Evaluation of Methods to Reduce Road Mortality of Red-Sided Garter Snakes at Narcisse Wildlife Management Area

by

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Master of Natural Resources Management

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"EVALUATION OF METHODS TO REDUCE ROAD MORTALITY OF RED-SIDED GARTER SNAKES AT NARCISSE WILDLIFE MANAGEMENT AREA."

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of Master of Natural Resources Management.

By

Mr. Joshua Chan

Abstract

Road mortality of red-sided garter snakes (*Thamnophis sirtalis parietalis*) at the Narcisse Wildlife Management Area, Manitoba has become a concern for the Department of Natural Resources. In fall 1992 roughly 10,000 snakes died while crossing the section of Provincial Trunk Highway 17 adjacent to the snake den area. Continued mortality of this magnitude could reduce the snake population thereby diminishing its value as an educational, tourism, and scientific resource as well as altering the local ecosystem.

This report reviews several techniques to mitigate road mortality adjacent to the Narcisse Wildlife Management Area. Techniques were evaluated through literature review of other cases of road mortality in reptiles and amphibians. Pilot field tests of four techniques were carried out including the use of fence materials as barriers, a culvert as a thoroughfare beneath the road, lights within a culvert, and application of snake pheromone to direct snakes to the culvert area. Methods investigated through literature review included funnel traps, tunnel systems, human assisted crossings and various fence materials.

The study found that mortality increased sharply from 1991 to 1992. During these periods the bulk of mortality occured in the fall, with spring mortality being disproportionately centred around road approaches. Fencing materials evaluated proved that the Terrajute fence material was superior to most in terms of wind damage resistance and cost. Pheromone application and lighting tests showed little effect on mortality.

The use of funnel traps in conjunction with drift fencing is recommended as a temporary measure to increase the population's success rate of crossing the road. Its long term effect on the snakes' migration particularly orientation is unknown and the technique is therefore not recommended as a long term mitigative measure. Continued experimentation with culverts should be pursued in order to improve their effectiveness. The placing of culverts near road approaches would provide more routes for the snakes to cross the road without having to divert them great distances. Of particular interest is the utilization of pheromone trailing and heat gradients in and around culverts to increase culvert usage.

Acknowledgements

I am indebted to many people who provided me with encouragement, guidance, and assistance throughout the "practicum process".

My committee members, Dr. John Sinclair of the Natural Resources Institute (NRI); Dr. Rick Baydack of the NRI; Dr. Ken Stewart of the Department of Zoology at the University of Manitoba; and Mr. Dave Roberts of the Department of Natural Resources (DNR) - Central Division; were extremely generous in providing their time, effort, and suggestions. Mr. Bill Koonz of the DNR supplied valuable information, contacts, and encouragement along with a healthy dose of his unique brand of humour. The pheromone field tests could not have been done without the help of Dr. Robert Mason of Oregon State University. His guidance and technical support is much appreciated.

The staff and students at the NRI were a constant source of information, help, and amusement, especially my office partners, Brad "Driver" Fulton, Ian K. Seunarine, and "Dr." Isaac Wamugi. I am proud to call my colleagues at the NRI my friends for they have made my memories of the NRI ones which I shall treasure.

My parents, family members, and friends have always supported me in my endeavours. The debt I owe to my family I can never repay. Everything I accomplish is a result of the hard work and perseverance of my parents.

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Chapter 1: Introduction

1.1 Background

The Narcisse Wildlife Management Area (NWMA), located 100 kilometres northwest of Winnipeg (Figure 1), protects an important population of red-sided garter snakes (*Thamnophis sirtalis parietalis*). The dens, or hibernacula, located within Manitoba's Interlake region represent the largest agglomeration of snakes in the world (Crews and Garstka 1982), making it a unique natural phenomenon, as well as a valuable area for scientific study. It is a well-known tourist attraction with over 10,000 people visiting the dens each year (Hak and Koonz 1991). The dens have received international attention from articles written in National Geographic (Aleksiuk 1975), Equinox (Bruemmer 1990), and Scientific American (Crews and Garstka 1982).

Hibernacula are used by the snakes to protect themselves in the winter from extremely cold temperatures which may fall to -40°C (Crews and Garstka 1982). Dens are usually located within limestone sinkholes, which consists of deep cracks and fissures that reach depths below the frost line. The snakes are able to survive at these depths because the temperature remains above the freezing point throughout the winter. Each spring the snakes emerge from their dens en masse and, after mating, will migrate to their summer feeding grounds - usually marshes and ponds. In the fall the snakes return to the den sites to spend another winter (Aleksiuk 1975, Bruemmer 1980).

PTH 17 lies between the snake dens and the marshes which serve as the snakes' summer feeding areas. During their bi-annual migrations the snakes must cross the highway to get to the marshes west of the dens in the spring and again in the fall to

