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The Roadside Environment

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A Visual Approach to Redesigning the Commercial Strip Highway

RICHARD C. SMARDON

ABSTRACT

An argument for the need for a comprehensive unified approach to commercial strip highway development is presented. Specifically, the author calls for a visual approach that (a) can be easily understood by all involved parties, (b) addresses important behavioral and perceptual driver functions, (c) uses visual simulation, (d) includes comprehensive treatment of all landscape components, and (e) allows involvement of multiple parties. These five principles are illustrated with results of two case studies in New York State that are commercial strip highway environments.

With the near completion of large highway systems, more emphasis is being placed on maintenance activities or slight modification and upgrading of existing highways (1). Often the highways that are in greatest need of upgrading because of current traffic congestion and safety problems are set in an environmental context of mixed land use often termed the commercial strip. Agencies charged with upgrading such roadways within the commercial strip are frequently faced with the unenviable situation of reacting to local uncertainty about what the community wants. Does the local community want to

1. Solve the traffic problem; or
2. Retain existing or prior land use, scale, quality, and so forth; or
3. Retain or promote commercial viability as a shopping destination point?

All three of these objectives, to some degree, conflict with each other. As a result, many local highway improvement projects have been stopped or aborted in mid-process because of disagreement between the various parties involved in the planning process. The "old main street" and the "new main street or commercial strip" are both very sensitive environments to proposed structural changes whether they be roads, buildings, or signs.

The School of Landscape Architecture, State University of New York, has been involved in a number of commercial strip projects in the Northeast (2,3), as well as scenic highway studies (4). From these case studies it is evident that a comprehensive unified approach to mixed-use highway strip development is needed.

PRINCIPLES OF THE VISUAL APPROACH

A comprehensive unified approach should have a strong visual landscape component for the following reasons:

1. Visual approaches improve communication and can be easily understood by all parties;
2. Important visual questions are usually involved that are both behavioral (e.g., motorist's way-finding tasks) and perceptual (e.g., an area's imageability or sense of place);
3. Visual simulation (either static or dynamic) is useful in presenting alternatives for examination, analysis, or public debate;
4. Comprehensive treatment of all the landscape components, such as roadways (public), landscaping (public and private), buildings and signage (private), is needed; and
5. A visual approach allows, from all of the foregoing, involvement of multiple parties in the planning and design process, including federal and state highway agencies, local government, and private individuals and groups.

In this paper, each one of these five principles is illustrated with actual work from two case studies: one in Western New York (2) and the other a recently completed study in North Syracuse, New York (3).

LITERATURE REVIEW

There exists a wide array of literature in which aesthetics and highway design are addressed (4). Corridor location of highways (6,7) or scenic highway attribute identification and analysis are addressed (5,8-11), and there are a few studies in which the urban or developed roadway is addressed (12,13). There is interesting empirical, behavioral, and perceptual work on perceptual selection and memory of road views (14); the effect of duration of view (10); individual variations in road view descriptions (15); and the role of personality differences in judgments of roadside quality (16). There is also research on user attitudes about the levels of roadside maintenance (17), visitor attitudes toward secondary roads (18), and residents' viewpoints on environmental quality of city streets (19).

Finally, there are comprehensive approaches that attempt to incorporate aesthetic or visual resources into the highway planning process (20-22). There are also general articles on aesthetics and highway design (9,23-25), the application of which is questionable.

The intended approach is not so much to stress the visual or aesthetic resource, but to stress visual as a communication process. The application is neither design of a new highway nor documentation of scenic highways, but redesign of intensively developed commercial strips.

What is proposed is simply a reemphasis of the need to mesh the highway development process with the community development process. This concept falls neatly into line with the 3-C planning process--coordinated, comprehensive, and continuous. Although what is proposed here is more complex, to propose otherwise would invariably lead to further functional deterioration of commercial strip highways and increased development goal conflicts.

REVIEW OF PRINCIPLES OF THE VISUAL APPROACH

Principle 1: Understand the visual functions and amenity values of the highway commercial strip. Just as origin-destination studies are often conducted to understand the amount of traffic traversing a section of roadway, it is necessary to understand how the strip functions from an ecological psychology point of view. Figure 1 shows this perspective. Who are the primary users? Truck drivers and long-distance travelers? Visitors to the area? Or local commuters and potential shoppers? Are their needs similar or different? Do conflicts result, or, are their driving decisions and behavior quite different? With such a complex behavior spectrum, studies need to be conducted as the ecological diagram implies in order to understand the behavioral nature of the problem.

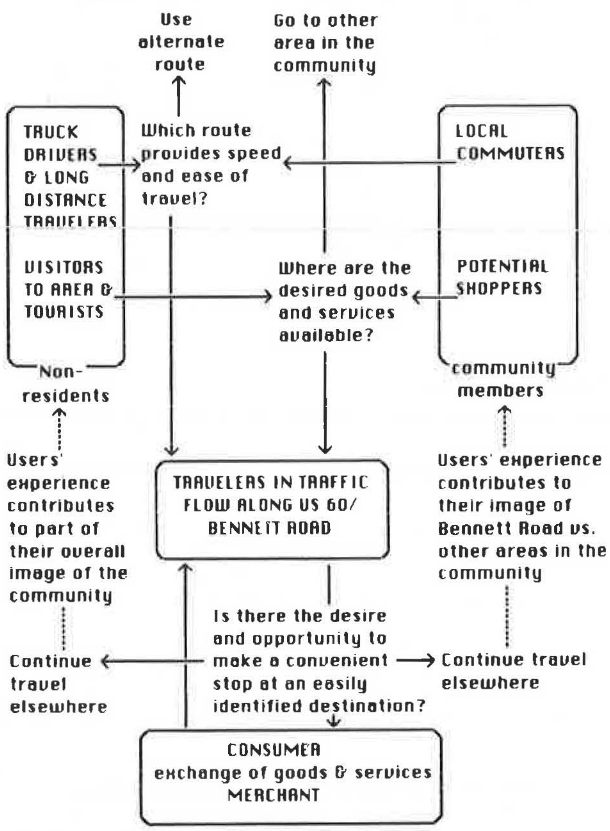

FIGURE 1 Ecological diagram of strip users *(2)*.

On an even more detailed level, actual behavior on the road can be examined for each of the highway user groups. For instance, how do they identify turning points? Do they rely on certain landmarks instead of signage? Can they find specific commercial establishments? Can they actually read commercial signage, or do they rely on the shape and color because there are too many letter characters to read at the distance and speed the driver is traveling (26)?

The driving experience is a dynamic one including many adjustments and decisions on the part of drivers on the roadway. To obtain a better understanding of what drivers see in complex visual environments,

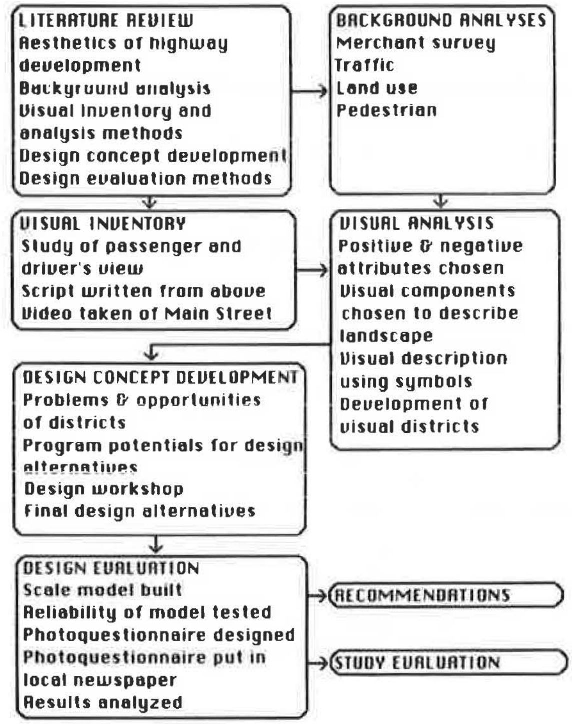

FIGURE 2 Flow chart of main street methodology *(3)*.

ACTORS	REASON FOR INVOLVEMENT
New York State Thruway Authority	Legal jurisdiction within 600' of of Thruway
New York State Dept. of Transportation	Legal jurisdiction of Route 60 right-of-way including design & maintenance
Chautauqua County Planning Agency	Knowledge of historical aspects, regional context, & local procedures
Local Municipalities	Political jurisdiction of adjacent properties
Local Land Owners	Legal ownership of adjacent properties
Chamber of Commerce	Support for new ideas, promotion of action
Community Development Council	Promote studies of potential change & facilitate coordinated action by decisionmakers (actors)
State University College of Fredonia	Provide local logistical support for study and faculty consulting
College of Environ. Science & Forestry at Syracuse	Provide technical expertise of both students and faculty
Users of the Site	Retail consumers exercise choice for specific goods and services in a community context

FIGURE 3 Actors of study and their reasons for involvement *(2)*.

Village Center Area 3

Proposed Alternative One
•No Change

Proposed Alternative Two

1. Signs would be removed unless hung flush with the buildings.
2. Curbs would be added with some on street parking eliminated.
3. Sidewalks would be extended away from the buildings and repaved.
4. Bigger planters would be added.

Proposed Alternative Three

1. Signs would be removed unless flush with the buildings.
2. Curbs would be added.
3. No on street parking would be allowed.
4. Sidewalks would have a textured finish and would be extended away from the buildings.
5. Planters would be added.
6. Street lights would be brought to a more human scale.
7. Utility poles and lines would be eliminated.

Response Form

Directions:
Please check the box which indicates the Design-Alternative you prefer for each area. Bring or mail this form to the Village Hall, 600 So. Bay Rd., No. Syracuse/The Star-News Office, 211 No. Main Street or drop it at Merchants Bank, No. Syracuse Free Library or No. Syracuse Pharmacy by Dec. 9.

Area 1-Taft Rd. Intersection Area

☐ Alternative 1
☐ Alternative 2
☐ Alternative 3

___ ___
Yes No Should the utilities be put underground?

Comments: ______________________

Area 2-Parochial Area

☐ Alternative 1
☐ Alternative 2
☐ Alternative 3

___ ___
Yes No Should the utilities be put underground?

Comments: ______________________

Area 3-Village Center Area

☐ Alternative 1
☐ Alternative 2
☐ Alternative 3

___ ___
Yes No Should the utilities be put underground?

Comments: ______________________

Where do you reside in relation to Main Street, North Syracuse?

☐ 0-3 miles ☐ 4-7 miles ☐ 7-10 miles ☐ 10 or more

Did you respond to this survey when it appeared in the Star-News before?

___ ___
Yes No

FIGURE 4 Sample black and white photomontage simulation with questionnaire *(3)*.

such as commercial strips, they were asked what they notice in the roadway environment (3). Drivers were given cameras to photograph what they notice, and they subsequently have developed video shooting scripts to help the research team record actual driver and passenger view sequences (27). Drivers were also asked to assess positive and negative attributes within these same view sequences (3). Many of the study steps are outlined in the North Syracuse flow shown in Figure 2. This study and others (10,15) enable investigators to better understand how drivers and passengers function in a complex visual environment.

Principle 2: Promote communication of multiple involved parties. Planning highways or highway improvements is quite complex because there are many different parties and jurisdictional questions involved. Figure 3 shows just how complicated such a project can become. This figure shows the role of 10 different types of involvements and more than 21 specific parties. A means of clearly communicating the descriptive aspects of the project, the project alternatives, and the impacts of each alternative is needed. This is a principle that has unfortunately been elusive for preparers of environmental assessments and environmental impact statements. Even though U.S. Department of Transportation (DOT) documents provide clear guidance for approaches to describing the scope of the project, especially those involving visual resources (28), aspects of the visual approach works for other resource areas as well (29).

Principle 3: The need for visual simulation of alternatives. The second principle leads to the third principle--the use of visual simulations of alternatives for examination, analysis, and public scrutiny. Visual simulation techniques, if carefully performed, can be used to realistically portray different highway development alternatives (30). This helps professionals, as well as publics, analyze and evaluate certain effects. Appropriate simulation of the highway visual experience has been stressed in other studies (10,15,20,29) as well.

Researchers at the School of Landscape Architecture have experimented with acetate overlays on color photographs, color photocopy with partial rendering (2), black and white photomontage (3), color photomontage (31), modelscope photography (32), modelscope video, and renderings on video freeze frame (3,27) images. The objective is to find satisfactory means of realistic and accurate portrayal of alternatives. (See Figure 4.)

Professionals and publics alike are interested in visual futures, not in plan form, but in a 3-dimensional spatial perspective that has a fair degree of realism (33). Beside debating points about how the alternatives appear visually, simulations facilitate discussions of other critical issues such as safety related to visibility and speed, appropriate land use and sign controls, and maintenance questions. Also, simulation is not limited to visual effects, but can be used to illustrate solar effects such as glare potential, shadow patterns, and wind effects (27,32).

Basic video inventory of moving sequences (27) have been found to be extremely useful for analyzing complicated highway strip environments (3) and black and white photomontages (see Figure 4) for use in gauging public reactions to alternatives (3,34).

