts on non-target species from the use of 1080 to control predators were for the most part undocumented, the available evidence may well have underestimated the true damage. The order further stated:

> It is appropriate to take administrative notice of the fact that isolated accidents involving wildlife are not apt to be reported. Isolated, even if routine and numerous instances of secondary animal poisoning would not have the visibility of a wildlife kill nor is there apt to be an observer present as in the case of human mishap. The administrative process need not be blind to these realities.

The order maintained that the use of 1080 in large bait stations posed an imminent hazard especially to endangered species and stated that the death of even one animal which belongs to an endangered species is an irreparable loss because it renders such species closer to extinction.

As noted earlier, the Agency relied heavily on information presented in "The Cain Report," The Natural Resources Defense

Council petition to ban 1080, and "The Leopold Report."

Cain et al. (1972) briefly reviewed the available toxicity data on 1080. Table VI-1 summarizes toxicity data from sources cited in Cain et al. (1972). The Cain Committee indicated that in comparison to other toxicants used in predator control, 1080 was more toxic to canids than to most other species. In other words, when species are compared on the basis of the amount of 1080 required to kill an average animal (expressed as mg of 1080/kg of body weight), canids are more sensitive to 1080 poisoning. This characteristic is called differential toxicity.

Proponents of 1080 argue that the differential toxicity would allow users to minimize hazards to non-target wildlife by controlling the concentration of 1080 in a bait station. "The Cain Report" cites Martin and Atzert as examples of this line of reasoning:

Martin (1971) stated:

> Although sodium monofluoroacetate is generally highly toxic, there is sufficient range of sensitivity between species to allow a degree of selectivity through formulating practices. Since the compound is highly soluble in water, it is possible to inject an aqueous solution into large pieces of meat which then may be securely fastened to the ground. When treated according to standardized Bureau directions, a coyote need eat only 1.4 ounce of treated meat to receive an LD_{50}. In contrast, a golden eagle must eat about 12 ounces, a great horned owl about 1 pound, a black vulture over 2 pounds, a bear from 4 to 8 pounds, and a human must eat from 3 to 8 pounds to obtain a lethal dose. This characteristic makes sodium monofluoroacetate unique for use in meat bait stations that are placed in remote locations during the fall and winter months to control coyote populations.

Atzert (1971) argued:

> The golden eagle, an animal that normally consumes the

Table VI-1. LD_{50}'s of sodium monofluoroacetate.

Species	LD_{50}* mg/kg	95% Confidence Interval	Route of Administration	Reference
MAMMALS				
Primates				
Man	0.7-2.1	Estimated	Oral	1,2
Rhesus monkey (Macaca mulatta)	4.0		I.V.	3
Spider monkey (Ateles geoffryi)	15.0		I.V.	3
Marsupials				
Opossum (Didelphis marsupialis)	60.0		Oral	9
Ungulates				
Cow				
adults (F)	0.393	0.247-0.625	Oral	4
juvenile (M-F)	0.221	0.149-0.327	Oral	4
Goat	0.6		I.M.	3
Horse (M-F)	0.35-0.55		Oral	5
Mule (M-F)	0.22-0.44		Oral	5
Mule Deer (Odocoileus h. hemionus) M-F	0.30-1.00		Oral	5
Sheep (M-F)	0.25-0.50		Oral	6
Swine				
adult	<1.0		Oral	3
young	0.4		Oral	3
Carnivores				
Bear (Urus sp.)	0.5-1.0		Oral	7
Bobcat (Lynx rufus baileyi)	<0.66		I.P.	8
Domestic cat	0.20		I.V.	8
Coyote (Canis latrans nebracensis)	0.10		I.V.	8
Grey Fox (Urocyon cinereoargenteus scotti)	<0.3		I.P.	8

Table VI-1 (continued)

Species	LD50* mg/kg	95% Confi-dence Interval	Route of Admin-istration	Reference
Badger (Taxidea taxus berlandieri)	1.0-1.5		I.P.	8
Domestic ferret (Mustela putorious)	1.41		Oral (S.T.)	5
Marten (Martes americana)	~1.0		Oral	7
Mink (Mustela vison)	~1.0		Oral	7
RODENTS				
Ground Squirrels:				
Columbia (Citellus c. columbianus)	0.9		I.P.	3
Fisher's (Citellus beecheyi fisheri)	0.3		Oral	3
Pocket Gophers:				
Breviceps (Geomys breviceps sp.)	<0.05		I.P.	3
Tuza (Geomys floridanus)	0.2		I.P.	3
Kangaroo Rats:				
Bannertail (Dipodomys s. spectabilis)	0.1		I.P.	8
Merriam (Dipodomys m. merriami)	0.15		I.P.	3

Table VI-1 (continued)

Species	LD_{50}* mg/kg	95% Confi-dence Interval	Route of Admin-istration	Reference
Rats:				
Norway-lab (Rattus norvegicus) M	2.1**		Oral	9
F	2.2**		Oral	9
Alexandrine (Rattus rattus alexandricus)	0.5		Oral	3
Black (Rattus rattus sp.)	0.1		Oral	3
Cotton (Sigmodon hispidus litteralis)	0.1		Oral	8
Norway-wild (Rattus norvegicus)	3.0		Oral	3
White-throated wood (Neotoma a. albigula)	<0.8		I.P.	8
Wood (Neotoma intermedia	1.5		Oral	3
Mice:				
Deer mouse (Peromyscus sp.)	4.0		Oral	8
House mouse (Mus musculus)	8.0		Oral	3
Miscellaneous spp:				
Meadow vole (Microtus pennsylvanicus)	0.92		Oral	9
Nutria (Myocastor coypus)	0.056		Oral	9
Porcupine (Erethizon dorsatum)	<1.0		I.P.	8
Prairie Dog (Cynomys ludovicianus)	0.3		Oral (S.T.)	8

Table VI-1 (continued)