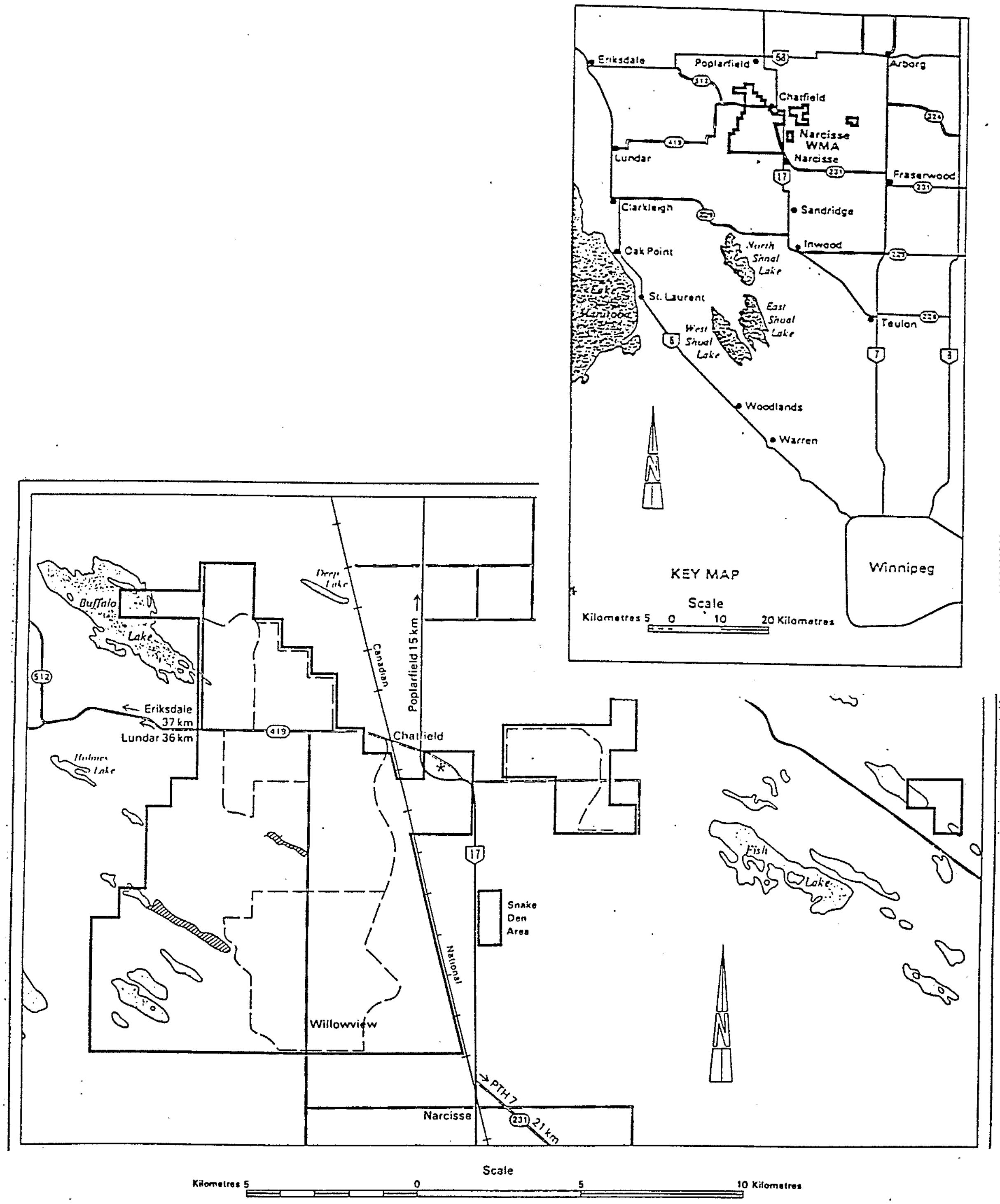


Figure 1: Location of the Narcisse Wildlife Management Area

(Cowan 1992)

return to the dens. While travelling across the highway the snakes are endangered by motor vehicles using the road. On the section of highway adjacent to NWMA, only one culvert (near the north entrance) is present to provide a safe route under the road.

Adding to the problem is the physiological nature of the snakes themselves. The snakes are poikilothermic (cold-blooded) and therefore seek warm areas to regulate their body temperature (Department of Natural Resources 1991). The road retains heat collected during the daytime and is a favourite resting spot for migrating snakes during the evening (Roberts, personal communication). This makes them especially vulnerable to being run-over by passing motorists.

1.2 Problem

Road mortality is considered to be a major cause of mortality for the Narcisse snake population (Cowan 1992). The Department of Natural Resources recorded over 4000 snakes killed on the 2.5 kilometre stretch of Provincial Trunk Highway (PTH 17) running along the west side of NWMA during the spring and fall of 1991 (Department of Natural Resources 1992). Nature and interpretive tours to the dens at NWMA have been operating since 1980 (Koonz 1991). High mortality rates caused by road crossing may significantly impact the population. The sight of dead snakes on the road to NWMA is not appealing to tourists and if that mortality reduces the number of snakes at the den then the quality of the viewing experience will decline as well (Cowan 1992). Reduced population at the dens would also mean a loss in research opportunities for scientists as much about the snakes' behaviour is still unknown. The loss of the snakes would alter the local ecosystem as it is an important link in the food web, directly affecting the amphibian and crow populations.

In an attempt to investigate the problem and develop possible mitigative measures, this practicum was contracted by the Department of Natural Resources with funding provided by the Critical Wildlife Habitat Program.

1.3 Purpose and Objectives of the Study

1.3.1 Purpose

The purpose of the study was to investigate the problem of red-sided garter snake mortality on Highway 17 adjacent to Narcisse Wildlife Management Area and to recommend potential mitigating techniques to rectify the problem.

1.3.2 Objectives

The objectives of the study were as follows:

1. to review the literature regarding road crossings of garter snake and other species,
2. to examine aspects of snake behaviour which may affect their acceptance of potential mitigative measures,
3. to identify potential mitigating techniques to reduce snake mortality on the highway adjacent to the Narcisse Wildlife Management Area,
4. to carry out a biological and economic feasibility analysis of each technique,

5. to make recommendations to mitigate road mortality at Narcisse Wildlife Management Area.

1.4 Methods

Methods to achieve the stated objectives included literature review, interviews, and pilot field tests. Through these methods, information was collected, allowing for the comparison of various mitigating techniques. These techniques were evaluated and the most economically and biologically feasible ones recommended. Methods are discussed in detail in Chapter 3.

1.5 Organization

This practicum is organized in six chapters. After an initial review of the literature in Chapter 2, the methodology of the research is described in Chapter 3. In Chapter 4 the results of the pilot field tests are discussed. Other mitigative techniques are examined through literature review and cost estimation in Chapter 5. Conclusions are drawn from the preceding chapters and recommendations are put forward with further discussion in Chapter 6.

Chapter 2: Aspects of Road Mortality and Mitigative Measures

2.1 Road Mortality Issues

Documentation of road mortality in snakes is rare. In general, snakes are not a high profile species that readily garners public sympathy. Widespread prejudice against snakes is still prevalent in today's society (Koonz 1983, Cowan 1992). Hence, concern about the affect of roads on snake populations is not a popular subject. Amphibian species experience many of the same problems. However, the literature concerning amphibian road mortality is more common. This is largely due to the recent interest in the preservation of amphibian species (mainly toads and frogs) in Western Europe. This newfound zeal lead to a conference held in 1989 dealing specifically with mitigative measures to reduce road mortality of amphibians in Europe. These methods gained international attention when they were shown on the science-information program "Nova" and also during the 1992 Winter Olympic Games coverage in France.