Principle 4: A comprehensive treatment of all landscape elements is needed. When a project is separated from its landscape context, it is often difficult to analyze relationships or judge certain effects. For example, in one case, a community believed that if they invested funds in building facade improvements they would drastically improve the appearance of their village center. By doing modelscope video and simple photomontage, community leaders were shown that a greater improvement could be obtained by using plants than by altering building facades. In another case, simple curbing along a roadway would not only improve the road edge appearance, but also would aid drainage and eliminate indiscriminate parking. To understand these relationships, a holistic visual approach can be used.

Principle 5: Encouraging involvement of multiple parties. All the techniques mentioned previously and clarity of organization can encourage the involvement of multiple parties as well as identify appropriate roles. The latter can be observed in Figure 5 (Action Plan). There will be few, if any, large federally financed projects, but there will be projects funded by complex arrangements of agency programs and even involvement by private parties. Appropriate roles and action plans need to be identified if projects are to succeed and to ensure the meaningful integration of road improvement projects into community planning.

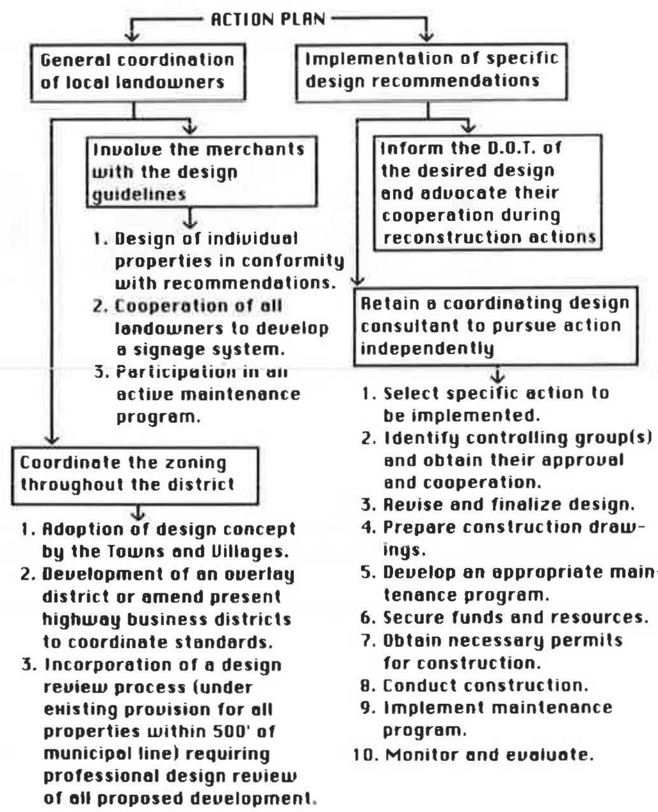

FIGURE 5 Outline of action plan *(2)*.

CONCLUSION

The highway commercial strip environment will be around as long as the automobile persists as a major transportation mode. The question is how can effective decision making and consensus be achieved for actions that affect complex environmental settings. A visual approach allows a more holistic and communicative means to be applied to this problem. It also facilitates environmental review and public disclosure obligations, hence, avoiding lengthy litigation (30,35) while holding open the possibilities of multiple party involvement.

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Design and Construction of Highway Underpasses Used by Mountain Goats

FRANCIS J. SINGER, WALTER L. LANGLITZ, and EUGENE C. SAMUELSON

ABSTRACT

US-2 was reconstructed in Glacier National Park, Montana, past a natural mineral lick and crossing area regularly used by mountain goats (Oreamnos americanus). A bridge was built over the highway as an underpass for goats (underpass dimensions = 12 to 28 ft high x 90 ft wide x 44 ft through). A second bridge over a stream crossing located 200 ft to the east was improved for mountain goat underpassages. Cyclone fencing 8 ft high and reinforced earth walls 8 to 24 ft high forced goats to use the bridges in a 500-ft crossing zone. Most crossing goats (99.4 percent) used the two bridges. Mountain goats were disturbed less after the bridges were built. Goats extended their season of visits to the lick into fall and winter, and individual goats doubled their number of lick visits per year after the bridges were built.

US-2 enters the southern tip of Glacier National Park for 3.6 miles from Walton to Nimrod. The highway through this steep, narrow canyon was sinuous, steep, and prone to more accidents and winter snow removal problems than adjacent sections (1). Adjacent sections of US-2 were reconstructed and widened in 1967, further contributing to a speed bottleneck in the Walton-Nimrod section.

Before highway construction in 1980-1981, a population of approximately 95 to 120 mountain goats (Oreamnos americanus) from Glacier National Park and 20 to 45 from the adjacent Flathead National Forest crossed US-2 in this area to visit a natural mineral lick (2). Highway crossings occurred primarily from April to August of each year. Goat mortality was low, apparently because of slow vehicle speeds (25 mph) past the 500-ft long goat crossing zone. However, 13 near hits of goats by vehicles were observed in 1975, and increased goat mortality was predicted should highway speeds substantially increase (2). In spite of little advertisement and only primitive access, visitation to the goat lick view area in 1975 was estimated at 66,000 visitors in 24,000 vehicles (2). Passing traffic and GNP visitors in the area disturbed goats. Many initial highway crossing attempts were unsuccessful, some goats altered their initial crossing route, and others hesitated on the highway edge or ran back from passing vehicles (see Figure 1). Three separations of nannies from their kids were observed in 1975, which could have ultimately led to kid mortality. Highway crossing success by mountain goats was lowest when both passing traffic and visitors in a west pullout were present (2). Visitors parking on and walking over the roadside presented additional highway safety hazards. FHWA funded preconstruction studies and construction monitoring of the mountain goats. Concurrence by the National Park Service and other responsible agencies and public support to proceed with reconstruction was received (1). The

FIGURE 1 Goats crossing highway surface before reconstruction of US-2 in Glacier National Park, Montana.

design and construction features of the US-2 underpasses built by FHWA to accommodate crossings by mountain goats are reported in this paper.

HIGHWAY AND BRIDGE DESIGN

A goat bridge was constructed in 1980 on which 80 percent of the 1975 goat crossings had occurred. The underpass area for goats varied from 12 to 28 ft high x 90 ft wide x 44 ft through (see Figure 2). Goats in the upslope approach to this bridge were at eye level with vehicles passing on US-2 (see Figure 2). Although forest cover existed here for goats, additional conifer saplings were planted and metal screening (4 ft high x 90 ft long) was placed on the upslope rail of the bridge to provide a greater sense of security for goats. A second, previously existing bridge over Snowslide Gulch was altered to accommodate goat crossings around its west abutment. A flat bench was gouged from the rock (12 ft high x 12 ft wide x 24 ft through). Existing goat trails were obliterated and new trails were dug leading to the entrances of both bridges.

The highway between both bridges and 200 ft west of the Goat Bridge were restricted to mountain goats by cyclone fencing uphill and a reinforced earth wall downhill of the highway. The cyclone fence was 8 ft high and was placed in a V shape pointed uphill in order to parallel or drift with the general direction of goat movements (see Figure 1). A reinforced earth retaining wall was placed parallel and downhill from the highway, which forced goats moving uphill to use the two bridges. This wall also served to build the highway up ±12 ft for a higher avalanche passage under the Snowslide Gulch Bridge.

National Park Service policy and the great popularity of the goat lick mandated that visitors be accommodated at the site, even though their presence had been demonstrated to disturb goats crossing the highway. An off-road view area and parking lot was constructed east of Snowslide Gulch where visitors could overlook the lick from a viewpoint. Its location away from the bridge area was intended to reduce any interference with goats. The viewpoint's location off-road was intended to reduce the safety hazards associated with faster through traffic and on-road parking and walking by visitors.

Highway design speed and width of the roadway cut were a compromise between conflicting objectives. On the one hand, a wider cut and straighter, more level road (higher design speed) contributes to faster melting of snow and ice, lower highway accident rate, better driver visibility, and facilitates winter snow removal. On the other hand, mountain goats in summer and elk that spend the winter in the area prefer to cross the highway where forest cover is closer to the road (3,4). Aesthetic considerations and National Park Service administrative policy suggest both minimal clearing limits and cut and fill through a more undulating grade-line and gradual curves instead of long tangents (5). The final compromised road width was 24 ft, and paved shoulder width was 5 ft. Reinforced earth walls were used extensively and totaled 1,344 ft in two locations. Highway design speed was 45 mph for 0.6 miles near the goat lick but 50 mph elsewhere.

Aesthetic and National Park Service policy considerations were addressed in a revegetation plan. The plan received input from landscape architects, engineers, plant ecologists, and foresters from the National Park Service, FHWA, Forest Service, and the Bureau of Indian Affairs (BIA). The revegetation plan included the following steps:

1. Initial seeding of cut and fill slopes was achieved by hydraulic slurry of native grasses that approximated adjacent natural vegetation (*Agropyron spicatum*, *Poa canadensis*, *Festuca ovina*);
2. Remedial plantings were conducted on the more severe sites where the initial seeding failed through seeding of the same grass species by hand and also planting of started bunchgrass plugs;
3. Security cover at the upslope approach to the Goat Bridge was increased by planting 2 to 3 ft conifer saplings;
4. Obliteration of the visual fence effect on the abandoned sections of old road and the far upper ends of cut slopes was achieved by planting conifer seedlings (*Pinus contorta*, *Picea engelmanni/glauca*) and shrub seedlings (*Cornus stolonifera*, *Symphoricarpos albus*, *Acer glabrum*, *Sambucus racemosa*). The project area was the source of seeds. The U.S. Department of the Interior (USDI) and the BIA nursery at Ronan, Montana, started the seedlings and provided planting crews. The plantings emphasized shrub species rather than conifers on sites less than 40 ft from the highway edge to minimize shading of the road surface. Revegetated zones resemble the natural bunchgrass-shrub-conifer mosaic with scattered patches of bare ground, instead of an artificial, monotonous carpet of exotic grasses.

CONSTRUCTION SCHEDULE

A number of restrictions were placed on the contractor in order to minimize disturbances to mountain goats: (a) construction on the Goat Bridge was not permitted between May 15 and August 1, 1980, in order to avoid conflict with most goat visits to the lick; (b) blasting was confined to the times of least daytime goat activity, 0800 to 1200 hr; (c) construction activity was restricted during the peak goat crossing hours of 0600 to 0730 hr and 1800 to 2200 hr; (d) no equipment was parked along the most significant 130-ft long goat crossing zone. Work areas and equipment were surrounded by temporary fencing to avoid goat injuries or entanglements; (e) the

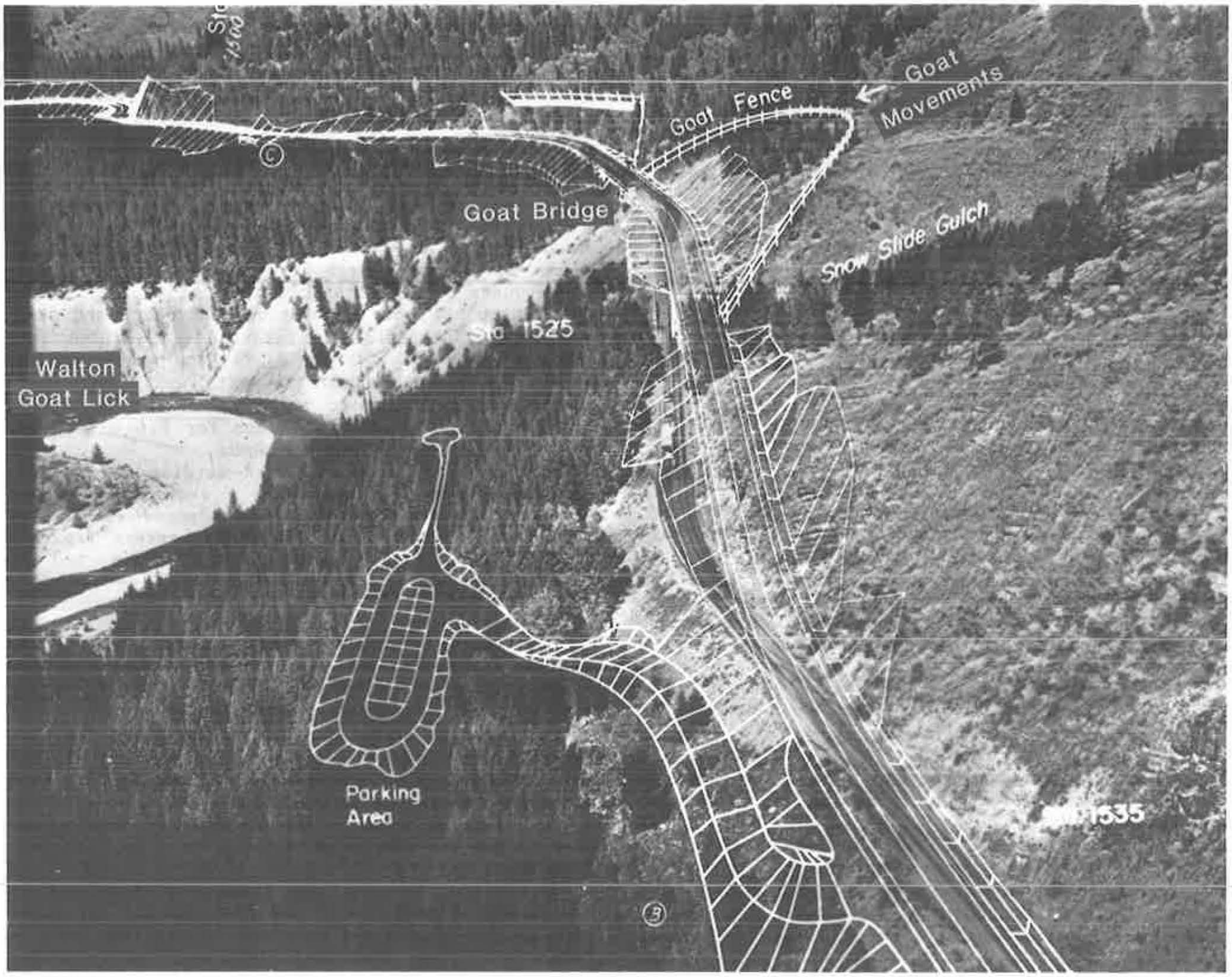

FIGURE 2 Reconstruction alterations to the mountain goat crossing area of US-2 at the Walton Goat Lick, Glacier National Park, Montana.

project area was checked for goats before equipment start up; (f) passing traffic was stopped by flag people to allow goats to cross the highway; (g) because of the open crossing route left near the Goat Bridge, construction on the Snowslide Gulch Bridge was not terminated because of the presence of goats (6). A National Park Service wildlife biologist (F. Singer) monitored the highway project for any serious disruptions or injuries to the goats and to warn the contractor and flag people of any impending goat crossing. During construction goat disturbances actually decreased as a result of less visitor activity and slow speeds of automobiles. Consequently, goat route preferences changed and the more exposed but steeper Route 3 received greater use by goats (see Figure 3).