Species	LD_{50}* mg/kg	95% Confidence Interval	Route of Administration	Reference
Lagomorphs				
Black-tailed jack rabbit (Lepus californicus)	5.55		Oral	9
European Rabbit (Oryctolagus cuniculus	<0.8		Oral	10
BIRDS				
Columbiformes				
Domestic pigeon (Columba livia) (M-F)	4.24	3.36-5.34	Oral	5
Mourning Dove (Zenaidura macroura) (M-F)	8.55-14.6		Oral (S.T.)	5
Anseriformes				
Mallard (Anas p. platyrhynchos)				
adult (M)	10.0		Oral (S.T.)	5
adult (F)	8.0		Oral (S.T.)	5
Pintail (Anas acuta tzitzihoa)				
adult (M)	10.0		Oral (S.T.)	8
adult (F)	8.0		Oral (S.T.)	8
Galliformes				
Chicken	7.5		Oral	3
Chukar (Alectoris graeca) (M-F)	3.51	2.58-4.78	Oral	5
Gambels quail (Lophortyx gambeli)	20		Oral	3
Japanese Quail (Coturnix coturnix japonica) (M)	17.7	11.0-28.7	Oral	
Ring-necked pheasant (Phasianus colchicus) (M)	6.46	3.85-10.8	Oral	5
Turkey (Maleagris gallopavo) (F)	4.00	1.20-13.3	Oral	5

Table VI-1 (continued)

Species	LD_{50}* mg/kg	95% Confidence Interval	Route of Administration	Reference
Passerines				
Brewer's blackbird (Euphagus cyanocephalus)	2.0-3.0		Oral	8
English Sparrow (Passer domesticus) (M)	3.00	2.38-3.78	Oral	5
Magpie (Pica p. hudsonia)	0.6-1.3		Oral	8
Raptors and Scavengers				
Golden eagle (Aquila chrysaetos canadensis)	1.25-5.00		Oral	5
American rough-legged hawk (Buteo lagopus sancti-johannis)	~10.0***		Oral	8
Ferruginous rough-legged hawk (Buteo regalis)	~10.0***		Oral	8
Marsh hawk (Circus cyaneus hudsonius)	~10.0***		Oral	8
Great Horned Owl (Bubo virginianus pallescens)	~10.0***		Oral	8
Black vulture (Coragyps atratus)	15.0		Oral	8
Turkey vulture (Cathartes aura)	<20.0		Oral (S.T.)	8
AMPHIBIANS				
Bull Frog (Rana catesbeiana) (M)	54.4	25.6-115	Oral	5
Leopard Frog (Rana pipiens)	150.0		S.C.	3
South African Clawed toad (Xenopis laevis)	>500.0		I.P. S.C.	3

Footnotes to Table VI-1.

1. Kaye (1970)
2. Arena (1970)
3. Chenoweth (1949)
4. Robison (1970)
5. Tucker and Crabtree (1970)
6. Jensen *et al*. (1948)
7. Robinson (1953)
8. Ward and Spencer (1947)
9. Denver Wildlife Research Center (Unpublished)
10. Lazarus (1956)

*	Where confidence limits are not provided the figure is assumed to be an observed non-statistical estimate.
**	Research has shown much variation between strains of laboratory rodents (Chenoweth, 1949).
***	Vomiting characteristic and early symptom.
M	Male
F	Female
I.V.	Intravenous
I.M.	Intramuscular
I.P.	Intraperitoneal
S.T.	Stomach Tube
S.C.	Subcutaneous
$<$	Less than
$>$	Greater than
$\sim$	Approximately

From Atzert (1971)

viscera before other portions of its food, demonstrates the low hazard of acute poisoning via secondary sources. To obtain an LD_{50} (1.25-5.00 mg/kg) of sodium monofluoroacetate from a secondary source such as coyotes, a 7-pound golden eagle must consume the viscera of from 7 to 30 coyotes killed by sodium monofluoroacetate, assuming the coyotes ingest LD_{50} (0.1 mg/kg) and do not excrete, detoxify, or regurgitate any of the toxicant, and that as in rats approximately 40 percent of the toxicant is present in the viscera at death. The viscera of coyotes account for approximately 20 to 25 percent of their live weight or 6 or 7 pounds. A golden eagle's daily consumption of food equals approximately 30 percent of its live weight, or 2 pounds (Denver Wildlife Research Center, unpublished data). As noted previously, animals can metabolize and/or excrete continued small doses of sodium monofluoroacetate without succumbing.

Both the Leopold and Cain committees agreed with these arguments, at least in theory. "The Leopold Report" concluded "that when properly applied, according to regulations, 1080 stations do an effective and humane job of controlling coyotes and have very little damaging effect on other wildlife." "The Cain Report" expresses this same thought, stating:

> If this [1080] and other toxicants were consistently applied under field conditions with the meticulous care specified in the operation manual, it is quite possible that a major portion of undesirable side effects could be avoided.

However, "The Cain Report" contended either that 1080 was not being applied carefully or that the persuasive assumptions made in laboratory tests did not apply. To support its contention "The Cain Report" referred to evidence indicating that non-target species were being killed. In particular, the report cited testimony by Alexander Sprunt IV of the National Audubon Society before the Senate Appropriation Subcommittee on Agriculture in 1971, that a bald eagle, a California condor, and 11 golden eagles had been killed by 1080. (See Table VI-2).

"The Cain Report also referenced Robinson (1948) who reported the results of tests evaluating both 1080 and thallium in large bait stations. "The Cain Report" cited the following incidents reported by Robinson (1948):

> Both thallium and 1080 are relatively slow in their toxic action, with the result that the creatures that succumb after feeding on the station are scattered over such wide areas that complete counts can never be made. Stockmen, sheepherders, service hunters and others working in the experimental area following the use of the stations have reported on the creatures found dead, presumably poisoned; the combined reports from these sources list the following: 888 coyotes, 3 bobcats, 37 dogs, 1 domestic cat, 2 badgers, 4 weasels, 8 eagles, 7 magpies, 4 hawks, and 2 ground squirrels. Some of these men were careful observers, but undoubtedly the majority were interested primarily in predators, and therefore the compilation may be considered as emphasizing the coyote.
>
> The search of another baited area by crews looking specifically for all species of dead animals turned up 61 coyotes, 4 badgers, 1 mink, 28 magpies, 2 hawks, 3 eagles, 9 deer mice, and 6 ground squirrels.
>
> The best indication of the extent of secondary feeding was furnished when crews were used to search station sites for victims or their scattered remains. During 39 man-days of hunting, 18 coyotes, 20 magpies, 2 golden eagles, and 2 hawks were located, of these, 9