2.1.1 Reptiles and Road Mortality

The majority of articles regarding road mortality of reptiles are merely accounts of road mortality occurrences. Examples of these are Fitch (1949), Wilkins and Schmidly (1980), Dodd et al. (1989), Seibert and Conover (1991) etc. The major component of these articles described instances of road mortality and attempted to determine its causes. Causes identified were; roads being built near migratory routes of the species, roads providing a place for the animals to bask and regain body temperature, and periods of high traffic volume coinciding with instances of high migration.

Several articles that research particular aspects of snake behaviour also note instances of road mortality. In some cases, road-killed snakes were used as observational samples to estimate characteristics of a population (Fitch 1949, Gregory and Stewart 1975, Dodd et al. 1989).

There are some articles concerning snakes that have conclusions that may be useful in developing management recommendations. Seibert and Conover (1991) cite two articles with implications to the planning process. The first, by Dickerson (1939), recommended better planning of roads and the road environment as a means of reducing road mortality. Roads should avoid cutting between a den site and a feeding area. If this situation is unavoidable, then suitable provisions must be made to allow animals to cross the road. The second, by McClure (1951), found road mortality to be proportional to the density of surrounding cover, age composition, and density of the wildlife population. Amount of traffic and degree of road improvement (increased speed of traffic) are secondary in importance. Wilkins and Schmidly (1980) also concur with this conclusion. They monitored road mortality rates of various species on three different highways, each of which had different traffic levels. The observed mortality rate (number of animals killed per kilometre of roadway per day) for reptiles was approximately the same for each highway. Therefore, they concluded that, for reptiles, mortality rate was not dependant on traffic volume.

There have been two studies of note in the United States in which management recommendations were made. Dalrymple and Reichenbach (1984) studied the eastern plains or prairie garter snake (*Thamnophis radix radix*). Particular attention was paid to the effect of grass mowing operations and automobile traffic on the population which was located within a state wildlife area. Road-kills were regarded as a considerable mortality factor with 56 instances recorded over a six hour period. Suggested mitigation techniques proposed consisted of; the re-routing of traffic to alternate roads away from the den sites, the construction of road bumps to reduce traffic speed, and the placement of warning signs to alert motorists to the snakes presence on the road.

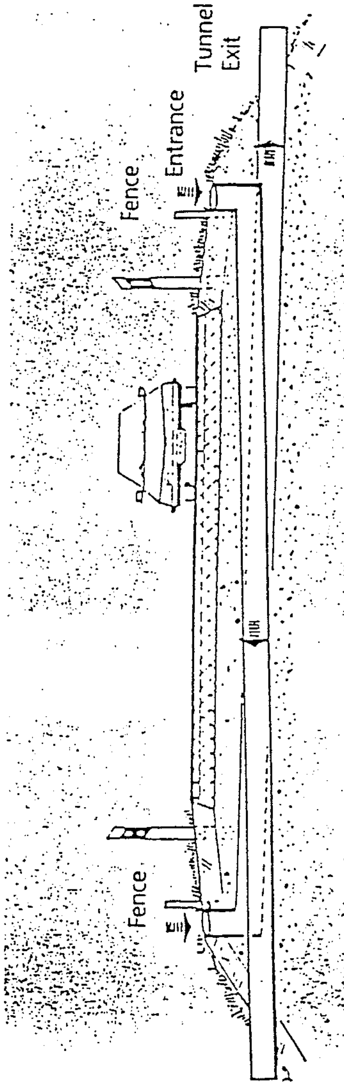
Bernadino and Dalrymple (1992) tackled a similar problem at Everglades National Park in Florida. Road mortality of any species was considered unacceptable within the park which was designed to protect endemic species of flora and fauna. The problem was made worse during the tourist season. Peak traffic volumes coincided with the highest volume of snake migration and thus mortality increased accordingly. Three options were recommended to ameliorate the problem:

1. Construction of an underpass,
2. Temporary closure of the road on main migratory nights,
3. Installation of reduced speed zones.

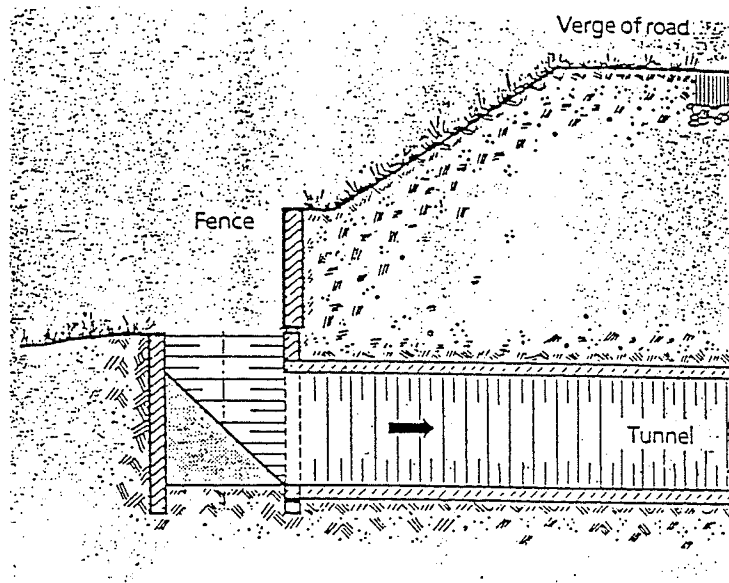
Option 1 was deemed the best alternative for several reasons. Both 2 and 3 required higher long-term management cost and inconvenience to the public. For example, they need acceptable levels of law enforcement to ensure adherence to regulations. Lastly, the methods would not be effective in reducing mortality throughout the day nor the entire year. An underpass system was also seen to have many associated benefits. It would move the animals without having to trap them, animals accidentally moving onto the road could move off of it, installation and maintenance requirements of required equipment (tunnels and fences) would be minimal, and the technique would not be dangerous to vehicles nor to visitors. Neither article discusses the success or implementation of its recommendations, however, Bernadino and Dalrymple (1992) suggested that cases with European amphibians were encouraging. To further explore this method, additional research of case studies involving this tunnel system was completed.