PRELIMINARY ASSESSMENT OF THE PLAN FOR GOATS

After completion of the goat underpasses, 99.4 percent of 924 observations of mountain goats crossing the highway were under either of the two bridges (see Figure 4). Only 0.6 percent of the goats passed around either end of the structures and fencing to cross the highway surface (7). Physical contact was made initially (charges, head butts, stand on hind legs) against the fencing, but goats rapidly adapted and eventually drifted along the fence and under the bridges with fewer hesitations (7). The underpasses apparently removed much of the stress associated with highway crossings. The following relaxations in goat behavior were observed: (a) lick visits per goat in 1981 doubled over 1980, and the lick season was extended into fall and winter; (b) highway crossing success increased by 16 percent, and hesitations and run-backs per crossing attempt declined; (c) the incidence of erect tails in goats, which indicate fear, declined for goats crossing under the bridges; and (d) the rate of potentially lethal nanny-kid separations declined by one-third (7). Some goats even spent time bedded, licking eroded road salts, or feeding under the bridges. Vehicles passing over the bridges while goats were at eye level in the upslope approaches continued to cause goat disturbances. Both the Goat Bridge and the Snowslide Gulch Bridge received about equal passage by goats. Some visitors parked and stood on top of the bridges, disturbing the goats, instead of using the off-road view area.

Mountain goats readily adapted to the noise of normal construction activity such as operating payloaders, graders, and bulldozers, but were alarmed by blasts and high-frequency drilling (7). The only severely disturbed goats were nine groups that moved downhill to cross when heavy equipment was operating

FIGURE 3 Goats crossing the more exposed and steeper Route 3.

on the Goat Bridge. These goats were held up for 3 to 6 hr and crossed only after the equipment shut down. A total of eight groups, crawled through or entered inadvertent gaps in temporary fencing. Several of these goats were trapped for 1 to 6 hr before finding a way around, and one of the groups crossed the road and encountered the 8 ft drop-off of the downhill reinforced earth wall. This group walked along the top of the wall until an approaching truck precipitated them to jump off--but none apparently received injuries. Mountain goats made little use of one-way deer gates (8) erected to allow goats to escape when they were caught inside the fencing. Visitors who crawl off the bridges, however, are often forced to exit the fencing through these gates.

Small groups (1 to 4) of mountain goats persisted in use of the Snowslide Gulch Bridge during all of 1980 in spite of the presence of low-level concrete work by one to four men. It should be emphasized that the low goat disturbance rates observed were a result of the frequent monitoring of the construction zone, the stringent restrictions on the contractor, the contractor's benevolent attitude toward the goats, the lack of harassment of the goats, and the protected status of goats in Glacier National Park. Mountain goats that are hunted or harassed might not have habituated as well.

DISCUSSION

The decision to build a highway underpass for goats was based on a review of the published literature on ungulate-highway relations and also an on-site inspection of highway-ungulate problems in the Rocky Mountain National Parks of Canada (4). The following information was gathered:

1. Mountain goats used a highway overpass (highway snowshed) in Glacier National Park, British Columbia. However, goats had been hit by vehicles at the snowshed approaches due to low driver reaction times. Also, the shaded snowsheds encouraged dangerous black ice, required lighting, and had been the scene of serious vehicle accidents.
2. Natural mineral licks along Trans-Canada 1 and 16 were the scene of a number of ungulate kills by vehicles. Also vehicle collisions occurred between very fast (60 to 70 mph) Trans-Canada traffic and park visitors pulling in and out of view areas or parked along the highways.
3. Ungulates known to use underpasses of highways or pipelines include elk, Cervus canadensis

FIGURE 4 Nanny with twins at side passing under the Goat Bridge of US-2, Glacier National Park, Montana.

(Halle Flygare, personal correspondence, Banff National Park; staff of Yoho National Park, British Columbia, personal correspondence), mule deer, Odocoileus hemionus (8,9), moose, Alces alces (10), and caribou, Rangifer tarandus (11), although pronghorn antelope, Antilocarpa americana (8) refuse underpasses.

A crossing structure of some type was deemed necessary to protect goats and humans. An overpass for goats was ruled out because of the Canadian experiences with safety problems. This information coupled with limited observations of mountain goats using a confined space under the Snowslide Gulch Bridge in 1975 (2) suggested that goats would likely accept an underpass. In addition, it was concluded that degree of acceptance of an underpass was likely to increase if it was not confining (9), if it was accompanied by restrictive lead-in fencing (8,9), if it was situated on a goat movement route (12), and if conifer covering or other shielding was present in the underpass approaches (2). The construction plan for US-2 followed these guidelines as closely as was feasible and resulted in very high (99.4 percent) acceptance of the two underpasses. In addition, a significant decrease in disturbances to the mountain goats was achieved.

Three design questions are posed by the 1981 observations of mountain goats using the two underpasses:

1. How critical was conifer cover near the bridges?
2. Was construction of the Goat Bridge necessary or would all goats have used the new Snowslide Gulch Bridge?
3. What were the minimum size dimensions for the Goat Bridge?

Conifer cover was a critical factor during highway crossings in 1975 (2), but with the reduction in disturbances in 1980 and 1981, goats made more use of the exposed approach routes. Cover on the downhill approach to the Goat Bridge still appeared to be important to at least some goats (7). The Snowslide Gulch Bridge and the Goat Bridge were used about equally in 1981, but the Snowslide Gulch Bridge was only about two-third the height and one-seventh the width of the Goat Bridge. This initially suggests some of the space under the Goat Bridge was superfluous. However, the overall visual window under a bridge may be more critical than that for the crossing path. The overall dimensions of the Snowslide Gulch Bridge are far greater than the Goat Bridge because goats cross on a relatively small bench near the west abutment of a large (60 ft high x 60 ft wide) crossing of the Snowslide Gulch. Only 3 percent of goats in 1975 used the Snowslide Gulch Bridge, but 50 percent used it in 1981.

It is not possible to predict if all goats would have used the Snowslide Gulch Bridge thereby precluding building the Goat Bridge. Longer fencing to the west would likely have been required. Additional fencing would have been expensive, and fencing in this area requires maintenance because of frequent avalanching. Previous experiences and learning during construction were apparently critical to route preferences by goats. Use of the Snowslide Gulch Bridge by goats developed slowly but steadily during construction in 1980 as other avenues of access were alternately blocked. Thus, if goats had been forced around the far western end of the fences during construction, that tradition might have proved difficult to break even after the Snowslide Gulch Bridge and all structures were later in place.

ACKNOWLEDGMENTS

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Wildlife Use of Roadside Woody Plantings in Indiana

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ABSTRACT

The Indiana Department of Natural Resources began a program of right-of-way plantings for wildlife in 1976. By 1983 almost 950,000 shrubs had been planted along 4-lane highways. The use of these plantings by wildlife was studied from June 1983 to January 1984. Shrub-planted study areas and grassed control areas were identified along four highways. All areas were walked four times during the study period and observed birds, mammals, and roadkilled wildlife were recorded. Incidence of roadkill was not affected by the plantings. The number of rabbits was increased only slightly by the presence of shrubs. Planted areas were used by a greater number of bird species and by a much greater number of individual birds than the grassed areas. The shrub plantings were important to birds as nest sites. Right-of-way plantings are an important addition to wildlife habitat.

Indiana is rapidly losing wildlife habitat to intensive farming, urbanization, industrialization, and highway development. Clean farming practices such as fencerow removal or reduction, continuous rowcropping, chemical control of weeds, and fall plowing are destroying wildlife habitat. Thousands of miles of state and Interstate highway right-of-way (ROW) are predominantly monocultures of closely mowed grasses and are of little benefit to wildlife.

Indiana Department of Natural Resources (IDNR) biologists recognized the detrimental effect of habitat loss and implemented a program of ROW wildlife plantings to partially replace lost wildlife habitat. From 1978 through 1983, IDNR planted various species of trees and shrubs along certain 4-lane highways.

Wildlife use of these plantings was unknown. A literature search indicated that little research has been done on wildlife habitat development, using woody plants, on highway ROW in Indiana or in surrounding states.

The objectives of this study were to determine the following:

1. Do IDNR-planted experimental plots attract a greater number of birds and mammals than unplanted control plots?
2. Is there a difference in species diversity for experimental plots as compared to control plots?
3. Is there a significant difference in the number of bird nests found on experimental plots as compared to control plots?
4. Is there a significant difference in the number of roadkills found on and adjacent to experimental plots as compared to control plots?

LITERATURE REVIEW

The need for and importance of highway ROW as wildlife habitat has been discussed by many researchers. Leedy (1) and Leedy and Adams (2) stated that nationwide there is an area the size of the state of Indiana in vegetated highway ROW--an area large enough to merit serious consideration in wildlife management. Leedy (1) indicated that few studies have been conducted of highway ROW as wildlife habitat per se. He recommended that the value of ROW should be determined, not only for pheasants, waterfowl and other game birds, but for songbirds and other wildlife as well.

The potential for improving ROW as wildlife habitat has been known for some time by wildlife managers. Michael (3) discussed research conducted in the 1940s that estimated that 75 percent of highway areas in the contiguous 48 states were providing food and cover for wildlife, and that, on approximately 75 percent of these lands, it was economically feasible to improve the quality of the habitat. Rongstad (4) stated that work done by Aldo Leopold indicated a high diversity of flora and fauna on old grown-up roadsides, whereas mowed and otherwise altered roadsides had few species. Dambach (5) stated that Ohio's highway ROW, then totaling 250,000 acres--an area larger than the state forests in Ohio, have a part in conservation, and he indicated that mile for mile and acre for acre, Ohio's roadsides, next to fencerows, probably are the most productive wildlife lands in the state.

Research concerning wildlife and highway ROWs is not limited to the United States. Laursen (6) studied bird use of road verges (ROW) and the influence of summer mowing on birds in Denmark. He found that different parts of the road verges are used for foraging, and that the road verge provides nesting habitat for species such as Skylark, Alauda arvensis. Way (7) discussed the need for research concerning road verges and habitat conservation in England. Kelcey (8) in reviewing the potential value of road verges for wildlife, indicated that wildlife and wildlife habitat have received little consideration during and after highway development.

Several studies have been conducted on the use of herbaceous plantings along roadsides. Michael (3) researched wildlife use of roadside cover plantings in West Virginia. He suggests that the ROW should be managed to attract species that pose no threat to vehicular traffic, while encouraging the attraction of species that are aesthetically pleasing. Wiegers (9) surveyed bird use of nesting cover along roadsides in Nebraska and found most pheasant and quail nests were found in brome grass (Bromus sp.). David and Warner (10) studied the development of nesting cover for pheasants along roadsides in east-central Illinois. They suggest that the roadside can be managed as a principal source of nesting habitat for pheasants. Joselyn and Tate (11) studied the management of roadside cover for pheasant and indicated that delayed mowing of roadsides, to allow pheasants to leave the nest, is an important factor in roadside management. Oetting and Cassel (12) investigated waterfowl nesting on highway ROW in North Dakota. However, studies involving the use of woody plants in ROW management are limited in numbers.

Highway development can have a beneficial or detrimental effect on wildlife by destroying habitat or creating new habitat. The impact of highway development on wildlife has been recorded by Leedy (1), Adams and Geis (13,14), Bruner et al. (15), and Getz et al. (16). Stapleton and Kiviat (17) studied vegetation management of railroad ROW and its effect on breeding birds. They stated that life histories of target bird species need to be considered when planning the management of ROW.

During the planning and design of highways, usually little or no consideration is given to wildlife. Leedy and Adams (2) discussed the planning and development of highway corridors with consideration given to wildlife.