Table VI-2

Denver Wildlife Research Center-Denver, Colorado
1080 and Strychnine in Reports

Invoice Number	Location	Sample Description	Chemical Found	Date Received
6725	California	California Condor, stomach lining, crop contents, heart tissue	1080 - 0.75 mg.	
		California Condor, stomach contents	No strychnine	
6756	South Dakota	Golden Eagle, heart, liver and stomach contents	1080 - 0.13 mg. No strychnine	4/12/66
6757	South Dakota	Golden Eagle, heart, liver and stomach contents	1080 - 0.20 mg.	4/12/66
6758	South Dakota	Bald Eagle, stomach contents	1080 - 0.24 mg. No strychnine	4/12/66
7508	South Dakota	Golden Eagle, viscera (liver and G.I. tract)	1080 - 0.55 mg.	12/10/66
7508	South Dakota	Golden Eagle, viscera (liver and G.I. tract)	1080 - 0.21	12/10/66
7510	South Dakota	Golden Eagle, viscera (liver and G.I. tract)	1080 - 0.29 mg.	12/10/66
7511	Colorado	Golden Eagle heart, liver and G.I. tract	1080 - 0.31 mg.	12/15/66
8540	South Dakota	Golden Eagle stomach contents	1080 - not found	1/16/68
10129	Nebraska	Golden Eagle stomach contents	1080 - 0.33 mg.	6/3/68
10130	Nebraska	Golden Eagle stomach contents	1080 - 0.02 mg.	6/3/68
10131	Nebraska	Golden Eagle stomach contents	1080 - 0.05 mg.	6/3/68
10228	Nebraska	Golden Eagle viscera	1080 - not found	8/20/68
10227	Nebraska	Golden Eagle viscera	1080 - not found	8/20/68

Table VI-2 (Continued)

Denver Wildlife Research Center-Denver, Colorado
1080 and Strychnine in Reports

Invoice Number	Location	Sample Description	Chemical Found	Date Received
10421	Nebraska	Golden Eagle, head	NaCN - present	12/18/68
10464	South Dakota	Golden Eagle, viscera	Strychnine - found 1080 - not found	11/19/68
10465	South Dakota	Golden Eagle, viscera	Strychnine - found 1080 - not found	11/28/68
10467	South Dakota	Golden Eagle, BKHLM	Strychnine - none 1080 - 0.86 mg.	11/28/68
10483	Colorado	Golden Eagle, viscera	Strychnine - none 1080 - 0.1 mg.	3/6/69

From Cain *et al*., 1972

> of the coyotes had been eaten in typical eagle fashion, and at least 8 of the magpies either were completely eaten, with only scattered feathers as evidence, or the remains were so dispersed as to suggest scavenger action.*

"The Cain Report" further indicated that Robinson (1948) concluded that eagles were the most likely non-target to be killed by secondary poisoning because of their feeding pattern (eating the viscera of poisoned coyotes), but surveys conducted during periods of large bait station use showed no significant reduction in the population of these birds.

Both "The Leopold Report" and the Natural Resources Defense Council petition to ban 1080 contained information concerning misuse of 1080. "The Leopold Report," although giving no supporting information, indicated that in many instances, regulations were not followed: 1080 stations were placed much closer together than they should be; excessive amounts of poison were used; and the poisoned bait was not always picked up in the spring. The report indicated that, under these circumstances, considerable damage could occur to wildlife. The Natural Resources Defense Council petition referred to a study conducted by Dr. Alfred Etter, who found that in one region of Colorado, 63 townships, or one-third of the baited townships there, contained three or more baits. In 18 of those, from five to 15 stations had been approved. The study also indicated that there was a ten fold variation in station weights, poison was not

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* Questions have been raised about the use of the field mortality information associated with large bait stations cited in "The Cain Report" to evaluate the hazards of 1080. The incidents cited in "The Cain Report" were from Robinson (1948), which reported the results of tests evaluating the use of large bait stations over a nine year period. The first seven years of the study dealt only with thallium, while the last two years also included 1080. Because of the manner in which animal deaths were reported, it cannot be determined whether 1080, thallium, or both were the cause of death. Therefore, this part of Robinson's work is of limited value in assessing the hazards of 1080 to non-target species.

injected uniformly in baits, and that over half of the users exceeded the norm, some putting more than twice the standard dosage in their baits (Etter 1968, 1969 in the Natural Resources Defense Council petition to ban 1080).

"The Cain Report" emphasized that evaluation of impacts must be on potential hazard, since data on which to base firm judgments, with the possible exception of data indicating hazards to endangered species, are scant. The report further added that individual animals of a wide variety of species have been destroyed by 1080 despite the greater toxicity of 1080 to canids. But, the report pointed out, that the death of some non-target animals does not necessarily result in a material reduction of the population of the species, unless the species is endangered. "The Cain Report" then noted that 1080 was thought to have caused the death of a Sierra del Nido (Mexico) grizzly bear and two California condors, both endangered species.

Based on this information, the Administrator found that there was evidence that a certain number of non-target animals were being adversely affected by 1080 products, particularly carrion eating birds and mammals. While EPA recognized the uncertainties about how various animal populations were being affected from poisoning of individuals, EPA found that the available evidence showed that 1080 had contributed to the death of endangered species. Also, the Agency believed that in many instances use directions were not followed, increasing potential damage. The Administrator concluded that the predator use of 1080 presented an imminent hazard to non-target wildlife, including some endangered species, and that suspension and cancellation was warranted.

2. New Information Since 1972 on 1080 - General

Since the 1972 ban on predacidal use of 1080, several points have come to the attention of the Agency in relation to evaluating potential hazards of using 1080 to control predators. Arguments presented either supporting the safety of 1080 or disputing the safety of 1080 when used to control predators have in several instances relied on chemical analysis results and/or published toxicity data on 1080 (Ketron, 1979; Audubon, 1971; Morton, 1971; Atzert, 1972; Connolly, 1980). In the Agency's regulatory review of applications to use 1080, it has become apparent that neither the chemical residue analyses nor the toxicity data are well defined.

The U.S. Fish and Wildlife Service's Denver Wildlife Research Center (DWRC) has reviewed the four basic analytical methods for 1080 (Okumo in Connolly, 1980). These methods were aconitase enzyme inhibition by citrate formation, colorimetry of fluoroacetic acid, measurement of total fluorine by colorimetry or ion-selective electrodes, and gas chromatography. This review indicates that each of the methods has one or more of the following shortcomings: the method is not quantitative; the method is not specific to 1080; and/or the method's reliability is not known. Okumo concluded that currently the best method for detecting the presence of low levels of fluoroacetate (1080) in animal tissues appears to be the Okumo and Meeker (1980) method using gas-liquid chromatographic determination.