2.1.2 Amphibians and Road Mortality

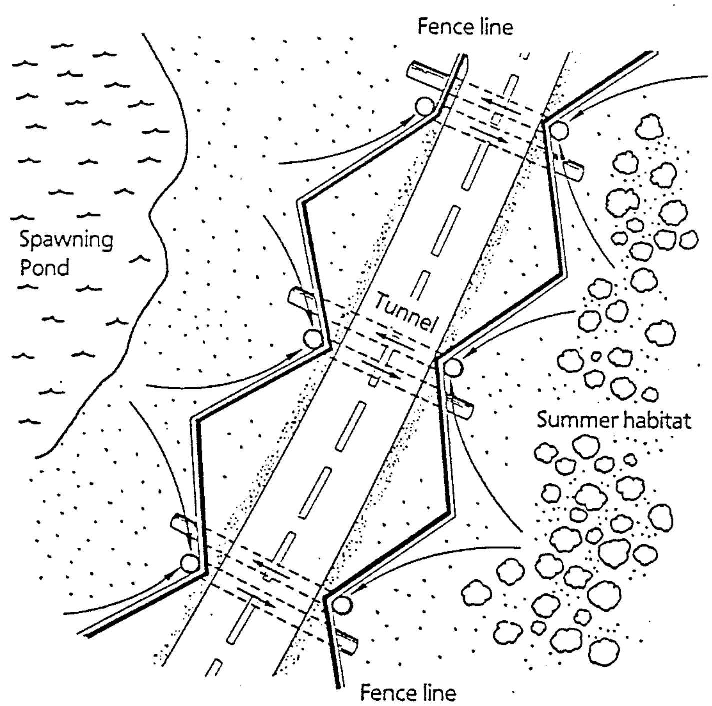
The use of tunnels to transport amphibians under roadways has been practised since the 1960's in Europe. Though many variations exist, the main components of the system are almost always consistent, including fencing system and tunnel. In some cases, the entrance of the tunnel is a pitfall trap. Exit from the entrance area can only be accomplished by passing through the tunnel to the other side of the road (Figure 2, page 10). This mechanism is called a "one-way tunnel" since it only permits travel in one direction across the road. Pairs of tunnels, one for each direction in migration, are used in the one-way tunnel system. Existing culverts have also been used. These tunnels allow travel in both directions and therefore such "tunnels" would be bi-directional.



Cross section of one-way tunnel system, showing the direction of movement in each tunnel.



Cross section of a 'pit fall' entrance to a one way tunnel system.



Paired one-way toad tunnel system, showing fence line 'zig-zagged' to guide toads towards tunnel entrances.

Figure 2: One-way tunnel system design

(Langton 1987)

Another variation of the method would be to eliminate the tunnel altogether and collect the animals in the pitfall traps. The collected animals would then be transported across the road by volunteers. This type of program has been coined "Toads on Roads"and was made famous by Thomas Langton. He also incorporated warning signs, tunnel systems, slow speed zones, and temporary road closures in his campaign to help protect threatened species of amphibians from the dangers of crossing roads. These tunnel, fencing, volunteer and traffic altering systems spread throughout Western Europe. Much discussion regarding effectiveness, drawbacks, and various details of many of these methods were highlighted at the Amphibians and Roads Conference in 1989 held in Germany. The details concerning proper installation, and findings regarding responses of amphibians to the system may prove valuable to this study in suggesting methods to be tried, and in predicting various responses to methods yet to be tried.

2.2 Aspects of Tunnel Systems and Their Design

2.2.1 Fences

The purpose of installing fences is to force the animals to follow the fence to either the culvert entrance or to a pit-fall trap for collection. Reptile species have been known to follow fences or other obstacles rather than travelling across open spaces (Fitch 1951). Often, natural barriers have been used as funnels to collect snakes or other animals (Fitch 1951, Stewart, personal communication). In closed experiments, many snakes often exhibit "wall-seeking behaviour" where, when presented with an area to travel across, the snake will seek the nearest wall and follow it (Ford and Low 1984, Costanzo 1989).

Experiments with drift fences in Europe showed that obstacles, including vegetation should be removed (Ryser and Gossenbacher 1989). The amphibians used the vegetation as springboards to leap over the fence to get on to the road. Fencing material should be durable and easy to maintain. Often, fencing was made of metal, though in some cases concrete trenches were used. Langton (1987) recommends that fences should be zig-zagged (Figure 2, page 10) so that the amphibian will encounter the fence at an angle of less than 60 degrees. If the angle is any greater than this the amphibians may turn back rather than move along the fence line and into the tunnel.

There have been reports of amphibians stalling at fences and remaining motionless for long periods of time but in these cases, a problem with design was identified as the main cause for that behaviour (Ryser and Gossenbacher 1989, Meinig 1989). In most instances, fencing systems have proven very successful in channelling amphibians into desired areas. Jackson and Tyning (1989) found that 68.4% of spotted salamanders (*Ambystoma maculatum*) encountering a fence eventually used the available tunnel system. They also discovered that fence efficiency was lower along the sections adjacent to the tunnel entrance, (65.6%) than sections 20 and 30 metres away from it (76.5% and 70.6% respectively). No explanation for this finding was given. Langton (1989) estimated that 98% of toads encountering fences eventually passed through tunnels located in England. In both instances, animals were marked as they entered the fencing area while the exit of the tunnel was monitored to note successful passage of amphibians through the tunnel.

Most authors agree that in any road crossing system involving tunnels and pit fall traps, the fencing design is the first crucial element of any installation and it deserves special attention. The success or failure of the system begins with the fencing.

2.2.2 Traps for Collection

Traps for the collection of amphibians and reptiles have been used to obtain specimens for research and also to gather animals to transport them across roads. This is especially true of amphibians in Europe. These traps can be divided into three categories: artificial shelters, pitfall traps, and funnel traps.

Artificial shelters are structures providing shelter for snakes or amphibians and are often made of metal, wood, or natural materials such as rocks. These can be highly effective if they satisfy needs not already provided by the natural habitat (Fitch 1987).

Traps for amphibians are often of the pitfall variety. They have also been used for snakes whose lengths are less than the depth of the pit. These traps have a large drop off after the entrance causing animals to fall into a container that serves as the trap. The animals will be unable to climb up the steep sides of the container. Design may be as simple as a large pail buried in the ground with the opening flush with the surface or with the pail turned on its side, slightly submerged. This technique has been proven to be effective in collecting snakes at the University of Manitoba's Delta Marsh Research Station (Stewart, personal communication).