Various researchers have studied the effect of highway ROW on a particular animal species or on the animal community in general. Ferris (18) found that red-tailed hawks (*Buteo jamaicensis*) and American kestrels (*Falco sparverius*) were observed within the highway ROW more frequently than would be expected by random distribution. He indicated traffic did not appear to have an adverse effect on hawks, and thus the ROW represents undisturbed habitat. Michael et al. (19) studied the effects of highway ROW vegetation and adjacent ecotonal vegetation on bird species, placing special emphasis on passerine birds and diurnal birds of prey. They recommended the development of highway ROW to increase the number of birds. Ferris et al. (20) investigated the ecological impact of a major highway in Maine on birds and mammals. Oxley et al. (21) found that the highway ROW habitat provided a ready supply of grass that allowed some Microtinae rodents to flourish and expand their ranges. Clark and Karr (22) concluded that the existence of highway ROW with extensive grass habitat and scattered shrubs in east-central Illinois should enhance breeding success and increase population density of red-winged blackbirds (*Agelaius phoenicus*). Ferris (23), in studying the effects of a major highway on breeding birds, found the presence of an edge component was reflected in increased species diversity.

Best (24) recorded use of fencerows and found that continuous tree and shrub fencerows have a higher number of species and greater numbers of birds as compared to herbaceous fencerows and fencerows with scattered trees and shrubs. Wandall (25) discussed the need for woody plantings in the development of songbird habitat. Using control areas having Osage-orange (*Maclura pomifera*) hedgerows, he found twice as many bird nests in planted areas of multiflora rose (*Rosa multiflora*), elderberry (*Sambucus* sp.), hazelnut (*Corylus* sp.), and dogwood (*Cornus* sp.).

In 1974 IDNR wildlife biologists participated in a statewide study to determine wildlife use of highway ROW plantings in Indiana [Machan (26)]. Data collected indicate that a greater number and greater diversity of birds and mammals use the tree-shrub planted areas. There was greater evidence of reproductive attempts (nests) on tree-shrub areas than on grassed areas. More animals were roadkilled adjacent to grassed areas than adjacent to planted areas. Machan concluded that wildlife numbers on ROW will increase without an attendant increase in roadkills if ROW are planted with trees and shrubs. Zewadski (27) suggested that unfortunately the Interstate fauna may be the predominant fauna of the future, and further research needs to be done on the impact of highway plantings on wildlife populations.

STUDY AREAS

Study areas included four central Indiana highways (US-31, I-65, I-69, and I-70) that had IDNR roadside plantings. The US-31 study area included 31.5 miles between State Road 16 and County Road W 13th in Miami, Fulton, and Marshall counties. The I-65 study area was a 12-mile portion of highway in Tippecanoe and Clinton counties between State Road 38 and State Road 28. The I-69 study area included 5 miles in Delaware and Grant counties between State Road 28 and State Road 26. The I-70 study area included 24 miles in Hendricks, Morgan, and Putnam counties between the intersections of US-231 and State Road 267.

Barnes (28) divided Indiana into zoogeographic regions. He described the Northeastern Lakes region, the area having most of the US-31 study area, as a region in which potholes, marshes, lakes, and streams offer edge cover for wildlife. The I-65 study area is in the Prairie Fringe region. This region is generally rolling and lower in productivity than the regions to the east and west. The Central Tipton Till Plain region encompasses the I-69 study area and is a gently rolling fertile plain in which intensive agricultural practices limit wildlife habitat. The I-70 study area is within the Prairie Fringe and Central Tipton Till Plain regions.

Fourteen species of wildlife shrubs and trees were planted in the four study areas (Table 1). With the exception of Autumn Olive planted along I-65 in 1975, all study plantings were accomplished in 1978.

TABLE 1 Shrubs and Trees Planted by IDNR on Study Plots

Species	US-31	I-65	I-69	I-70
Autumn Olive, *Elaegnus umbellata*	X	X	X	X
Flowering Dogwood, *Cornus florida*				X
Shrub Dogwood, *Cornus* sp.	X	X		X
Amur Honeysuckle, *Lonicera maackii*			X	X
Flowering Crabapple, *Malus* spp.	X			X
Hawthorn[a], *Crataegus* spp.	X	X	X	X
Redbud, *Cercis canadensis*		X		
American Hazelnut, *Corylus americana*	X		X	
Smooth Sumac, *Rhus glabra*		X	X	
Japonica Lespedeza, *Lespedeza bicolor japonica*	X	X		
Ninebark, *Physocarpus opulifolius*	X		X	X
Bristly Locust, *Robinia hispida*	X	X		
Common Elderberry, *Sambucus canadensis*				X

[a]Two species of Hawthorn, Washington Hawthorn, *Crataegus phaenopyrum* and Downy Hawthorn, *Crataegus* sp., were planted by IDNR, but were not identified to species in this study.

MATERIALS AND METHODS

Plots 100 m long were selected along the four highways. Plot width ranged from 15 to 40 m. Plot width was from right-of-way fence line to the near edge of the highway. Mean plot width was 22.4 m. Experimental plots were located within the IDNR plantings. Control plots were in grassed ROW. Control and experimental plots were interspersed along each highway with a gap between plots. Plots could occur on either side of the highway. Plots were marked with orange flagging on fence posts and with paint on the highway. A brief description of adjacent habitat and dominant plant species on the plots was recorded.

A total of 156 plots, 79 experimental and 77 control plots, was surveyed during each study period. US-31 had 21 experimental and 21 control plots; I-65 had 20 experimental and 20 control plots; I-69 had 17 experimental and 15 control plots, and I-70 had 21 experimental and 21 control plots.

A census was taken along each highway during four study periods: (a) the last 15 days of June 1983, (b) the last 15 days of July 1983, (c) the last 15 days of September 1983, and (d) the last 10 days of December 1983 and the first 10 days of January 1984. A census was conducted of each highway once per study period. Birds and mammals observed on plots were recorded. Fence-sitting birds were recorded as being on the plot. Each bird nest was counted then marked with orange flagging at the base of the tree or shrub to avoid counting the nest twice. Other observed animal signs (tracks, feces, gnawings) were recorded. A census of control plots was conducted by a single observer. A census of experimental plots with tall, dense foilage was conducted by two observers, each on opposite sides of the tree-shrub plantings. Time expended conducting a census of a plot was about 10 min. Each survey began at sunrise and ended when the census for all plots for that highway had been completed. Usual finish time for a given highway was early afternoon. Each survey began with the same plot and traveled in the same direction during each study period (e.g., US-31 surveying began on plot 1 and ended with plot 42 for each study period).

Surveys were conducted on days of little or no precipitation with wind velocity less than 10 mph. Ambient air temperature, wind velocity, and percent cloud cover were recorded at the beginning and end of each survey day.

Statistical treatment involved an analysis of variance and covariance with repeated measures. A probability value of 0.05 (P=0.05) was used in analyzing data.

RESULTS

The Red-winged blackbird was the most abundant bird species on both experimental and control plots. American goldfinch (Carduelis tristis), house sparrow (Passer domesticus), song sparrow (Melospiza melodia), American robin (Turdus migratorius), and common grackle (Quiscalus quiscula) were some of the more commonly observed birds. On control plots with more than three individuals of each species sighted, eastern meadowlark (Sturnella magna), house sparrow, and field sparrow (Spizella pusilla) were the most abundant species. Twenty-five bird species, with flycatchers Empidonax spp. being counted as a single species, were observed on experimental plots. Seventeen bird species were observed on control plots (Tables 2,3). Rabbit sign found on 38 experimental plots and on 22 control plots was significantly more often present on the planted plots (Table 3). Deer sign occurred on three experimental plots and seven control plots. This was not a significant difference. No determination was made of the number of deer or rabbits actually using a plot.

Eastern cottontail (Sylvilagus floridanus) was the most abundant species observed (Table 3). The 24 mammals observed on the experimental plots were not a significantly different number than the 15 observed on control plots (Tables 3,4). Three mammalian species, excluding the unidentified sightings, were observed on both control and experimental plots.

Experimental and control plots had the same number of roadkilled animals (Tables 3,5). Raccoons (Procyon lotor) were the most common roadkill.

Tree-shrub planted areas contained a much greater number of bird nests per individual highway and in total (Tables 3,6). Autumn olive and Crataegus spp. were the IDNR plantings that held most of the bird nests found. Multiflora rose held the greatest number of bird nests on control plots (Table 7).

TABLE 2 Birds Observed on Experimental and Control Plots

Species	Experimental	Control	Total
Red-winged Blackbird, *Agelaius phoeniceus*	155	63	218
American Goldfinch, *Carduelis tristis*	56	12	68
House Sparrow, *Passer domesticus*	23	40	63
Unknown	47	10	57
Song Sparrow, *Melospiza melodia*	41	8	49
Unknown Sparrow	23	12	35
American Robin, *Turdus migratorius*	21	6	27
Common Grackle, *Quiscalus quiscula*	18	6	24
Mourning Dove, *Zenaida macroura*	7	4	11
Eastern Meadowlark, *Sturnella magna*	3	8	11
Indigo Bunting, *Passerina cyanea*	5		5
Gray Catbird, *Dumetella carolinensis*	5		5
Field Sparrow, *Spizella pusilla*	1	4	5
American Tree Sparrow, *Spizella arborea*	4		4
Northern Cardinal, *Cardinalis cardinalis*	2	1	3
Dark-eyed Junco, *Junco hyemalis*	3		3
White-crowned Sparrow, *Zonotrichia leucophrys*	3		3
Unknown Flycatcher, *Empidonax* spp.	2		2
Brown Thrasher, *Toxostoma rufum*	2		2
Northern Bobwhite, *Colinus virginianus*		2	2
Eastern Kingbird, *Tyrannus tyrannus*	1	1	2
Ruby-throated Hummingbird, *Archilochus colubris*	2		2
Starling, *Sturnus vulgaris*	1	1	2
Common Yellowthroat, *Geothlypis trichas*	2		2
House Wren, *Troglodytes aedon*	1		1
Philadelphia Vireo, *Vireo philadelphicus*	1		1
Northern Oriole, *Icterus galbula*		1	1
Blue Jay, *Cyanocitta cristata*		1	1
Horned Lark, *Eremophila alpestris*		1	1
Downy Woodpecker, *Picoides pubescens*	1		1
Yellow Warbler, *Dendroica petechia*		1	1
Yellow-billed Cuckoo, *Coccyzus americanus*	1		1
Total	431	182	613

TABLE 3 Analysis of Data Using ANOVA and Covariance With Repeated Measures

Categories	P-Value
Bird nests	<0.0001[a]
Bird numbers	<0.0001[a]
Rabbit sign	0.0065[b]
Deer sign	0.1455
Roadkills	0.9785
Mammal numbers	0.1547

[a]Indicates a highly significant difference between experimental and control plots.
[b]Indicates a significant difference between experimental and control plots.

TABLE 4 Mammals Observed on Experimental and Control Plots

Species	Experimental	Control	Total
Eastern Cottontail, *Sylvilagus floridanus*	17	11	28
Eastern Chipmunk, *Tamias striatus*	2		2
Unknown mammal	4	1	5
Vole, *Microtus* spp.		2	2
Woodchuck, *Marmota monax*	1		1
House Cat, *Felis catus*		1	1
Total	24	15	39

DISCUSSION

The IDNR plantings were made to provide an ecotonal habitat that would attract wildlife. Do experimental

TABLE 5 Roadkills Along Experimental and Control Plots

Species	Experimental	Control	Total
Raccoon, *Procyon lotor*	6	2	8
Unidentified mammal	3	1	4
Eastern Fox Squirrel, *Sciurus niger*		2	2
Thirteen-lined Ground Squirrel, *Citellus tridecemlineatus*		2	2
Red-winged Blackbird, *Agelaius phoeniceus*		2	2
Striped Skunk, *Mephitis mephitis*	1		1
Norway Rat, *Rattus norvegicus*		1	1
Woodchuck, *Marmota monax*		1	1
Virginia Opossum, *Didelphis marsupialis*	1		1
Bat	1		1
Dog, *Canis familiaris*		1	1
Brown Thrasher, *Toxostoma rufum*	1		1
Unidentified Bird		1	1
Total	13	13	26

TABLE 6 Bird Nests Found on Experimental and Control Plots

Highway	Experimental	Control	Total
US-31	44	2	46
I-65	40	1	41
I-69	17		17
I-70	33	8	41
Total	134	11	145

TABLE 7 Trees and Shrubs With Bird Nests

Species	Experimental	Control	Total
Autumn Olive, *Elaeagnus umbellata*	76		76
Hawthorn, *Crataegus* spp.	20		20
Multiflora Rose[a], *Rosa multiflora*	14	3	17
Ninebark, *Physocarpus opulifolius*	7		7
Amur Honeysuckle, *Lonicera maackii*	5		5
Flowering Crabapple, *Malus* spp.	4		4
Red Mulberry[a], *Morus rubra*	2		2
Common Elderberry, *Sambucus canadensis*	2		2
Red Cedar[a], *Juniperus virginiana*	1		1
Willow[a], *Salix* spp.		1	1
Japonica Lespedeza, *Lespedeza bicolor japonica*	1		1
Common Catalpa[a], *Catalpa bignoniodes*	1		1
American Hazelnut, *Corylus americana*	1		1
Sumac, *Rhus* spp.	1		1
Ash[a], *Fraxinus* spp.		1	1
Trumpet Creeper[a], *Campsis radicans*		1	1
Cherry[a], *Prunus* spp.		1	1
Box Elder[a], *Acer negundo*		1	1
Total	135	11	143

[a]Indicates volunteer plants—not planted by IDNR.

plots attract a greater number of birds and mammals than control plots? The results of this study indicate that they do. The results in Tables 2 and 4 indicate that 455 (70 percent) of the birds and mammals were observed on experimental plots, whereas 197 (30 percent) of the birds and mammals were observed on control plots. The data in Table 3 indicate that there is a highly significant difference in bird numbers on experimental and control plots. The IDNR planted plots provided food and cover for birds that were not available on control plots. There is no significant difference in mammal numbers on experimental and control plots. Although there was no difference in actual mammal numbers, there was a significant difference in rabbit sign on experimental and control plots. The closely spaced IDNR plantings provided cover for rabbits. Gnawings observed during the winter study period indicated that rabbits used these planted areas for feeding as well as for shelter during heavy snow. Wildlife numbers were greater on experimental plots, indicating that these areas are providing a better habitat than grassed ROW.