The Okumo and Meeker method, however, appears to be less than completely reliable (Connolly, 1980). In tests to evaluate its reliability, several blind duplicates and one known negative tissue were submitted for analysis. Of three pairs of blind duplicates of muscle samples that were analyzed, two yielded values that agreed closely. The third pair of values were consistent in that both showed high 1080 content, but one result was more than double the other. Analysis of the sample that was known to contain no 1080 indicated that it contained trace amounts of 1080. Also, false negatives appeared. Of three different coyotes that were known to have died of 1080 poisoning, none was reported to contain 1080.

This latter result could be explained by the mode of action of compound 1080. Connolly (1980) speculated that the lethal action of 1080 is due to its conversion in animal tissues to (-) erythrofluorocitric acid. Once 1080 has been converted, it is no longer susceptible to detection by current analytical methods. It follows that an animal could die from a minimum, lethal dose of 1080 that would not leave detectable amounts of 1080, if all of the ingested dose were converted to fluorocitrate before the animal died.

In sum because the confidence limits for quantitative estimates of 1080 residues in various animal tissues have not been established and the reproducibility of such estimates has not been determined, the use of chemical analysis results must be interpreted with caution when assessing hazards.

Published toxicity data are also used frequently to assess the hazards of 1080 to non-target species. Much of the toxicity data is based on studies by Ward and Spencer (1947), who report toxicity figures for 44 species.

Examination of these data makes them suspect for use in predicting potential risk to non-target wildlife. For example, the magpie LD_0 is reported to be 0.67 mg/kg and the LD_{100} to be 1.3 mg/kg. According to the test report, the toxicant was "fed" to a group of 12 magpies. No other details of the test are reported. When a test substance is administered in feed, its toxicity is usually reported as a LC (lethal concentration) rather than a LD (lethal dose). More importantly, it is difficult to determine how to use the data to predict hazards under field conditions without details on the feeding schedule and the concentration of the toxicant in the feed. Another example from this same paper is the reported lethal dose for the bobcat. Five bobcats received an intraperitoneal injection of 1080 equivalent to .66 mg/kg. All animals died. While a dose of .66 mg/kg resulted in 100 percent mortality, the data do not indicate whether a lower dose would also produce similar results. Moreover, it is difficult to use the data to predict hazards in the field, since the route of administration in the test differs from that expected in the field, where bobcats will eat 1080. Most of the other toxicity figures reported by Ward and Spencer (1947) have weaknesses similar to those described in the above examples.

These questions on toxicity and residue data are strengthened by examining studies on secondary poisoning by 1080 reported by the U.S. Fish and Wildlife Service (Connolly, 1980). A dose of 333 mg of 1080 (300 mg A.I.) was administered to a coyote. After the coyote died, two groups of magpies were fed tissues from this coyote. Neither group of birds was reported to exhibit ill effects, either during the experimental feeding or the observation period.

However, based on the assumed LD_{50} for the magpie of 1 mg/kg (estimated by Connolly (1980) from Ward and Spencer's reported LD_0 0.67 mg/kg and LD_{100} of 1.3 mg/kg) and the reported muscle contents of 2.4 ppm 1080 from chemical analysis, at least some mortality would have been predicted. At an LD_{50} value of 1 mg/kg a 180 g magpie would have to ingest .18 mg of 1080 to receive a median lethal dose. At the reported concentration in muscle tissue and a daily consumption rate of 90 to 100 grams per bird, each bird was consuming .216 to .24 mg of 1080 per day, slightly more than a median lethal dose per day. Five birds ingested such amounts of poisoned coyote tissues daily for 7 days, but no mortalities resulted and no sublethal symptoms of intoxication were seen.

Because of the uncertainties with toxicity data, the U.S. Fish and Wildlife Service has initiated tests to determine the toxicity of 1080 to magpies and other species. In his testimony given at the information gathering hearings, Connolly stated, "Trials in mid-July raised the possibility that magpies are more resistant than we had thought." Although these tests are incomplete, and additional work is planned, test results to date appear to underscore the questions raised on the reliabilty of available toxicity values for use in evaluating hazard to non-targets.

Questions have also been raised about the likelihood of secondary poisoning from 1080. Dr. Kun of the University of California briefly addressed this point in his testimony at the informational gathering hearings in Denver. He stated the following:

> The question of secondary poisoning is essentially no problem. Obviously if you have very large amounts of fluoroacetate (1080) in the animal's stomach, and some other animal eats that stomach, happens to be eating fluoroacetate in large quantities, it is just the same problem as eating the poison in the first place, but in lethal doses of fluoroacetate, which is relatively small, it is in very, very small quantities, and fluoroacetate ingested is rather non-toxic. It undergoes a change in the cytoplasm. I don't really understand the problem of secondary intoxication. If you eat very much of something, and another animal eats you, of course, he gets intoxicated, and it is not a real scientific problem.

Dr. Kun in Appendix I of Connolly (1980) addressed this point in somewhat more depth in the following:

> It should be recognized that (-) erythrofluorocitric acid exhibits its unusual potent toxic action only if it is biosynthesized in mitochondria by the following reaction:
>
> equ.1.: F-acetyl-CoA + Oxalacetate $\xrightarrow{\text{condensing enzyme}}$ (-) erythrofluorocitric acid + CoA.
>
> If F-citrate were ingested, its toxicity is probably negligible, because (-) erythrofluorocitric acid, after entering cells from the blood stream, is efficiently detoxified by the ubiquitous cytoplasmic enzyme: ATP-cytrate lyase, that cleaves F-citric. The minute amounts of cytoplasmic F-acetate after hydrolysis of F-acetyl CoA formed from ingested

is selectively consumed." Also, the report of coyotes dying one to two weeks following 1080 application for rodent control (Hegdal et al. 1979; Malloy, 1980) seems to raise questions with the statement that "F-acetate in decaying tissues is likely to be defluorinated in 5-10 hours to harmless glycolic acid + F- thus a serious concern about 'epidemic' F-acetate poisoning through poisoned carcasses appears unreasonable."

3. New Information - Bait Stations

In addition to the information discussed above (which pertains generally to the environmental hazards of 1080) EPA has become aware of other information which pertains directly to the hazards of 1080 use in large bait stations.

The uncertainties about the reliability of the analytical methods used to detect 1080 residues in animal tissues raises questions about the reliability of data presented in "The Cain Report" showing residues in dead raptors. Although the analytical method used is not specified, if it resulted in false positives, the conclusions drawn from the data may over-estimate potential problems. On the other hand, if the chemical method used gave false negatives, conclusions drawn from the data could under-estimate potential problems.