Funnel traps consisting of open-air metal cages that snakes can crawl into but are unable to crawl out of have also been used successfully by researchers. Variations on a design originated by Fitch (1951) have been used to trap snakes by many researchers, including Dargon and Stickel (1940), Imler (1945), Woodbury (1951), Clark (1966), Gregory (1971), Lohoefener and Wolfe (1984) etc. The trap consists of a wire cylinder, funnel and cap (Figure 3, Fitch 1987). Gregory (1971) used a cylinder 30.5 centimetres long, 12 centimetres in diameter, and was able to capture up to 14 snakes at a time.

All of the traps were more effective when used in conjunction with drift fences. They also suffer many of the same problems. In public access areas, the devices may attract the attention of "meddling persons resulting in damaging interference" (Fitch 1987). Desiccation (dehydration) of snakes is a problem found especially in funnel traps. Gregory (1971) recommends covering the trap with branches and other material to help weight down the trap and provide shelter from the sun for captured snakes. The traps should also be located away from ant colonies since ants will attack trapped snakes (Gregory 1971). The union of funnel and cylinder should be near perfect to prevent snakes attempting to escape from getting lodged between the two pieces (Gregory 1971). Mortality may result in the traps if weather is extreme, if two or more incompatible animals are trapped together, or if a predator breaks into the trap (Fitch 1987).

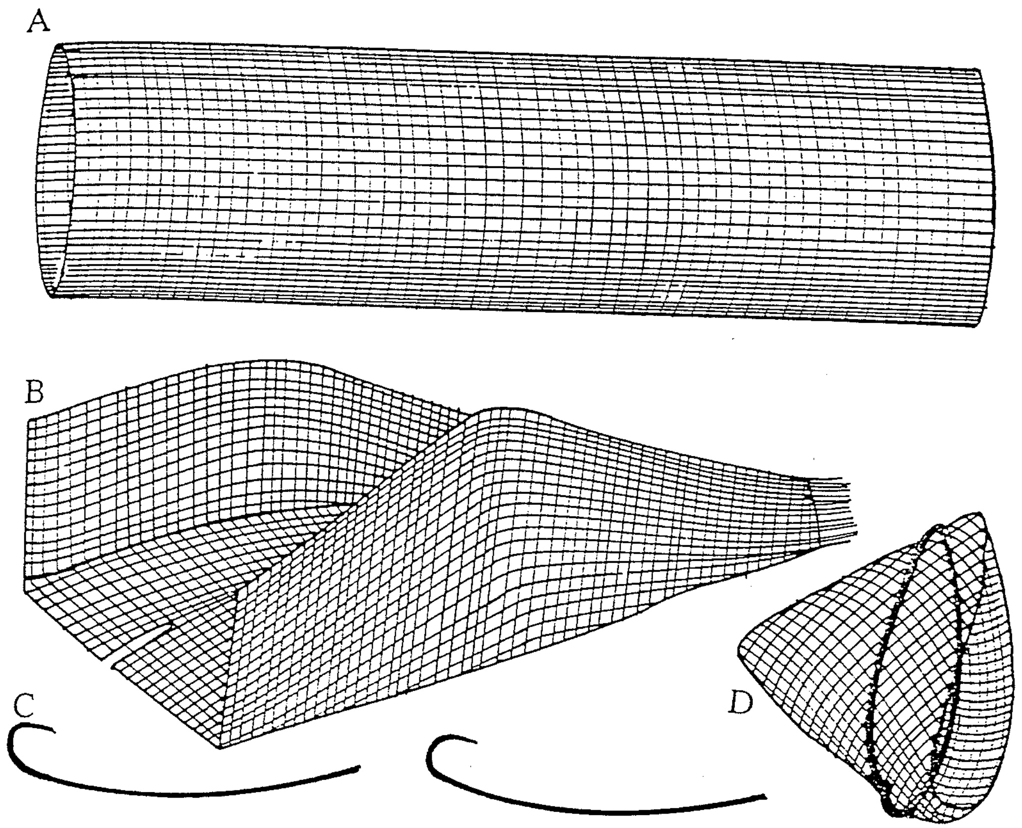


Figure 3: Portable Wire Funnel Trap for Snakes, Disassembled

A) Trap Body, a cylinder with inward flange at each end.
B) Entrance Funnel, with inward projecting prongs and slit base to fit on end of drift fence.
C) Hooked and Bowed heavy wire pins to lock funnel and plug in place at end of trap.
D) Cone-shaped plug reinforced by heavy wire ring. (Fitch 1987).

2.2.3 Volunteer Transportation of Animals Across Roads

Throughout Europe, the "Toads on Roads" campaign has enlisted the help of volunteers to transport amphibians across the road. Some less organized programs consist of having volunteers stand at the road side to watch for animals crossing. Upon sighting one, the volunteer will go onto the road, pick the amphibian up and carry it across the road. More effective programs use traps; the volunteers arrive at the traps periodically and carry them across the road where the amphibians will be released. School aged children make up the bulk of volunteers. This method is inexpensive since labour is free, and it also gives the organization a chance to instruct the children on various topics relating to the conservation of wildlife. The lessons of conservation from toads can be applied to other animals as well.

Some problems have arisen from this practice. For roads with high traffic volumes, the crossing of roads becomes hazardous for humans as well as for the animals they are trying to save (Langton 1989). In some less organized programs toads which are waiting for potential mates are picked up and carried across the road. These toads often attempt to go back across the road to resume their search for a mate and in the process endanger their lives again (Corbett 1989). Snakes that have been handled and transported take some time to regain their orientation. In orientation experiments conducted by Lawson (1989), subjects were kept in a cage for five minutes to regain their orientation before being let loose to study their orientational abilities. Garter snakes at the Narcisse site have also shown disorientation after being handled. On some occasions, snakes that have been picked up and carried across the road immediately try to return to the side from which they were moved (Roberts, personal communication).

2.2.4 Tunnel Systems

The main focus of the Amphibian and Toad Conference (Langton 1989) was the description and effectiveness of tunnel systems. The tunnel system designed by ACO Polymer Systems was especially scrutinized because of their widespread use.