The second objective of this study was to determine if there is a difference in species diversity between experimental and control plots. The ecotonal habitat produced by the tree-shrub plantings attracted eight more bird species. The IDNR plantings attracted bird species that are commonly found in old field habitat. Brushland bird species such as indigo bunting, gray catbird, and American tree sparrow were observed in experimental plots, but not in control plots. Eastern meadowlark, a grassland species, was observed more often in control plots. Red-winged blackbirds were abundant on both experimental and control plots. Evidently, redwings have adapted to the ROW habitat whether planted or not. Many red-winged blackbird nests were found in the experimental plots. Redwings used IDNR plantings as perch sites as well as nesting sites. Redwings were commonly observed in control plots perched on the fence.

Adams and Geis (14) in studying the effect of highways on wildlife in the Midwest found that red-winged blackbirds comprised 50 percent of the bird community adjacent to Interstates and 28 percent of the highway bird mortality. Hewitt (29) in researching red-winged blackbirds along roadsides states that roadsides provide excellent habitat for territorial redwings, with the presence of fenceposts, wire fences, telephone posts, and water-filled ditches.

A highly significant difference was noted in the number of bird nests found indicating that the experimental plots (planted) provided better nesting habitat than control plots. No ground nests were found, which was probably due to observers focusing attention straight ahead to observe flushing birds. Volunteer plants, not planted by IDNR, were found to hold bird nests on both experimental and control plots. Multiflora rose, red mulberry, and red cedar held 17 bird nests on experimental plots (Table 7). The control of mowing and the prohibition of spraying with herbicide allowed the establishment of woody plant species useful to wildlife regardless of plantings made by IDNR. I-70 had eight bird nests on control plots. The control plots on I-70 had more woody vegetation than the control plots on other study areas.

Machan (26) found more roadkills on or adjacent to grassed plots. However, roadkill numbers in this study were the same for experimental and control plots. More than twice as many animals were observed in the experimental plots, yet the incidence of roadkill was the same as along control plots (Table 5). These results indicate that the ROW habitat can be developed with woody vegetation to attract wildlife without an attendant rise in roadkill.

CONCLUSIONS AND RECOMMENDATIONS

This study indicates that IDNR plantings do provide a habitat that attracts a greater number and greater diversity of wildlife, primarily birds. Evidence was found to indicate that rabbits used planted areas more than grassed areas. Nesting attempts suggest that the bird population finds ROW plantings suitable habitat for nesting. The roadkill data demonstrate that ROW can be developed to attract wildlife without an attendant increase in highway mortalities. The use of volunteer plants as bird nest sites suggests that more research is needed on areas that have been allowed to grow without mowing, spraying, or planting with woody species. ROWs have great potential for wildlife habitat development and will need to be used in the future as other areas of wildlife habitat diminish. The following recommendations are made:

1. Continuation of the IDNR planting program;
2. Develop a study to determine bird preference for individual species (i.e., autumn olive) and then discontinue planting of species that attract undesirable bird species (i.e., red-winged blackbirds); and
3. Initiate a study of ROWs that have been allowed to grow up with native woody vegetation because allowing roadsides to grow without spraying or mowing may provide wildlife habitat without the monetary cost of a planting program.

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Wildlife Populations Utilizing Right-of-Way Habitat Along Interstate 95 in Northern Maine

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ABSTRACT

From 1975 to 1982 the impact of the construction of Interstate 95 in northern Maine on the distribution, abundance, and diversity of birds, rodents, and other mammals was assessed. Populations and activities of breeding birds and mammals were examined before, during, and after construction of I-95 along sections adjacent to various forest habitat types. Movements and densities of birds and mammals adjacent to and away from I-95 did not differ significantly during and after construction. The use and avoidance of newly created edges by some species was examined. Immediate losses of habitats for breeding birds were noted, and the long-term effects on populations of birds and mammals are discussed.

Construction of the Interstate highway system has provided many benefits. It has minimized travel time, increased driving safety, and created additional economic opportunities for many areas. When construction of the Interstate began in 1957, the effects on the surrounding environment apparently were not always considered because of the lack of available information. Recently, additional emphasis has been placed on environmental considerations as a result of a growing awareness of the problem presented by construction of the Interstate, which in turn has generated public concern. This concern is exemplified by the National Environmental Policy Act of 1970 and amendments to the Federal Fish and Wildlife Coordination Act of 1934, which requires highway agencies to reevaluate the environmental impact of highway construction and maintenance. Until recently there have been few scientific studies relative to the impact of highways on adjacent vegetation and existing wildlife.

This study was the first of its kind in the northeast and is one of the few long-term studies of this nature on highways. The sites studied along I-95 in Penobscot County, Maine, were ideal because they involved construction through forests heavily populated with both hardwoods and softwoods (Figure 1). Future new construction will, in many instances, be an encroachment similar to the one studied on this highway.

The impact of I-95 in northern Maine on wildlife before, during, and after construction was studied from 1975 to 1982. The objectives of the study were to assess the impact, both positive and negative, of I-95 on the distribution, abundance, and diversity of birds, rodents, and mammals, with particular emphasis on rodents or small mammals as indicator species.

Beginning in 1975 during the preconstruction phase of the study, the status of songbirds, small- to medium-sized mammals, and white-tailed deer (Odocoileus virginianus) were investigated. From 1977 to 1980 the study concentrated on the behavioral responses of songbirds to construction activities while continuing to monitor mammal populations and activities. The final phase of the study or postconstruction evaluation was conducted in 1981 and 1982.

The study was conducted along two 15-km sections

FIGURE 1 Location of study areas.

of I-95. The southern section, representing a control area, was completed before the study, whereas two southbound lanes, that constituted the experimental area, were completed in the northern section during the study. The distance between north and south lane fences or right-of-way (ROW) boundaries was about 150 m, with a 30-m wide residual median strip separating north and southbound lanes.

Sample plots for softwood stands were comprised of balsam fir (Abies balsamea), red and white spruce (Picea rubens and P. glauca), eastern hemlock (Tsuga canadensis), eastern white pine (Pinus strobus), and northern white cedar (Thuja occidentalis) 40 to 100 years old. Hardwood plots along the southern section contained aspen (Populus tremoloides and P. grandidentata), gray and paper birch (Betula populifolia and B. papyrifera), American beech (Fagus grandifolia), and red maple (Acer rubrum) 20 to 40 years old. Hardwood plots adjacent to the northern section were principally American beech, sugar maple (Acer saccharum), and eastern hophornbeam (Ostrya virginiana) 20 to 120 years old.

SONGBIRDS

Preconstruction Phase

The status of birds residing in the forest was determined by examining species abundance and composition of populations at increasing distances from the highway (1). A census was conducted of numbers of breeding birds by spot-mapping (2) on 12 study plots, each 200 x 400 m (8 ha), oriented at right angles to the highway beginning at the ROW edge (Figure 2). A census was conducted of each plot along four 400-m transects spaced 50 m apart. Censuses were conducted during early morning hours from late May through early July 1975-1977. Three replicates in each cover type (hardwood and softwood) were placed adjacent to the highway in both northern and southern sections. Plots were located in patches of uniform habitat to minimize variation within plots (Figure 3).

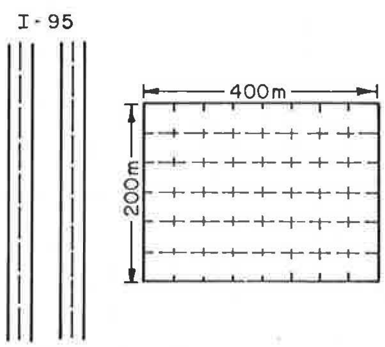

FIGURE 2 Plot showing transects.

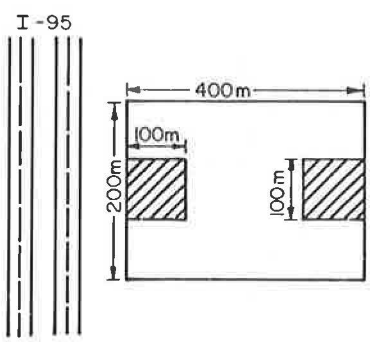

FIGURE 3 Study plot with small mammal trapping grids.

Habitat Characteristics

Breeding and Wintering Birds

Slight differences in habitat within a census plot could affect the distribution of birds and possibly mask any effects caused by the highway. Consequently, an intensive analysis of vegetation composition and structure was undertaken to measure such variation and isolate the influence of the highway on individual species. The analysis involved measuring several habitat variables within 0.04-ha circular plots located at each of the grid reference points. Breeding pairs of each species were then correlated with those measurements.

This sampling scheme is shown in Figure 4. Within the large circle closest to each territory, all trees were recorded by species and 2.5-cm diameter classes; dead trees were recorded separately by the same classes. Woody stems less than 1.25 cm in diameter were counted within the four 0.004-ha circular plots and recorded only as deciduous or coniferous. Percentage of the ground covered by moss, ferns, herbs or by litter (needles, leaves, sticks, rocks) was estimated on 0.0004-ha circular plots nested within the medium-sized plots. At four locations within the large plot (one in each quarter), canopy height was measured with a Speigel Relaskop,

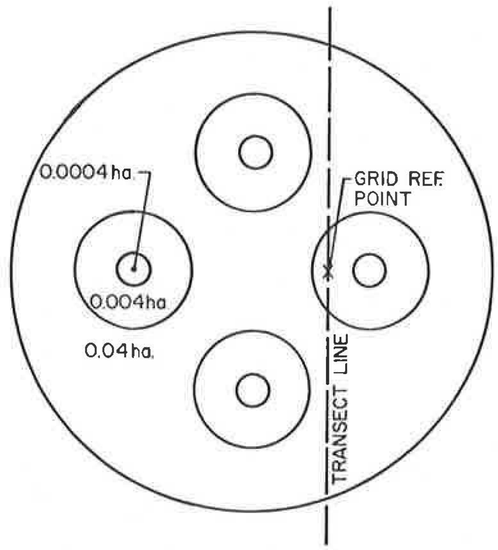

FIGURE 4 Vegetation sampling scheme.

and percent canopy closure was estimated with a spherical densiometer.

At each of 21 stations along ROW transects, measurements were taken of several characteristics of the ROW and edge to quantify development of edge vegetation and to correlate vegetation characteristics with numbers and species composition of breeding birds. The width of the strip maintained in grass, from the berm to the beginning of woody vegetation associated with the forest edge, and the width of the edge from the maintained area to the residual forest line were measured.

During-Construction Phase

To examine the effects of construction on individual breeding songbirds, an intensive study investigating behavioral response to daily construction activity was designed. Two sites were chosen: the experimental area was an active gravel pit and the control area was an unused, 12 year old gravel pit located 1 to 2 km away and surrounded by vegetation similar to the experimental site.

In each area the singing behavior of five male rose-breasted grosbeaks (Pheucticus cianus) was monitored from dawn until 10:00 a.m., when singing stopped. The relative amount of time individual birds spend singing in each area was recorded.

Postconstruction Phase

Using the methods previously described, a census was conducted again of the four plots examined during the preconstruction phase in the northern study area. Breeding bird populations were examined within successive 100-m intervals using analysis of variance.

Results

Total numbers of breeding pairs and species including both edge and forest species along the forest edge did not appear to change with time since construction. Within the median strip, the number of edge species remained similar; however, the number of forest species decreased from 8.2 to 4.2 species per transect.

Although total numbers of breeding pairs were not related to time since construction, the proportion of edge to forest species comprising the total breeding population increased. Along the 5 year old forest edge, edge species comprised only 23 percent of the total population, whereas forest species comprised 77 percent. Along the 18 year old forest edge, however, edge species comprised 42 percent of the total population and forest species comprised 5 percent.

As expected the median strip contained a larger component of edge species than the forest edge. Edge species comprised 42 percent and 68 percent of the total population for the 5 and 10 year old median strips. Correspondingly, forest species comprised 58 percent and 36 percent, respectively.