In testimony at the information gathering hearings in Denver, Dick Randall, a representative of the Defenders of Wildlife, provided new information on the potential hazards of 1080 bait stations. Beginning in the fall of 1969 and continuing until the predator toxicant ban in 1972, Randall monitored non-target mortality associated with large 1080 bait stations. A tracer material (zinc and cadmium sulfide) was combined with the 1080 poison used by the U.S. Fish and Wildlife Service in predator control to identify animals killed by the baits. Of 82 animals found dead and necropsied, 37 contained the tracer material from the 1080 bait stations.

Table VI-3 shows the species which Randall found dead. Neither Randall's written nor oral testimony specify the concentration in the baits. However, in telephone contact with the witness, he indicated that, although it was difficult, he had made every effort to dose the bait at the recommended rate, 1.6g 1080 per 100 pounds of meat.

Lyle Crosby of the Wyoming Department of Agriculture also gave testimony on a monitoring study conducted in Wyoming in the winters of 1975-76 and 1976-77 when over 1,000 1080 bait stations were used. Baits were placed in every county of the state. In oral testimony given in Denver, Mr Crosby indicated that one dog was found dead in association with the control program; Mr. Crosby also reported seeing two skunks which may have been killed by 1080. In personal communications with the witness he indicated that in total he was aware of one dog, two skunks and one badger which were found dead in the vicinity of 1080 bait stations used in Wyoming during the winters of 1975-76 and 1976-77. He also indicated that some other species were found dead, but did not know the specifics.

Finally, regarding the large bait stations, Guy Connolly of the Denver Wildlife Research Center, in his testimony, suggested that hazards could be reduced in the large bait station, while still providing control, by reducing the 1080 concentration from the previously recommended rate of 1.0 mg/oz. to 0.5 mg/oz. of bait. According to Connolly, even at the reduced concentration, 4 ounces of bait would be lethal to most coyotes.

Examination of results of the feeding studies reported by Robinson (1948) supports this suggestion. In order to determine the effect of 1080 stations on non-targets, Robinson fed meat from a bait station (treated at a rate of 1.6g 1080/100 lbs. bait) to several non-target species. Table VI-4 shows the results. These data were not discussed in "The Cain Report," though that report did reference other parts of Robinson's work.

Table VI-3* Species Found Dead in Vicinity of 1080 Bait Station Which Contained Tracer Materials.

Species	Numbers
Coyote	4
Dog	1
Badger	8
Bobcat	2
Pine martin	2
Mink	1
Weasel	1
Golden eagle	6
Red tailed hawk	1
Magpie	4
Prairie falcon	2
Unidentified hawk	2
Sharp-shined hawk	1
Canada jay	1
Rough-leg hawk	1

* From D. Randall's testimony, Denver.

Table VI-4. Results of Feeding Trials of Meat Treated at a Rate of 1.6 mg. of 1080 per 100 lbs. Bait.

Species	Number	Amount Consumed	Result
Badger	2	11 and 7 oz.	One badger died. The other was left with nervous disorders.
Raccoon	1	6 oz.	Left with nervous disorders.
Magpie	3	19.4, 11.0, & 10.9 grams	All died
Magpie	7	Each fed 4.5 grams	4 died
Golden eagle	4	10, 13, 16 & 22 oz.	The one receiving 16 oz. died.
Ferruginous roughleg hawk	2	All they could eat	One died
Marsh hawk	2	All they could eat	One died
American rough leg	1	Less than an oz.	Survived
Ferruginous roughleg hawk	1	Less than an oz.	Survived
Prairie falcon	1	Less than an oz.	Survived
Marsh hawk	1	Less than an oz.	Survived

(Robinson 1948)

4. New Delivery Methods: Single Lethal Baits

Prior to the 1972 order, the use of single lethal baits containing 1080 was not common. Since then, several individuals and organizations have proposed this application method as an alternative to large 1080 bait stations to control canids (Beasom, 1976; Nesse, 1977; Wade, 1977; Wyoming Department of Agriculture, 1977; South Dakota Department of Agriculture, 1977; Colorado Department of Agriculture, 1977; Ketron Inc., 1979; National Woolgrowers Association, 1981).

In general, the documents cited above propose three slightly different use strategies for single lethal baits made of ground or rendered lard, tallow, or other animal tissues. The following is a summary of the three methods which have been proposed:

1. Beasom (1976) proposed using baits weighing 9 grams containing 2.9 mg 1080 each, systematically placed on a 20 acre grid pattern, with baits located at the most likely animal travel lane within 20 feet of each grid intersection. This would equal 32 single lethal baits per square mile.

2. Nesse (1977) proposed baits weighing 15 grams containing 3.6 mg 1080 each to be placed around livestock or wildlife carcasses, coyote travel trails, scent posts, den sites, or other "draw" stations. A maximum of two baits at a single placement location and use rates not to exceed 10 single lethal baits per section was proposed, with bait placement locations situated at least 1/4 mile apart.

3. Wade (1977) recommended baits generally smaller than 20 grams each containing 5.0 mg 1080 per bait for coyotes, 3.0 mg 1080 per bait for red

> foxes and 2.0 mg 1080 per bait for gray foxes. Baits should be placed near established draw stations or preferred travel routes in suitable locations for the target animals to find them. The number of baits placed at each station site, normally from 10 to 30, is determined by field inspection and by the history of target and non-target species' activity around each station area.

It is useful to contrast the relative hazards of large bait stations vs. single lethal drop baits, to the extent such comparison can be made. Any comparison of the two delivery mechanisms is rendered difficult by uncertainty as to the density, or number per unit area, of small baits used. Of the three approaches described above the lowest density, suggested by Neese, would permit 10 baits per section (one square mile). If each bait contained 3.5 mg, the total amount of 1080 used would amount to 35 mg per section. The typical large bait station, in contrast, would be a 60-80 lb. piece of horse or sheep containing 1.6 g of 1080 per 100 lb., or 1 mg of 1080 per ounce. The entire station would contain 960-1280 mg of 1080. At a prescribed density of 1 station per 36 sections, the 1080 used would equal 27-36 mg. per section, an amount comparable to that for single lethal baits. The question becomes: Which poses more hazard, one large bait in 36 square miles, or 360 small baits dispersed over 36 square miles? (Connolly per. comm.).