Many aspects of tunnel systems were discussed in great detail. For the purposes of this discussion they are categorized as follows; general tunnel characteristics, the ACO system, advantages and disadvantages.

2.2.4.1 General Tunnel Characteristics

Many recommendations were made regarding tunnel set up and design at the conference. One of the larger issues was the comparison of one and two-way tunnel systems. One-way tunnel systems have a pit-fall entrance out of which the frogs or toads are unable to jump. Their only alternative is to follow the tunnel through to the exit (Figure 2, page 10). The exit is placed several feet above the ground surface to ensure that no amphibians can enter it. To facilitate the two-way migrations back and forth across the road, juxtaposed pairs of one way tunnels are set up running in opposite directions. Two-way tunnel systems are simpler in design. They are merely culverts which can be entered at either end. It has been long thought that one-way systems are more effective, however very few studies have been done to verify this (Ryser and Gossenbacher 1989).

Recommendations regarding lighting within the tunnel are also discussed in the literature. It was suggested that light within the tunnel be greater at the exit than at the entrance (Krikowski 1989, Ryser 1989). When using one-way tunnel systems the toads will fall into the pitfall entrance. The tunnel is dark with light coming from the entrance and exit. The toads will make their attempted escape towards the nearest, closest source of light. The entrance, being initially closer than the exit, would be the attempted exit point. However, most toads and frogs are unable to jump out of the pitfall entrance. Some eventually followed the tunnel to the exit while others would die of desiccation or freezing from staying too long in the tunnel. Krikowski (1989) experimented with making the pitfall entrance darker than the exit in order to justify his hypothesis, that these tunnel systems with darker entrances would be more effective. However, in the discussion that followed, some researchers disputed the significance or validity of his findings (Krikowski 1989). One criticism suggested that because the species Krikowski was concerned with normally travels at night, dark and light zones in the tunnel would have little effect on their migration.

Research on the difference in behaviour caused by light of various wavelengths has not been found. Instances of reptile species following artificial light has been noted for two species of turtles, Hawksbill turtles (*Eretmochelys Imbricata*), and Loggerhead turtles (*Caretta caretta*). In both cases, hatchling turtles were attracted to artificial light sources of varying intensity. However, there was no mention of differences in wavelength (Philibosian 1976, Salmon and Wyneken 1987).

Other miscellaneous items were also discussed at the conference. It was suggested that the tunnels be less than 50 metres apart (Ryser and Gossenbacher 1989). Though no reason was given, this distance is presumably the maximum length an amphibian will follow a fence without turning back. Ryser and Gossenbacher (1989) also suggested that tunnels should be straight. The diameter of the tunnel is also important for its acceptance by animals. Brehm (1989) states that tunnels for amphibians and other small animals (reptiles included) should have a diameter of at least one metre to be effective. This size pipe or tunnel admits some light to enter and allows air currents to keep tunnel temperatures near those of the external environment. If installation of tunnels of this size is not feasible for reasons of road structure stability, Brehm suggests an alternative tunnel system; the ACO tunnel system.

2.2.4.2 ACO Tunnel System

Brehm's article concerning the ACO tunnels extols the system's virtues and its faults, along with a description of some field tests he conducted in Germany. These tunnels are made of a polymer concrete mixture and were originally intended for use as drainage pipes (ACO pamphlet). Many of the tunnel systems discussed in the conference papers are ACO drainage systems. The following is a list of the characteristic properties of the ACO system according to Brehm (1989):

a. diameter 0.2 metres;

b. light/air slots in top for aeration and equilibration of temperature;

c. total height 0.4 metres;

d. very smooth surface within the tunnel (easy to clean);

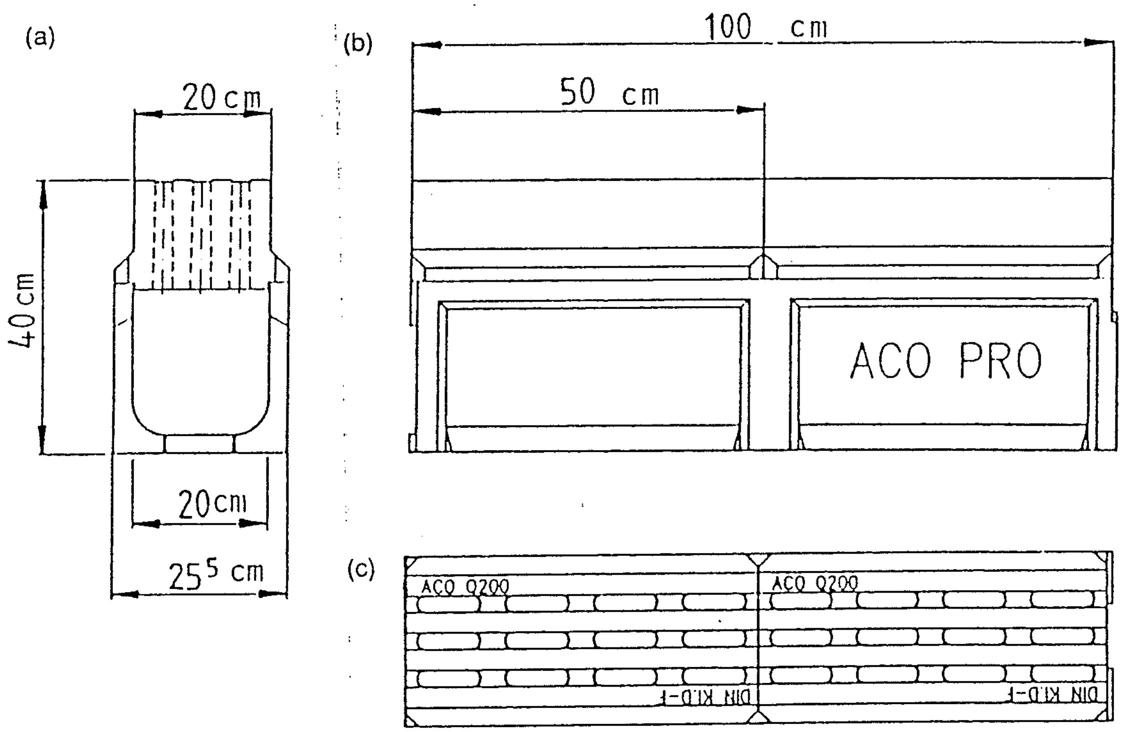
e. low costs in comparison with conventional large tunnels;

f. wear from vehicles identical with conventional road surfaces

(Brehm 1989 - see figure 4)

There are drawbacks associated with the system. The slots not only allow air and light into the tunnel but also debris such as sand and salt from the road surface. Cleaning of the system is recommended before the onset of migration. Noise from the wheels of vehicles riding over the tunnel has been shown to result in amphibians hesitating in the tunnel (Langton 1989, Meinig 1989). This will delay their migration and cause them to spend more time inside the tunnel. The smooth surface that was listed as an asset of the system by Brehm is a disadvantage to snakes because of the problems they have with moving on smooth surfaces.