The forest edge and median strip supported similar but still different communities of breeding birds. Twenty-seven forest and 15 edge species were found to be breeding along the forest edge. Within the median strip 21 forest and 17 edge species were observed. Nine forest species bred only along the forest edge. However, all edge species breeding along the forest edge also bred in the median strip. Edge species appeared to be less-habitat-specific than forest species.

Total populations of breeding birds within the median did not differ from those along the oldest edge. This would be expected because the median was created (at least one side) at the time the first lane was constructed. However, the median strip was not as high in pairs of true "edge" species as was the ROW, but species richness was comparable.

The relationship between development of edge vegetation and the breeding bird populations was examined using least squares regression analysis. Both the numbers of breeding birds and the number of species were correlated with the cross-sectional area of the edge (see Figures 5 and 6; r = 0.85 and r = 0.87, respectively).

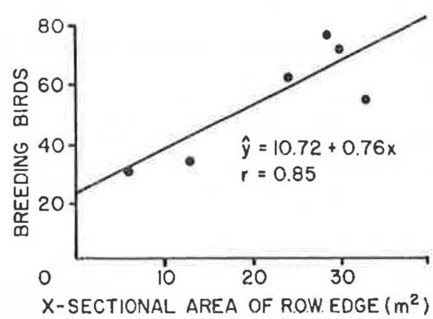

FIGURE 5 Number of breeding birds.

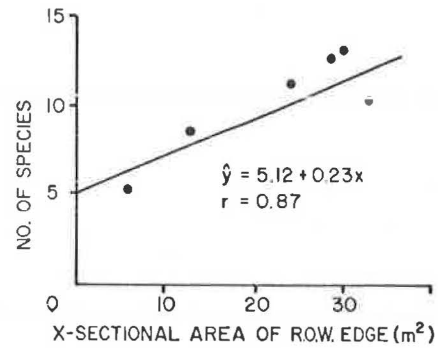

FIGURE 6 Number of breeding species.

Species diversity did not change with time since construction along the forest edge and median strip. Diversity in the forest edge was similar to that in the median strip.

Discussion

The increase in abundance of edge species was associated with the development and encroachment of vegetation outward from the forest edge and median strip to the mowed grassy shoulder (1). Generally, as the forest edge and median strip became older, there was an increase in edge species and a corresponding decrease in forest species. This decrease in abundance of forest species was believed to be a result of competition with edge species, which are better adapted to use these edge and open habitats.

Populations of breeding birds 100 to 400 m from the forest edge in relatively undisturbed habitat were found to contain only 0.6 percent edge species with the remainder comprised of forest species (3). The edge species found in the adjacent forest were associated with small clearings and openings in the forest canopy. With the creation of ROW habitat, there was a substantial increase in the edge species previously found in the adjacent forest as well as in new edge species uncommon in the area before the ROW.

This study indicated that ROW habitats might lead to a greater variety of birds in a region when considered with the total bird populations in the adjacent forest. Some forest species decreased in abundance within the highway ROW, but most edge species increased. However, the total region should be considered when assessing the impact of ROW habitats on breeding songbirds. Given the large amount of forest land that I-95 bisects, ROW habitats probably are beneficial in maintaining the rich and diverse bird population characteristic of northern Maine.

SONGBIRDS USING BRIDGES

A census was conducted of breeding birds with nests beneath bridges that intersect the ROW on June 15 and July 6, 1981. A census was conducted of 40 bridges.

A total of 387 active nests of 3 edge species, barn swallow, cliff swallow, and rock dove, were found. Bridges over water with I-beam flanges on the undersides were most commonly used as nest sites.

CROWS AND RAVENS IN THE ROW

A census was conducted of crows and ravens along the highway. Roadkills, including those being eaten by crows and ravens, were also recorded.

The census indicated that crows, an edge species, and ravens, a forest species, were common along the ROW. Crows were more abundant than ravens between March and October. Of 59 roadkills recorded, 8 were directly observed being eaten by a crow or raven. It was assumed, however, that more roadkills existed in the ROW than were recorded because of the difficulty in locating them.

SMALL MAMMALS

As with breeding songbirds, small mammals select areas on the basis of habitat. Within the ROW, the forested residual median strip contains habitat suitable for small mammal (mice, voles, and shrews) communities to exist. However, because of separation from the adjacent forest by the highway pavement and grassy shoulder, and because of habitat alteration, it is uncertain whether population structures within the median strip are similar to those in the adjacent forest. It is also uncertain whether these populations are related to the age of the median strip.

Preconstruction Phase

Populations of small mammals (includes Cricetidae, Zapodidae, Soricidae, and Talpidae) were sampled during the preconstruction phase on census plots used for birds described previously (1). Two trapping grids measuring 100 x 100 m were placed in each study plot sampled for a total of 16 grids; one was placed in the forest adjacent to the ROW boundary, the other was placed 300 to 400 m distant from the ROW boundary (Figure 3). Grids close to the highway represented experimental samples whereas those farthest from the highway represented controls.

Each grid contained 121 trap stations spaced 10 m apart in an 11 x 11 arrangement. Two Victor snap traps baited with peanut butter were placed within 2 m of each station. Every third station had a pitfall trap containing 3 to 5 cm water because shrews were underestimated using snap traps alone. Each grid was trapped for three consecutive nights over three periods during the summer.

During Construction and Postconstruction Phases

Small mammals were sampled during construction in the summers of 1978 and 1979 and during 1980 for the postconstruction phase. Four study plots located in the northern study area were resampled using 50 x 50 m trapping grids. Each grid contained 36 trap stations spaced 10 m apart in a 6 x 6 configuration. Trapping was carried out the same as during the preconstruction phase. Results of small mammal trapping were analyzed statistically using a nested analysis of variance (ANOVA).

Results

A total of 190 small mammals were caught in 1,920 trap nights; a ratio of 9.90 animals per 100 trap nights. Catches from the median and control transects were similar with 8.23 and 11.56 per 100 trap nights, respectively.

Red-backed voles in the 10-year section were found to be significantly more abundant in control transects than in median strip transects. For the 5 year old highway section there were no significant differences between median strip and control transects, although more were caught in the control transects.

Cover type had a significant effect on the number of red-backed voles caught in the 5 year old highway section, with more captures in softwoods. There was no significant difference in the number caught between cover types in the 10 year old section, although more were found in softwoods.

Deer mice within both the 10 and 5 year old median strips were found to occur in similar numbers as in the control transects, with slightly more occurring in the median strip. There were no differences related to cover type and trapping period.

Catches of short-tailed shrews were too small to draw conclusions about their populations; however, the abundance of shrews on median strip and control transects appeared similar.

The number of small mammals in the total catch was similar for the two cover types sampled within the 5 year old section, but was significantly different within the 10 year old section. In the latter section, more total captures were obtained in softwood transects. There were no differences detected for transect location and trapping period within both areas.

Discussion

The greater abundance of red-backed voles in the 10 year old median strip as compared with the control transect was apparently related to differences in habitat. The median strip generally contained a greater amount of ground vegetation than the control transect. Red-backed voles may also be indirectly affected by a competing species such as the meadow vole.

For the 5 year old median strip, the ground vegetation was not well developed. As with the adjacent forest (control), it apparently provided a more suitable habitat for red-backed voles than the 10 year old median strip. Because red-backed voles are predominantly forest dwellers, it was not surprising to find no significant differences in abundance between the 5 year old median strip and control transects. In time, however, with the development of ground vegetation within the median strip, red-backed voles may become less common.

Because red-backed voles are known to chiefly inhabit mesic coniferous and mixed forests, it was also not surprising to find more of them caught in softwood than in hardwood cover types within the 5 year old section. The lack of difference in numbers caught between the two cover types in the 10 year old section is unclear.

Deer mice for both the 5 and 10 year old median strips were not affected by transect location, cover type, or trapping period. The use of a wide variety of habitat types by this less-habitat-specific animal has been documented by numerous researchers. The roadside grids in these studies began at the forest edge and did not include the ROW.

In summary, the altered habitat for a 5 and a 10 year old median strip within the ROW were found to support similar small mammal populations, with the exception of red-backed voles. However, it should be understood that with time through plant succession, ROW maintenance practices, and other unknown factors, trends in small mammal populations could change.

MEDIUM-SIZED MAMMALS AND WHITE-TAILED DEER

Preconstruction Phase

The distribution and relative abundance of medium and large-sized mammals were determined by counting tracks in relation to distance from the highway during the winters of 1975-1976 and 1976-1977 (4). Signs were recorded for mammals common to the study areas. Insufficient data were accumulated for analyses, however, for moose (Alces alces), black bear (Ursus americanus), bobcat (Lynx rufus), and marten (Martes americana). Counts were conducted within 2 to 6 days following snowfall on the two outer 400-m transects within each plot because most animals walked parallel to the highway when crossing all four transects. At least 7 separate counts were conducted on each of the 12 plots. All tracks and other animal signs were recorded on maps of the study plots. Transects were marked at 50-m intervals to aid location of individual tracks.

The distribution of white-tailed deer in relation to the highway was examined using pellet group counts. Counts were conducted in early spring soon after snowmelt and in early autumn, before leaf-fall. Pellet groups were counted on the same plots as winter tracks. Pellet groups within 1 m of the transect line were counted and destroyed or removed to prevent recounting later.

During Construction and Postconstruction Phases

Using the methodology described previously, approximately four separate snow track surveys were conducted on the six northern plots during the winters of 1978-1979 and 1979-1980 during construction. Deer pellet group counts were conducted on the same plots during spring and fall for both phases.

Data were analyzed using a chi-square test (5). Each 400-m transect was divided into eight 50-m sections; the number of tracks or pellet groups in the four sections farthest from the highway were averaged to determine the expected value and compared with the actual value of each section. If the expected chi-square value was less than 5, adjacent sections were lumped and tested as four 100 m sections.

Results

Mammals crossing the ROW were recorded by counting snow tracks along a 14-mile section of highway including both north- and south-bound lanes. Although the ROW probably acts as a barrier to some mammals, 71 individual tracks were recorded along 70 miles of ROW.

In the median strip, snowshoe hares, red squirrels, weasels, and coyotes were surveyed by counting tracks within six plots (three softwood, three hardwood cover types). Two parallel 400-m transects, located on either side of the median strip center, were run in each plot. As with songbirds and small mammals, the median strip provided suitable habitat for some medium-sized mammals.

CONCLUSIONS

The impact of I-95 on birds and mammals in forest ecosystems in Maine was examined from 1975 to 1982. Baseline data were collected. These data imply that the effect on breeding birds and small, medium, and large mammal populations has been limited to immediate loss of habitat. The extent of the effect of this habitat loss on populations as a whole in the vicinity of the highway is as yet unknown, but is probably insignificant for those species studied to date. Clearly the effects of the highway as a physical barrier to movement, particularly of small mammals, are not understood.

Some species have, however, adapted to or have taken advantage of habitats created by the construction of I-95. Chipping sparrows, yellowthroats, chestnut-sided warblers, crows, ravens, meadow voles and red foxes, to name a few, are using the newly created ROW, whereas species adapted to forest habitats such as bay-breasted warblers, red-backed voles, and fishers appear to be avoiding it. To what extent the use of the ROW affects populations of species now found there is also unknown. Some species, particularly crows and ravens, use the highway itself as available habitat.

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Exposure and Risk Assessment, Health Monitoring, and Risk Management for Herbicide Applicators

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ABSTRACT

State departments of transportation across the country use herbicides in roadside vegetation management and insect control. Significant employee, public health, and environmental issues arise from such use. Issues of potential exposure, health risks, health monitoring, and risk management have assumed importance in design and maintenance of transport corridors. Programs that address these issues are described, including a numerical, relative hazard rating scale for ranking herbicides and pesticides. The state of Maine Department of Transportation has incorporated such programs into its decision making regarding use and restriction of herbicides. The programs, program results, and a critique of program capabilities and limitations are described. Critical issues facing prospective consumers and providers of such programs are analyzed.

Roadside vegetation management poses risks of applicator exposure to herbicides and risks of consequent adverse health effects for persons applying (applicators) these substances. Such occupational risks give rise to a need for employee health monitoring programs, as well as for risk management strategies. Such strategies must be simultaneously preventive (prospective) in their frequent ability to detect early warning signs of illness (such as reduced lung function) and flexibly responsive to the clinical findings of health monitoring programs (retrospective). Hence, four issues are identified:

1. Exposure potential,
2. Health risks,
3. Health monitoring, and
4. Risk management.

Two of the four issues have been addressed through provision of consulting services to the state of Maine Department of Transportation (MDOT). Specifically, MDOT has engaged Envirologic Data to perform health monitoring for MDOT employees, including herbicide applicators, and to assess potential health risks that may be associated with herbicides in use or considered for use by MDOT. In addition, the remaining two issues have been addressed through provision of services to other clients. Based on these experiences the purposes of this paper are to (a) describe appropriate service methodologies for exposure and health risk assessment, health monitoring, and risk management; (b) report program results and related activities in the state of Maine; and (c) discuss critical issues faced by both consumers and providers of the services described in this paper.

SCOPE

The four issues set forth correspond to distinguishable service programs that address the needs of potential users of herbicides. These programs are defined in the following paragraphs.