Proponents of 1080 single lethal baits theorize that this use would mitigate 1080's hazards to non-targets species. They argue that the hazard to non-targets of primary poisoning is reduced because each single lethal bait contains less than an average lethal dose for many of the non-target animals at risk. This, coupled with widely spaced placement of baits in treated areas, reduces the chance of non-target species consuming a lethal dose. Proponents of 1080 baits also contend that the risk of secondary poisioning is reduced. Since this risk is related to the amount of 1080 consumed by the primary consumer, and the amount of toxicant consumed by a primary consumer is limited by the widely spaced placements and the amount of toxicant in a bait, the single lethal dose presents a lower secondary hazard than large meat bait stations. (Beasom, 1976; Ketron Inc., 1979)

While the arguments concerning the safety of drop baits are logical, the hypothesis remains relatively untested. More importantly, the argument is based primarily on available toxicity data which indicate that target species are more sensitive to 1080 than most non-target species. But, as pointed out earlier, these toxicity data are of questionable reliability. Therefore, any discussion of potential hazards of this use pattern must be considered speculative.

Of particular interest beyond toxicity is selectivity of acceptance of single lethal baits. Several factors appear to influence this, including application rates, bait placement, timing, bait acceptance by target and non-target species and their relative densities. Although little research has been initiated which specifically addresses the use of 1080 in single lethal baits, some studies have been completed using other toxicants in drop baits. In addition, other studies using non-toxic marking agents also provide insight into potential non-target species exposure.

Beasom (1974), evaluating selectivity of various predator control techniques in southern Texas, experimented with strychnine single lethal baits composed of chicken eggs, horsemeat and pork fat. Approximately 2,000 eggs and 8,000 horsemeat or pork baits were used over a two year period. The latter, which may closely resemble the baits proposed for 1080, was placed on the ground against or under grass at the side of study area roads. Species found dead at or near the horsemeat or pork fat baits were: 35 coyotes, 1 raccoon, 17 striped skunks, 1 spotted skunk, 5 opossum, 2 badgers, 2 cotton rats, 7 white-footed mice, 4 grasshopper mice, 1 pygmy mouse, 3 western harvest mice, 5 Harris' hawks, 2 marsh hawks, 7 caracara, and 1 great horned owl. Species reported dead near the strychnine egg baits were: 5 coyotes, 2 bobcats, 31 raccoons, 16 striped skunks, 4 opossum, 6 badgers, 2 collard peccaries, 6 armadillos, 36 cotton rats, 1 ground squirrel, 17 white-footed mice, 15 grasshopper mice, 2 pygmy mice, 7 western harvest mice, 3 marsh hawks, 13 caracara and 11 indigo snakes. The author also indicated other species could have been killed and not found, especially in the case of raptors which could pick up a bait and fly some distance away before devouring it.

As part of a study evaluating an antifertility agent, information was collected on consumption of drop baits by coyotes and other species (Linhart et al., 1968). Rendered beef tallow baits, aproximately 1/3 ounce with 1 percent seal oil rolled in liver meal or blood meal, were placed on coyote sign along ranch roads and at stock tanks. Each station consisted of a smoothed or sifted circle of sand and dirt in the center of which was placed one to three test baits. Species consuming the bait were determined by tracks left at the station. In six tests made in New Mexico and Texas, 321 baits were eaten or carried off by various animals. Of these, coyotes took 22 percent, rodents 52 percent, ravens 12 percent, and miscellaneous species 1 percent, while the remaining 13 percent were taken by unidentified animals. Based on these tests the researchers believed that other carnivores, with the possible exception of the skunk and fox, seldom eat baits intended for coyotes, and that selective bait placement, the relatively small number of baits per square mile, and the extended home range of coyotes also decrease the likelihood of other carnivores eating baits.

Other tests conducted by the U.S. Fish and Wildlife Service addressed the use of single lethal drop baits around draw stations (Tigner, 1981). Two tests were conducted in the winter of 1976-77, one near Rawlins, Wyoming and the other near Ft. Sumner, New Mexico. Draw stations, consisting of half a sheep carcass in Wyoming and about 1/4 of a cow carcass in New Mexico, were located based on coyote sign with 20 small baits placed around each station and replenished a week later. Twenty-four draw stations were used in Wyoming and 19 in New Mexico. Each small bait was made of lard, coated with fish meal, and impregnated with a physiological marker. Two weeks after the last baiting, coyotes and other species were collected and examined for presence of the markers. Following are the results of the tests in Wyoming (animals sampled/ animals marked): deermouse 8/8, magpie 6/2, golden eagle 3/1, coyote 55/5, bald eagle 1/0 and rough-legged hawk 1/0. In New Mexico the following were found: swift fox 2/1, striped skunk 8/3, coyote 11/3, grasshopper mouse 5/1, greathorned owl 5/1, porcupine 6/0, hognosed skunk 1/0, bobcat 1/0, red-tailed hawk 1/0, raven 2/0, vulture 3/0, deer mouse 1/0, kangaroo rat 5/0, woodrat 1/0, marsh hawk 2/0, rough legged hawk 1/0, spotted ground squirrel 1/0.

These studies suggest that several species would eat single lethal baits intended for coyotes. However, in the absence of reliable toxicity data potential impacts can not be further assessed.

Connolly, in his testimony given in Denver, referenced recent tests conducted by researchers at the Denver Wildlife Research Center and Texas A & M University evaluating primary hazards of single lethal baits to non-targets. Although details of the tests were not presented, he indicated that both raccoons and golden eagles had been fed single lethal bait containing about 3 mg of 1080. Although he indicated only a few animals had been tested, most showed symptoms of intoxication but all survived and all appeared to have recovered fully. He went on to say much additional work is needed to determine the hazard of single lethal dose coyote baits to all non-target species whose habits make them likely candidates for exposure.

Also, the number of single lethal baits which non-target as well as targets would consume needs to be addressed. This would appear to be related to the selectivity of baits, and baiting strategies, neither of which is well defined. If the countryside were saturated with single lethal baits, chance of exposure to non-target species may be significant and may increase the chance of multiple exposures as well. As the number of baits at a site is reduced it seems reasonable that the chance of exposure is reduced. However, the use of draw stations may have the tendency to concentrate some species. Under these conditions, even at low application rates, exposure of non-target species may result in individual mortality and affect populations, i.e. wide-ranging carnivores and raptors, particularly eagles.

Secondary poisoning from 1080 when used in single lethal baits is also of concern. As stated earlier, proponents argue that secondary risk is related to the amount of 1080 ingested by the primary consumer.