There is also a fencing design produced by ACO. The fence is made of curved polythene sheets 0.4 metres high, cut in 1 metre sections. The sections are imbedded in the road verge (Figure 5, page 22 - Brehm 1989). The major advantage of this fence is that animals on the inside of the fence are unable to climb over it, while those on the outside are able to enter the fenced area. The fence is also meant to be a permanent structure.



The ACO tunnel has slots in the upper surface: a) end-on view, b) side view, c) view of the surface from above.

Figure 4: The ACO Tunnel System

(Brehm 1989)

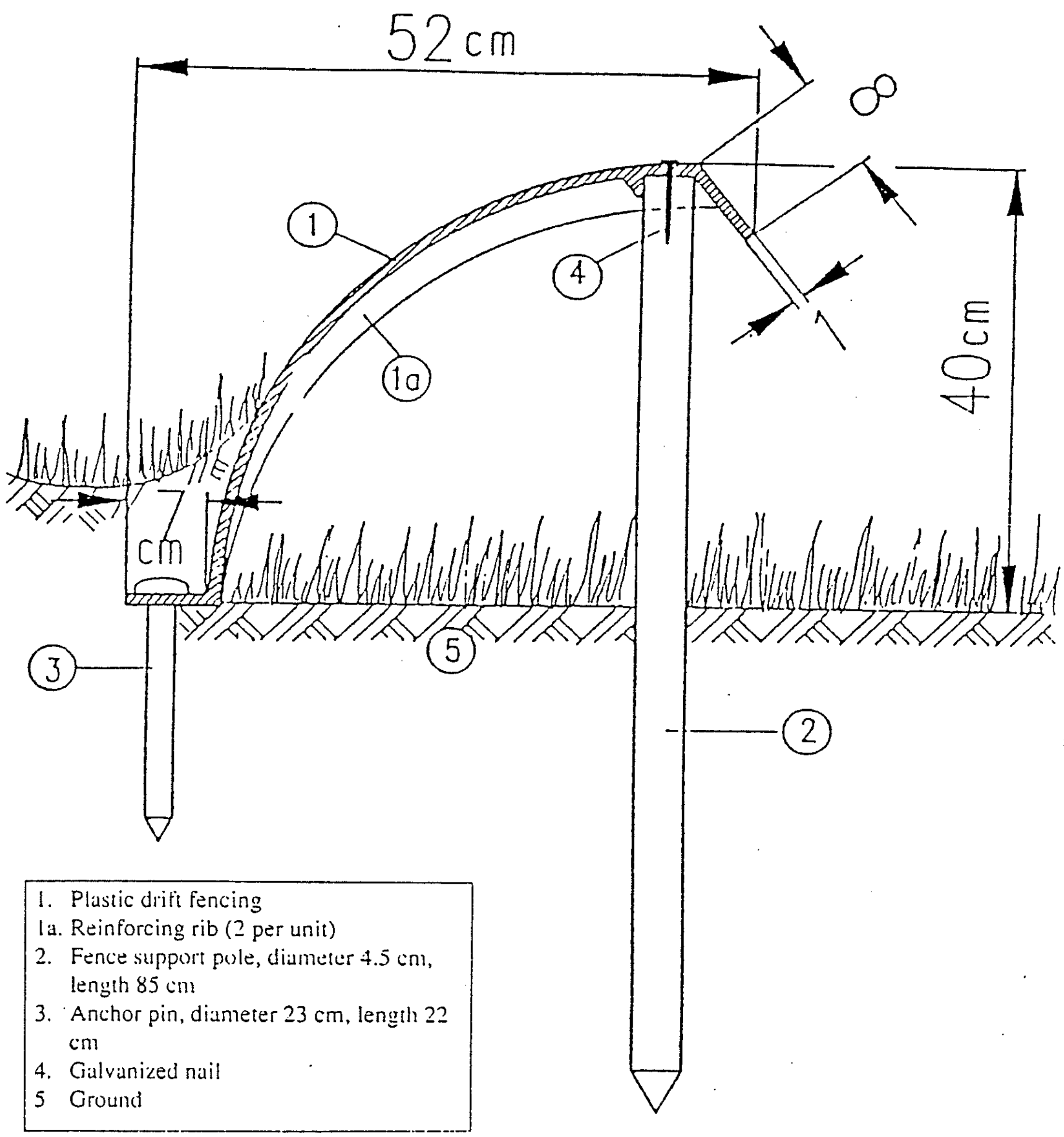


Figure 5: The ACO Fencing System

(Brehm 1989)

2.2.4.3 Advantages of Tunnel Systems

There are many advantages that tunnel systems have over other alternatives. Tunnels provide a year round system of moving animals across roads. No direct surveillance is needed to operate the system and maintenance is minimal. Besides the construction needed to install the tunnels, there are no disruptions to vehicular traffic when tunnels are in use. As stated earlier, tunnel systems have been very effective in some cases (Henry and Epaine-Henry 1989, Jackson and Tyning 1989, Langton 1989). Failures of the system often occur at the fence.

2.2.4.4 Problems with Tunnels

Not all tunnels are working perfectly. Podloucky (1989) cites over twenty non-functioning tunnel systems in Lower Saxony. He suggests that unsuitable tunnel pipes, inadequate directing systems (fences), and a lack of prior planning or studies of migrating population, their size and habits, have led to a lack of acceptance by amphibians of non-functioning tunnels.