Exposure Assessment

Exposure assessment is the process of evaluating the potential for human or environmental contamination due to accidental or deliberate release of a substance, such as a herbicide. For herbicide applicators, the potential occupational exposures of concern primarily arise from two routes of exposure: inhalation and skin contact; ingestion is typically, but not always, of only secondary importance as a route of exposure.

Health Risk Assessment

Health risk assessment is the process of evaluating the potential adverse health effects that might occur following exposure to a particular hazard, such as a herbicide. [Terminology has been adopted consistent with the U.S. Congressional Office of Technology Assessment, in which a "hazard" is defined as a substance or exposure that harbors a "risk" to people (1). For example, a carcinogen is itself a hazard; risk is the probability of developing cancer as a result of exposure to the hazard.] For herbicide applicators, the health risks of concern may arise from chronic exposure (over a period of more than 3 months), from subchronic exposure (over a period of up to 3 months), or from acute, accidental exposure (on a single day). Adverse health effects may vary from acute poisoning which, though potentially fatal, is usually transient, to long-term effects such as cancer, mutations, and birth defects--or there may be no adverse health effects at all following exposure.

The likelihood of developing adverse health effects has been impossible to accurately quantify for most substances. Inability to quantify risk reflects the current, insufficiently advanced state of the art in toxicology and related sciences: quantitative risk assessment is more frequently undertaken than are its results believed by reasonable scientists. The difficulty primarily arises from the need to acquire experimental data by use of test animals exposed to high doses of a substance for only short durations to produce high response rates (risks of 1/10 to 1/2). To quantify risk, it is then necessary to extrapolate to the human situation of relatively low doses for long durations with very low response rates (risks of 1/1,000,000 to 1/10,000 usually being regarded as acceptable). A numerical, relative risk assessment rating scale has been adopted that goes beyond qualitative risk assessment but avoids the current pitfalls of fully quantitative risk assessment.

Health Monitoring

Health monitoring is the process of clinically observing individuals to establish a baseline health picture for comparison with any future conditions that may arise. Health monitoring may also detect adverse health effects associated with particular hazards, such as herbicides. Health monitoring may continue beyond the clinical stage by means of periodic questionnaires aimed at detecting any new symptoms that might trigger further clinical observation or treatment. There are three objectives of employee health monitoring:

1. Establishment of a health baseline for protection of employers against liabilities for alleged job-related health damage to employees and former employees;
2. Protection of past and present employees by diagnosing and treating conditions revealed by health monitoring, whether related or unrelated to employment; and
3. Alleviating the fears and concerns of employees and families of employees who believe they may have been exposed to health hazards at their jobs, particularly when only insignificant changes are noted compared with any baseline health picture established earlier.

Risk Management

Assessment of exposure and health risk may raise the issue not only of health monitoring, but of risk management. The issue of risk management may also arise from the results of health monitoring, particularly if they reveal job-related pathology. Risk management is the process of developing strategies for maintaining risks at acceptable levels. Risks of exposure and of health damage associated with a particular hazard, such as a herbicide, may prove to be insignificant and unworthy of intensified management. However, at the opposite extreme, such risks may raise the issue of whether use of a particular substance should be continued. Most frequently, exposure and health risk assessment lead to effective as well as economical strategies of risk management.

EXPOSURE ASSESSMENT

Methodology

Although the state of Maine has recently expressed interest in exposure assessment, exposure assessments have not yet been performed for MDOT. The methodology described here is based on experience with other clients. Potential occupational exposure of applicators to herbicides would be regarded as a situation worthy of separate analysis. In performing such an analysis, assumptions would be made about the number of work days in each year, the number of work hours in each day, the percent of each work day during which exposure risk exists, as well as the efficacy of protective garments and breathing apparatus, and the concentration of the herbicide in the formulations being applied. Exposure estimates are then generated from the assumptions: consequently, the validity of exposure estimates depends entirely on the validity of the assumptions on which they were based.

Exposure assessments for herbicide applicators should be consistent with methodology established and approved by the U.S. Environmental Protection Agency (2). Moreover, much has been written to advance the field of exposure assessment [see, for example, Zervos and Fringer (3)], and such advances should be rapidly incorporated into standard methodologies as their use becomes feasible.

The environmental dynamics of a substance give rise to sources of exposure, such as air, drinking water, and food, which must be separately quantified. Ultimately, exposure is estimated by quantifying intake of the substance in air, drinking water, and food based on critical assumptions about inhalation rates, daily drinking volumes, and intake of various types of food. Exposure estimates are separately presented for adult males, females, children, and infants, as well as for any identified subpopulations at unusually high risk, either through excessive exposure or sensitivity to the substance.

Results

Exposure assessment can significantly complement employee health programs. MDOT has recently requested a proposal for services to review herbicide application operations and procedures to facilitate analysis of the potential for exposure of employees. In the past, in lieu of detailed exposure assessment, MDOT has used employee education and training programs supported by a detailed spray manual to reflect the assumption that exposure can occur and should be minimized through known and reasonable practices.

HEALTH RISK ASSESSMENT

Methodology

The health risk assessment process begins with an evaluation of the efficiency of absorption of the substance into the body by each potential route of exposure--that is, it begins where the exposure assessment ends. The health risk assessment process is divided into three tasks: (a) information search, (b) acquisition, and (c) analysis. Information search begins with in-house literature holdings and client-supplied documents. Initial search is followed by an on-line data base search using bibliographic retrieval services. This search generates a list of data sources from which a selection of relevant sources is made. Relevant sources of data are located among the most conveniently situated research libraries, and copies are acquired as expeditiously and economically as possible.

Once acquired, all literature is selectively distributed to appropriate specialists for summary and analysis. Specialists then synthesize the diverse information into the context of the risk assessment format specified in advance of each project. This format would typically include the following relevant information:

- General information, chemical and physical properties;
- Pharmacokinetics, including absorption into the body, distribution to various tissues and organs, metabolism, and excretion;

- Chronic, subchronic, and acute toxicity;
- Causation of cancer, mutations, birth defects, reproductive and other long-term effects;
- federal and state regulatory statutes and guidelines;
- Conclusions regarding adequacy of the data and specific research needs; and
- Literature citations and appendices.

Numerical, relative rating scales have been established for key health effect categories. Acute toxicity is rated on an ascending scale of 1 to 3, in which 1 corresponds to lowest toxicity [an oral LD_{50} (LD_{50} is the dose of a substance that is lethal within a specified time to 50 percent of a population of exposed test organisms) exceeding 5,000 ppm (parts per million, or milligrams per kilogram of body weight)]; 2 corresponds to an intermediate toxicity (oral LD_{50} of 50 to 5,000 ppm); and 3 corresponds to the highest acute toxicity (oral LD_{50} of less than 50 ppm). Long-term health effects [carcinogenicity (causation of cancer), mutagenicity (causation of mutations), teratogenicity (causation of birth defects) and reproductive effects (reduction in fertility, potency, or other measure of reproductive competency)] are rated on a scale of 0 to 3, in which 0 corresponds to no adverse health effects, 1 corresponds to insufficient or conflicting evidence of effect, and 2 and 3 correspond to increasing potency or evidence of potency of the substance of interest. The specific criteria for numerical ratings are listed in the Appendix.

Results

The state of Maine, via the Maine Board of Pesticides Control (MBPC) and the MDOT, has incorporated health risk assessment into its regulatory and policy making procedures. Health risk assessment services are procured by a three-step process: (a) publication of a request for proposals (RFP) fulfilling specified health risk assessment service requirements, (b) evaluation of competing proposals, and (c) negotiation of a 1-year contract with the private consultant whose proposal was deemed most appropriate relative to the needs of the state.

In Maine the Commissioner of Agriculture and the MBPC are responsible for regulating herbicides. Herbicides that are shown to pose significant public health hazards through the risk assessment process are reviewed through public hearings to allow full consideration of economic and health concerns before regulation. MDOT has the additional concern and responsibility for employees who apply herbicides and has shared costs of herbicide risk assessments with MBPC since early 1984. MDOT management then makes judgments regarding the hazards of the various herbicides from an occupational perspective. Such judgments are made independently of MBPC regulatory responsibility relating to the overall public health and welfare of the citizens of Maine.

Several pesticides and herbicides have been examined through public hearings sponsored by MBPC because of the hazard potential. At the hearings, the methodology used for risk assessment was critically examined and found to have scientific validity. Because of the health data brought to light by risk assessment, the Commissioner of Agriculture applied additional restrictions on the use and application of herbicides in the state.

Envirologic Data has, since its inception, provided all of MDOT's health risk assessment services. The following herbicides have been assessed:

- Fosamine ammonium (trade name, Krenite™);
- Glyphosate (trade name, Roundup™);
- Dicamba (trade name, Banvel™);
- Triclopyr (trade name, Garlon™);
- Dalapon (trade name, Dowpon™);
- Diuron (trade name, Karmex™); and
- Bromacil (trade name, Hyvar™).

MDOT has reviewed the risk assessments of herbicides to determine which pose the least threat to employee health. Decisions are made as to which herbicides should be used for the various spray program needs throughout the growing season. Eventually, with health risk assessments for each herbicide, detailed comparisons can be performed to identify the least hazardous herbicides for use.

HEALTH MONITORING

Methodology

An ongoing health monitoring program for employees potentially at risk is an important tool in evaluating the effects of chronic, low-level exposure or acute exposures related to accidents in handling or application of herbicides. Although acute toxicity is usually readily recognized and medically manageable via established treatment procedures, chronic or long-term toxicity is neither manifested quickly nor easily recognized. Thus, an employee health monitoring program must be comprehensive in scope and include indicators of subclinical disease and exposure. Specifically, laboratory testing capable of detecting biochemical or physiological changes that may be precursors of overt disease is a necessity.

The health monitoring program should include the following components:

- Review of herbicide use and principal health effects of herbicides;
- Review of nonoccupational (avocational) exposures to chemicals;
- Medical screening;
- Data analysis and reporting; and
- Periodic monitoring.

A review of herbicides used in a spraying program is important in identifying relationships between exposures and possible health effects. With a knowledge of principal health effects, interpretation of results of laboratory tests and other medical screening is possible. Ideally, information from the health risk assessment provides definitive information regarding possible human health effects. Where such data are lacking, results of animal testing and other research methodologies may be used to reflect the potential for effects in humans.

The initial medical screening program establishes a baseline medical profile for comparison with test values to be derived from future periodic monitoring. Initial screening also identifies medical problems that may place the employee at above-normal risk in relation to occupation. The following constitutes a broad-based initial screening:

- History and physical examination. The employee's past medical and occupational histories are ascertained via the Milcom Health History Questionnaire and interview with the physician. The physical examination includes a detailed evaluation of body organ systems that are most likely to be affected by herbicide exposure.
- Laboratory evaluation. An extensive battery of laboratory tests complements the history and physical examination. Acute exposure to toxic sub-

stances is generally recognized and medically manageable based on established procedures and manifested symptoms. However, because chronic exposure to low levels of potentially toxic materials may not produce obvious signs and symptoms of illness, detailed laboratory assessment is necessary to detect changes in biochemical and physiological parameters. The battery of laboratory tests performed allows evaluation of blood composition, electrolyte balance, enzyme levels, organ function, the immunological system, and pulmonary function.

Data analysis and reporting involve compilation of the initial medical screening data to allow statistical comparisons of individual test results with group norms, and group norms with general population norms. For large groups, this is facilitated by using computer data base management software. Data analysis may detect deviations from acceptable normal limits, group trends, and identifiable symptoms possibly related to exposure. Medical concerns unrelated to occupational exposures are reported to individuals for followup with their personal physicians. Results relating to possible occupational exposure are reported for consideration by management.

Periodic reexamination of employees involved in the program is important for monitoring current health status and for comparing followup results with the baseline values originally established. Recommendations for ongoing monitoring should be based on initial test results and the degree of potential exposure, among other criteria.

Results

A health monitoring program for MDOT was initiated in May 1984. Initial program results for more than 30 employees have been reported (4) and include findings of abnormalities that may or may not be related to occupational causes.

Nonoccupation-related problems were reported directly to monitored individuals; four, in particular, were treated as special cases in that early medical treatment of existing conditions was indicated. Several other individuals were advised to follow up on potential medical problems such as lung disease, liver inflammation, lipid disorders, high blood pressure, anemia, diabetes mellitus, and nonhemolytic jaundice. Single cases of possible atherosclerotic vascular disease, carpal tunnel syndrome, early rheumatoid arthritis, connective tissue disorder, gastrointestinal blood loss, urinary tract infection, eczema, and tinea were discovered.

No definitive findings of occupational illnesses have yet been made. However, based on statistical comparison of individual test results with group norms, several individuals were identified who may possibly be responding to occupational exposures and who require further testing. In particular, tests for liver enzyme activity and cholinesterase levels in plasma and red blood cells revealed marginally abnormal results for several individuals. The liver enzyme levels were slightly to moderately elevated, whereas the cholinesterase values were slightly depressed compared with statistical norms. These test results may indicate exposures to herbicides used in MDOT's spray programs; however, the same results can be caused by other substances commonly encountered in our highly technological society--or they may be unrelated to exposures to particular substances. If it were deemed important to establish a causal relationship as a condition for corrective action, further testing for specific substances would be necessary.