Again, although logical, several questions about this theory need to be addressed before a complete assessment of potential secondary hazard from single drop baits can be made. The questions include: How many baits would a target or non-target species be likely to consume before death? Will the resulting tissue 1080 levels be in the toxic range of scavengers? What amount of 1080 will remain in the gastrointestinal tract? Once again, answers to these questions depend on the existence of reliable toxicity data and residue analysis methods.

5. New Delivery Methods: 1080 Toxic Collar

With the collar, exposure of either target or non-target species to 1080 occurs only after a collar is punctured. After a collar is punctured, the potential hazards associated with other predacidal uses of 1080 are present, i.e., secondary poisoning of animals that scavenge remains of target coyotes, and primary poisoning of animals that scavenge carcasses of coyote-killed collared livestock.

Although most of the research to date has been on the efficacy of the toxic collar, work by the U.S. Fish and Wildlife Service has addressed some of these potential hazards posed to non-target species from the use of 1080 in the toxic collar (Connolly, 1980).

Most of the research by the U.S. Fish and Wildlife Service has addressed the potential for secondary poisoning of scavengers which might feed on the remains of poisoned coyotes. Three methods were used to investigate this hazard: 1) observations of scavenging under field conditions; 2) analysis of 1080 residues in poisoned carcasses; and 3) feeding poisoned coyote carcasses to avian scavengers, specifically magpies. The latter two methods appear to show the most promise of providing information which can be used to assess the potential for secondary hazards from using 1080 toxic collars.

However, the usefulness of the data collected by these two methods to assess hazard once again relies on the accuracy of the chemical residue analysis and toxicity data for scavengers. As discussed earlier, the data in these areas are not completely reliable. Therefore, until the reliability of this data is determined, caution should be employed in drawing general conclusions from the results of these tests.

With this in mind, the information reported by Connolly (1980) is encouraging with respect to secondary hazard to avian scavengers when 1080 is used in the toxic collar. The most significant results come from studies in which magpies were fed poisoned coyote carcasses or tissues.

Five groups of five magpies were confined with carcasses or tissues from four coyotes known to have been poisoned by 1080. For the test, magpies spent seven days of continuous confinement with a carcass or tissues of a poisoned coyote. No other food was available. This was followed by a seven day observation period during which uncontaminated rations were fed to the magpies. During the first trial, researchers reported that magpies fed heavily on the poisoned carcass, but no birds showed any ill effects. The coyote used in this test, as in the second and third, had died after attacking a collared lamb in pen trials.

In the next two trials, which were run concurrently, four of the 10 test birds died. Researchers concluded that the magpies died of starvation, rather than 1080 poisoning. This conclusion was based on two observations. First, hot weather during the trial dried out the coyote carcasses so that the birds were unable to feed for the entire seven day trial; and second, the average weight of the four dead birds, 107.4 g, was well below that of four wild birds which were collected for comparison, 181.0 g. The researchers also noted that low 1080 residues were found in breast muscle and gizzard from one test bird. They suspected that this bird also died of starvation, as the following explains:

> The bird that contained 1080 residues had been caged with coyote #DM 385, in which the highest 1080 concentration was 0.27 ppm in the hip muscle. If the LD_{50} for magpies is 1 mg/kg, this bird would have to eat over 650g of muscle form this coyote to have ingested an LD_{50}. Actually little feeding had occurred, so it is doubtful that the bird could have died of secondary poisoning.

Due to the complications in the above test, the next trials did not place an entire carcass with test birds. This trial used coyote tissues which were dissected soon after death, with muscle separated from all other soft tissues (heart, liver, kidney, stomach, intestines, etc.). Tissues were refrigerated until fed to birds. Daily feedings were adjusted to achieve maximum voluntary consumption of about 90-100g per bird per day. Also, in these tests the coyote was orally administered the entire contents of one 30ml collar, 333mg of 1080. Two groups of five magpies were fed tissues from this coyote. One group was fed 500g of muscle tissue each day for seven days, the other 500g of soft tissue each day for two days. Researchers did not observe ill effects in either group during the test or the subsequent seven-day observation period.

These two trials appeared to subject magpies to substantially greater risk of secondary poisoning than the magpies might reasonably be expected to encounter under field conditions. Again, questionable residue analysis and toxicity data hamper interpretation of the results. If the reported residues in tissues are accurate, the dose received by magpies in these tests was approximately two and a half times the highest residue reported for a coyote which was known or suspected of being killed by 1080 from the collar. If the magpie is as sensitive to 1080 as available toxicity data indicate, secondary hazard to other avian scavengers would appear limited from the use of 1080 in the toxic collar.

In addition to avian species, the potential for secondary poisoning to mammalian species is of concern. No specific tests are available which address this aspect of 1080's use in the toxic collar.

Possibly presenting greater non-target hazard are the carcasses of sheep or goats with punctured collars. If both bladders of the 30 ml collar are broken, 333 mg of the toxicant could be present on and around the neck area of the dead sheep or goat (twice this amount for the 60 ml collar). Even if available toxicity data are in error by several times, this amount of 1080 may present a lethal dose for most scavengers. For example, the turkey vulture, one of the least sensitive species to 1080 according to studies by Ward and Spencer (1947), could receive a multiple median lethal dose from the neck area. The reported LD_{50} of 1080 for the turkey vulture is 20 mg/kg; hence, a median lethal dose for a 1.6 kg bird is 32 mg, an amount which could easily be present on the neck area of killed collared livestock.

Connolly (1980) presented the results of four trials which were designed to assess this concern. One magpie test, using the same approach as described for the assessment of secondary hazard, was conducted. A coyote-killed lamb with a punctured collar was caged with five magpies for seven days. The birds scavenged heavily, but none were poisoned. Caged birds were reported to have limited their feeding to lamb tissues exposed by the killer coyote, and not on the neck and collar area. This feeding pattern was indicated to be similar to what Connolly observed for vultures in the wild.

In addition, three trials with domestic dogs were conducted. They were allowed to scavenge at will on carcasses of coyote-killed collared goats at field test sites in Texas. As soon as a kill with a punctured collar was found, a dog was taken to the carcass and allowed to feed. The first two trials consisted of one feeding, while the third trial allowed the dog to feed once or twice daily for nine days. In the three trials, no evidence of poisoning was observed. Researchers concluded that apparently little or no toxicant was consumed because the dogs did not feed on or near ruptured collars.