It is important to emphasize that these results do not indicate the presence of herbicide-induced disease, nor do they indicate that occupational exposures have occurred. An alternative possibility is that, for some or all of these individuals, nonoccupational medical effects may have been detected. Additional testing and analysis are required to define the causes of the abnormal test values. These results demonstrate the importance of ongoing monitoring. Through reexamination and specific evaluations, and repeating key tests, trends can be delineated or suggestive findings can be confirmed.

RISK MANAGEMENT

Methodology

Risk management, when necessary, is the responsibility of the client; moreover, the issue of acceptable risk levels that would trigger risk management action can only be determined by the client. Nevertheless, options for addressing this question can be proposed. In general, if risks are perceived to be sufficiently great to trigger health monitoring, simple risk management strategies should, at a minimum, be developed.

Risk management strategies must be implemented when exposure to a particular substance exceeds regulatory exposure guidelines. Such strategies may be simple and economical. The greatest expense for risk management is, of course, justified when the required degree of risk abatement is greatest, and this situation typically arises most urgently in the unusual event that health monitoring reveals job-related pathology.

The methodology for determining whether a disease is job-related is most difficult when the disease is common in the general population, and easiest when it is rare except in association with a particular occupation (clustered). Clustering of health effects can arise from on-the-job experiences or from off-hours experiences shared by an occupational group, such as social activities. Determining job-relatedness of disease is accomplished by statistically comparing the observed incidence (frequency) of cases of the disease among employees with the expected incidence among the general population. As a rule, the more commonly a disease occurs in the general population, the more of an excess of disease cases among employees would be necessary to document its job-relatedness. Moreover, some evidence is necessary that the disease can, at least potentially, be causally related to the substance(s) to which employees are known to be exposed.

What does risk management mean for herbicide applicators? It may mean no change in operations, if there is no evidence of occupational illness. On the other hand, it may mean substituting safer herbicides; using less volume, lower concentrations, or alternate formulations of a given herbicide; applying the herbicide under more restrictive weather conditions or over shorter periods of the growing season; or wearing protective garments or breathing apparatus. In any case, employee training programs must be designed to educate employees about the importance of adhering to appropriate risk management strategies and numerous other standard operating procedures.

Results

MDOT's risk management program is currently implemented in-house rather than via procuring private risk management services. MDOT's in-house program emphasizes careful herbicide selection and exposure control. To date, Envirologic Data's work for MDOT has only involved making recommendations regarding health monitoring results and the proposal for reexamination. After confirmation is obtained for the cause of the abnormal values discovered in the baseline testing, specific actions may be recommended to MDOT management for incorporation into the existing risk management policies and procedures. This complements well the current use of the health risk assessment data the department uses for selection of herbicides.

DISCUSSION OF CRITICAL ISSUES

By incorporating several of the program elements described in this paper into its approach to regulating and managing use of toxic substances, MDOT has assumed an aggressive posture in protecting the public health and the health of state employees who apply or otherwise encounter such substances. Herbicides will continue to be used in maintaining transportation corridors. Developing and establishing the means to assess and manage risks incurred through such use is the only rational approach to the complex environmental and health issues posed.

Exposure Assessment

Potential exposure to a particular hazard generally varies in proportion to the production volume of the hazard. This potential for exposure assumes, in the worst case, that all of the substance that has been produced is released into the environment. The realistic case is then determined by evaluating the actual practices that are designed to prevent fugitive releases during production, distribution, use, and disposal. Hence, the substance of interest may spread progressively over a geographically wider area, but its concentration would diminish rapidly in the process in proportion to the effectiveness of control measures.

In addition to possible geographic spread there is a time dimension, that is, the substance exhibits a degree of stability or instability that determines its half-life (time required for half of an initial amount of the substance to degrade) in each environment. The half-life is, more specifically, determined by the ability of the substance to withstand physical, chemical, and biological degradation processes acting on it in varying proportions in terrestrial, aquatic, atmospheric, and other environments. A substance that exhibits a low water solubility and high vapor pressure may rapidly move from the aquatic to the atmospheric environment through strictly physical transformations of state. A substance that hydrolyzes readily might be chemically stable in dry soil, but unstable in aquatic environments. The issue of whether instability of the substance corresponds to detoxification must be addressed via examination of the breakdown products.

The accuracy of exposure assessment depends on the realism of the assumptions on which it is based. Decisions by MDOT regarding herbicide use must frequently be made before experience has been accumulated in the state. Consequently, realistic exposure assumptions are more difficult to formulate.

Providers of exposure assessment services should prominently set forth the exposure assumptions that underlie their estimates. Moreover, they should convey some sense of the degree of uncertainty, statistically or otherwise, attending their estimates and assumptions. When these practices are followed, the reward for undertaking exposure assessment is likely to be increased protection of potentially exposed populations and environments, as well as--in the longer term--less need for stringent regulatory action for protection.

The advantages of exposure assessment, cited earlier, can be simultaneously achieved because, in the absence of exposure assessment, worst-case assumptions should properly be adopted by decision makers. Such assumptions protect workers and the public to the maximum extent possible. The role of exposure assessment is not to relax that high level of protection; rather, it is to identify the routes of exposure that contribute most to overall risk, and thereby to suggest the most cost-effective means of exposure risk management. Thus, exposure assessment contributes to definition of controls that must be imposed on use of substances such as herbicides. Controlled use usually constitutes safe use, as well as a viable alternative to prohibition of use.

Health Risk Assessment

A critical issue in assessing health risks is the proprietary nature of some of the most useful data. The degree of disclosure required of manufacturers by law (by the Federal Insecticide, Fungicide and Rodenticide Act and its amendments, as well as by other statutes, including administrative law) is in flux; however, proprietary information is frequently voluntarily made available under constraints of a nondisclosure agreement signed by the consulting firm and, possibly, the client firm. Nondisclosure may be interpreted in many ways, but any such agreement should permit the use of company data for drawing conclusions regarding exposure and health risk, though limits may be placed on the freedom of the consultant or client to cite or otherwise reveal company data in support of consulting or decision documents.

A second critical issue involves the appropriate scope of the consultant's health risk assessment services. For example, a criterion of risk is persistence of the hazard in natural and agricultural ecosystems. Persistence is measured by the half-life of the substance, but half-life of the substance may be very different from half-life of toxicity. Consequently, the question arises of whether the consultant's scope of work should include evaluating intermediate breakdown products. This can be of critical significance in cases where the breakdown products are themselves persistent and/or toxic. If breakdown products are excluded from the consultant's scope of work, the possibly erroneous impression may be conveyed that a risk is transient, when what is meant is that a substance is transient.

A third critical issue is the consultant's willingness and ability to examine and interpret data that might be ambiguous, complex, or controversial. One error that consultants may make is to conclude that a particular adverse health effect, for example cancer, is not caused by a substance when in fact it might be. The error may easily arise from the consultant's acceptance and misinterpretation of an investigator's conclusion that the substance was not carcinogenic in a test organism, or in any number of tests. Tests for carcinogenicity frequently involve small numbers of test animals, severely limiting the power of the test to detect cancer causation except when a very high proportion of the animals develop it. Hence, carcinogenicity tests tend to be one-sided; negative results should not signify absence of carcinogenic risk. The maxim holds that "absence of evidence is not evidence of absence".

Health Monitoring

The primary objective of the health monitoring program is to detect adverse health effects that may be associated with occupational exposure to herbicides. However, because of the frequently comprehensive nature of medical screening, abnormalities not associated with occupational exposures may be found. Such findings should be reported to the affected individuals for followup with their personal physicians. Therefore, the results of a program normally are reported as either related or not related to occupation.

An issue of confidentiality is raised in connection with findings of nonoccupation-related disease. Such medical screening results must remain confidential in keeping with the normal patient-doctor relationship. These results are reported only to the monitored individuals. However, the issue of confidentiality is again raised in cases of abnormal findings which, though unrelated to occupation, may be exacerbated by particular job assignments. As a resolution of this issue, the service provider may inform the employee, who then seeks reassignment to an alternative job compatible with his or her medical condition. Alternatively, the service provider may seek permission of the employee to confer with management regarding any medical conditions constraining the employee's position assignment.

Risk Management

The most critical issue is that of acceptable risk, that is, deciding on an acceptable target for risk management strategies. As a general rule, costs increase with increasing management and decreasing risks. The consultant should, if possible, set forth several risk management options, ranked by expected risk reduction efficacy. The client or the consultant can supply the cost estimates corresponding to each option. Implementation by the client typically begins with the option that reduces the most risk at the least cost, and proceeds by selection of each best-remaining risk reduction option. The process typically ends when either the acceptable risk target or the budget endpoint is reached.

Determination of acceptable risk by budget is not recommended from a toxicological viewpoint and, in some situations, may be illegal. However, there are rarely guidelines for determining acceptable risk with regard to exposure to the many hazards for which regulatory standards are nonexistent. Traditionally, but for no toxicologically justifiable reason, occupational risks regarded as acceptable have been higher than acceptable risk levels to the general population. Typically acceptable general population risks, based on historical U.S. Environmental Protection Agency (EPA) regulatory actions, have been on the order of 10^{-6}, that is, one additional death associated with a regulated substance per million individuals over a lifetime. Occupational risks of 10^{-4} (one in 10,000) and even greater have been tolerated. Recent trends have resulted in toleration of higher risks (5) and, at least among workers, to expressions of concern about risk (6).

A corollary of acceptable health risk is acceptable liability, that is, liability for health damage that can be linked to occupational causation. Liability includes Workmens' Compensation insurance, toxic tort law settlements and awards, as well as victims' compensation legislation, which may be on the horizon. The implication of the emerging toxic tort, victims' compensation, and acceptable liability issues is that risk management must increasingly adopt a prospective philosophy. This means making essentially speculative investments in risk reduction when uncertainty about health risk exists. The services described in this paper, taken together, aim at "fine-tuning" to avoid both health damage and associated liabilities, but the state of the art in toxicology is insufficiently advanced to fully accomplish this mission. Nevertheless, the client can make effective decisions with regard to selection of highly qualified consultants and application of stringent risk management standards today to avert potential problems tomorrow.

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Appendix

Envirologic Data Digital Relative Rating Scale and Rating Criteria

Acute Toxicity

1 LD_{50} >5,000 ppm
2 LD_{50} 50-5,000 ppm
3 LD_{50} <50 ppm

Teratogenicity

0 = Studies show substance to be nonteratogenic
1 = No data available or data inconclusive
2 = Teratogenic in nonmammalian species or
Teratogenic in one mammalian species
3 = Positive in human epidemiological study or
Teratogenic in two or more mammalian species
or
Teratogenic in one mammalian species with teratogenicity in nonmammalian species

Carcinogenicity

0 = Studies show substance to be noncarcinogenic
1 = No data or data inconclusive
2 = Positive in short-term carcinogenicity tests
or
Positive in long-term carcinogenicity bioassay in one mammalian species without corroboration
3 = Positive in human epidemiological study, or
Positive in long-term carcinogenicity bioassay in two or more mammalian species,
or
Positive in long-term carcinogenicity bioassay in one mammalian species with corroboration by replication and short-term carcinogenicity tests

Mutagenicity (Sample short- and long-term mutagenicity tests are included at end of this Appendix.)

0 = Studies show substance to be non-mutagenic
1 = No data available or data inconclusive
2 = Positive in short-term mutagenicity tests or
Positive in long-term mutagenicity bioassay without corroboration
3 = Positive in human epidemiological study or
Positive in two or more long-term mutagenicity bioassays or
Positive in long-term mutagenicity bioassay with corroboration by short-term mutagenicity tests

Persistence

0 = Half-life of less than 24 hr
1 = Half-life of 24 hr to one week
2 = Half-life of one week to one month
3 = Half-life of one month or greater

Reproductive Rating Scale

Female

0 = Substance shows no reproductive effects
1 = No data or
Data inconclusive or
Uterine weight change in animals or
Hormonal pattern change
2 = Decrease weight of offspring < 15 to 20 percent
3 = Human uterine weight change or
Follicular failure [Note follicular failure: destruction, change in maturation, depletion, corpus luteum.] or
Anovulation (interruption--temporary or permanent) or
Decrease number of offspring (litter per year, number per litter) or
Fetal resorption due to maternal effects or
Decrease weight of offspring > 15 to 20 percent or
Positive human epidemiological study

Male

0 = Substance shows no reproductive effects
1 = No data or
Data inconclusive or
Prostate weight change or
Alteration of prostate secretions
2 = Decrease sperm count is greater than level for fertility [Note fertility level: at least 16 to 20 million sperm/ml.; 50 percent should have rapid motility and mature oval heads; accept 30 percent abnormal forms.]
3 = Decrease in sperm count is less than level for fertility or
Arrested spermatogenesis or
Testicular atrophy or
Positive human epidemiological study

Examples of Short-Term and Long-Term Tests Used in Mutagenicity Rating

Short-Term Tests

Ames *salmonella*/microsome test
Mitotic recombination and gene conversion in *S. cerevisiae*
Transformation in cell culture
Chromosome aberrations in cell culture
Unscheduled DNA synthesis
Sister chromatid exchange
Microbial host mediated assay
Experiments with *Drosophila*
Bird studies
Relative toxicity test

Long-Term Tests

Dominant lethal test in rodents
Heritable translocation assay
Specific mutation assay
Mouse micronucleus assay
In vitro human chromosome breakage