Although these tests appear to indicate minimal hazard, the tendency of test species not to feed near ruptured collars may not be representative of feeding behavior of other scavengers. Field observations from other studies indicate that in some instances, particularly when food supplies are limited, soft tissues of livestock carcasses are completely scavenged leaving only hide and bones (Fite pers. com.). This suggests the possibility of scavengers ingesting the toxicant. Also, scavenging of carcasses under field conditions is not limited to one species; some species, such as the golden eagle, are capable of penetrating the skin, exposing tissues. Such scavenging could provide those, such as the magpie, which are not capable of penetrating the skin, with other openings in which to feed, possibly on contaminated portions.

A further indication of the potential for scavengers to be poisoned by feeding on dead collared livestock is gained from the cited U.S. Fish and Wildlife Service report on three coyotes that died in pens where contaminated lamb tissues had been buried (Connolly, 1980). Reseachers indicated that because of the possibility that the coyotes could have been poisoned by 1080 contamination of the pens, the affected coyotes were analyzed for the toxicant. One coyote proved positive for 1080. Researchers speculated that this coyote had consumed contaminated lamb remains cached by coyotes that had killed collared lambs.

In summary, the major potential hazards to non-target species from the use of 1080 in the toxic collar are to avian and mammalian scavengers from carcasses of poisoned coyotes and carcasses of sheep or goats with punctured collars. Due to scanty toxicity data and questions on the accuracy of quantitative estimates of 1080 residue in tissues, the extent of these potential problems cannot be fully assessed. Present results are encouraging, however.

B. Hazards to Humans

1. Information Used In 1972 Decision:

Risks to man were a factor in the 1972 decision to cancel the use of 1080 for predator control. Specifically, the Agency found:

> 19. 1080 is highly toxic to all species. The dangerous dose for man is 0.5-2 mg/kg. The chemical acts rapidly upon the central nervous and cardiovascular systems with cardiac effects. Effect is usually too quick to permit treatment, and antidotes are relatively valueless.
>
> 20. According to one authority, prior to 1963 there were 13 proven fatal cases, five suspected deaths, and six nonfatal cases of 1080 poisoning in man, although it is not clear to what extent predator control materials were implicated.

During the period 1950 to 1972, 1080 was being used both as a predacide and as a rodenticide primarily to control field mice, ground squirrels, prairie dogs, and other field rodents.

2. Summary of New Information

a. Use History Since 1972

Since 1972, the only federally registered uses of 1080 have been for the control of rats and mice. While the target pest and the bait material (treated grain, oat groats, etc.) differ from the predacide uses of 1080, the human exposure from preparing the poisoned bait is roughly comparable. For the most part both the 1080 rodenticide and predacide were prepared by state personnel from concentrated 1080 purchased from the manufacturer. The treated bait was also distributed and placed by state personnel or people under their direct supervision.

Two aspects of the use of 1080 have changed. First, since 1978, 1080 has been classified as a restricted use pesticide. (See 40 CFR §162.31.) As a result, 1080 may be used only by a certified applicator--that is, a person who has been specifically trained in the safe use of highly toxic pesticides--or a person under his direct supervision. (Prior to 1972 EPA lacked the authority to require that a pesticide be used only by certified applicators.) Second, the directions for using federally registered uses of 1080 have been clarified and expanded so that users applying the treated bait will know how to minimize risk to humans and the environment.

EPA has reviewed the reports of pesticide poisonings submitted since 1972 and has found seven incidents of human poisoning involving 1080. None of these poisonings was fatal. In two cases 1080 involvement is considered highly unlikely, and another of the cases was an attempted suicide.

Guy Connolly testified at EPA's public hearings in Denver that 1080 is used extensively in New Zealand (over 4,000 lbs. per year) and that no human fatalities have occured from such use.

Another witness at the Denver hearings, Lyle Crosby, stated that use of 1080 bait stations to control predators in Wyoming in 1975-77 did not have adverse effects on any humans.

Another witness at the Denver hearings, V.M. Howard, testified that a 1080 filled collar broke when it was being removed from a goat. Some of the 1080 contents splashed onto his hands which he then washed. The collar was placed in a plastic bag for disposal, with some of the 1080 spilling on the ground which was subsequently covered with dirt. Howard said he suffered no ill effects.

For the period 1966 to 1981, 50 incidents involving domestic animals were reported. Over 110 dogs were killed, more than 10 dogs survived after treatment, 30 other domestic animals (mostly cats) were killed, and three other cats were affected but survived. At least half of the dogs' deaths were the result of possible intentional poisonings (EPA, PIMS, 1981).

b. Toxicity to Humans

Signs and symptoms of 1080 poisoning vary. However, they may be classified into three categories: CNS (central nervous system), cardiac, and depression syndromes. The CNS syndrome is characterized by hyperactivity, phonation, tonic spasms and convulsions which lead to respiratory paralysis. The cardiac syndrome is associated with blanching of the retina, muscular weakness, clonic convulsions, and ventricular fibrillation. The depression syndrome is associated with decreased activity, respiratory depression and bradycardia. The time before the onset of symptoms of poisoning almost always exceeds 1/4 hour and death most often occurs between one hour and one day after ingestion of a lethal dosage. The LD_{50} for humans has been estimated to be approximately 2.0 mg/kg.

The development of pathologies is frequent, even after single dosages. Definite histologic abnormalities in the myocardium have been reported. Hermorrhagic changes in the liver, heart, aorta, and brain sometimes particularly occur in poisoned mammals.

Biochemically, 1080 is thought to exert its toxic effect by inhibition or blocking of citrate and succinate metabolism within the Kreb's cycle. The necessary biochemical transformations and the time required to impair functions account for the lag between ingestion and the development of symptoms.

c. Symptoms and Antidotes

1080 is absorbed rapidly from the gastrointestinal tract and symptoms may not appear for 30 minutes or more. Therefore, after an accidental poisoning, first aid measures should be started as soon as possible. Vomiting must be induced without delay to remove any unabsorbed 1080 in the stomach.

A physician can provide several beneficial treatments. In addition to stomach lavage followed by purging, the physician can institute acetate therapy, which is to some degree antidotal. Monacetin, sodium acetate, ethanol, and acetamide have been recommended. Monacetin appears also to act directly to counteract cardiac arrythmias, which could lead to death in humans. Monacetin would be the antidote of choice if available. It is unfortunately generally unavailable and therefore has not been used in the treatment of humans. Barbiturates are used to ameliorate convulsive episodes. Continuous cardiac monitoring is advisable.

A true antidote to 1080 poisoning is not available. If treated immediately, however, and if the amount of poison ingested is not too large, first aid measures (induced vomiting, stomach lavage, purging) are effective.

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