Functioning tunnels have also experienced problems. Amphibians have been observed attempting to leave tunnel systems from the entrance (Krikowski 1989). They have also been known to hesitate when vehicles travel over the tunnel (Meinig 1989, Krikowski 1989). These factors lead to animals spending too much time in the tunnel, making them vulnerable to desiccation, predation or freezing over night.

Hesitation by amphibians outside of the tunnel also delays migration. Langton (1989) observed many toads and frogs turning back after pausing at the tunnel entrance.

These toads usually returned later to try once more. Langton believes that the difference in temperature and light within the tunnel could cause this hesitation.

Predation is also a potential problem. Reading (1989) observed predation of toads by "crows, rats and hedgehogs" when the toads were trapped in pitfalls. The predators were attracted to the high concentrations of potential prey. In this particular case, the trapping, done for research purposes, had to be discontinued because of the high levels of mortality arising from predation.

It is conceivable that this situation could occur at the entrances and exits of tunnels as well. Predation by crows in the spring at NWMA dens is already a problem (Hak and Koonz 1991). However, no sign of predation at the tunnels has been observed.

2.3 Pheromones and Chemical Communication in Trail Laying

Chemical cues are used by snakes for many reasons. Among these are feeding, sexual behaviour, aggregation, and trail laying. Numerous studies have researched each of these aspects. For this particular project, the use of pheromones to lead snakes to a desired location is the purpose for this review of pheromone and chemical communication in garter snakes and other snake species.

Trailing behaviour is prevalent in many aspects of snake behaviour. Use of pheromones to lay trails for purposes of sexual aggregations is probably the most extensively researched topic in this field (Ford 1986). Trailing of females by males for purposes of locating mates is a very strong instinctive behaviour. Ford (1986) found that trailing is much stronger in the spring (mating season) than in the summer months. He found that 67% of snakes following pheromone trails in spring versus 10% in July. Chemical communication is a powerful tool in snake socio-biological behaviour. From chemical cues they are able to able to discern if a female is mated or unmated (Crews and Garstka 1982), and whether the snake it is following is of the same species (Ford 1986, Ford and Schofield 1984, Halpin 1990). Trailing is also important in location of prey (Ford 1986). Garter snakes were found to be attracted to earthworm alarm pheromone (Halpern et al. 1987). Earthworms are one of the main food sources of garter snakes. It was hypothesized that this characteristic aids snakes in locating prey.

2.3.1 Den Location

Use of pheromone trails to find den locations has also been studied. The pheromones in this case are not for sexual aggregations but rather serve a trail laying purpose (Ford 1986). It has been hypothesized that juvenile snakes are much more heavily dependant on these chemical cues to locate den sites than mature snakes (Costanzo 1989, Ford 1986, Graves et al. 1986). The younger snakes, having no prior knowledge of den location, would have to follow older snakes to arrive at den sites. In experiments conducted by Costanzo (1989), the vast majority of trail-following snakes were smaller, younger snakes, while non-following snakes were usually larger and older. Graves et al. (1986) studied den location by neonatal prairie rattlesnakes (*Crotalus viridis viridis*). They concluded after tests in the laboratory, that trailing does occur and juveniles tended to follow trails laid by adults.

The older snakes are believed to use other clues to find traditional den sites. Clues include topographic landmarks (Costanzo 1989) and celestial clues (Lawson 1989). Lawson (1989) tested the orientational abilities of "Common garter snakes" (*Thamnophis sirtalis*) in Wood Buffalo National Park with emphasis on the use of the sun as a directional orientation device. After trapping and moving snakes, she found the snakes were able to orient themselves to the "denward" location. When delaying the light/day cycle by six hours she found a 90 degree shift in orientation thus supporting her hypothesis that garter snakes have a sun-compass in phase with local time. Gregory et al. (1987) hypothesized that snakes use pheromonal cues in conjunction with solar cues to orient themselves and locate den sites. He felt that a fuller spectrum of chemical cues besides those released by other snakes may explain snake orientation abilities. Gregory et al. (1987) conclude that more research in this area is needed.

Ford (1986) believed that although snake trailing behaviour does exist, the tendency is not as strong as is trailing for sexual aggregations. Costanzo (1989) concentrated his research on autumn trail laying (non-sexual purposes) and felt that trail following was very strong. His experiment consisted of a large box which was divided into "lanes" by pegs. The snakes were unimpeded from crossing over lanes. A snake would be placed on the floor of the box and its exact path in the box recorded. Another snake would be placed in the box to see how well its path matched that of the first snake. Costanzo found that 25% of subjects exhibited strong trailing tendency. These snakes found the exact gate which was used by the previous snake. Fourteen percent followed the trail closely enough to exit the box through an adjacent gate. Thirty six percent were found to trail initially before going their own way. The distance trailed initially averaged 74 centimetres. Twenty five percent of subjects showed no trailing tendency at all but do exhibit "wall seeking behaviour". Both males and females were found to follow trails. Costanzo concluded that these results further supported the hypothesis that, in nature, pheromones are used to locate dens.

A method of detecting directionality was hypothesized by Ford and Schofield (1984). They saw a problem with how the snake would know in which direction the trail was leading. In this experiment they discovered that trailing was much more prevalent in the experimental arena when the floor included objects for the snake to push up against versus a bare floor free of objects. This experiment also used film of the snakes movements to measure the tendency of the subject to follow the trails laid. Their results led them to believe that the following snakes would pick up the pheromonal cues on the pegs. They would then examine pegs in close proximity through tongue flicking behaviour to determine which peg had the greater concentration of pheromone. By attaining this information the snake would then follow in the direction of the "fresher" trail. This experiment was conducted in spring, so sex pheromones were at work in this case. Results obtained may be different if pheromones for non-sexual aggregations are used.

2.4 Thermal Biology and Snake Behaviour

Snakes are poikilothermic animals and therefore spend much of their time and effort attempting to achieve a desired body temperature at which their metabolism allows them to carry out actions necessary for survival, such as foraging, searching for cover, mating, etc. Temperature preferences are very specific and can vary between species (Gregory 1984, Stewart 1965), sex (Gibson and Falls 1979, Stewart 1965) and gravid versus non-gravid females (Stewart 1965).

In all reported cases, females are reported to be more adept at temperature regulation than males (Gibson and Falls 1979). Females captured by the researchers had a narrower range of body temperatures than those recorded for males. The average body temperature for females was also higher than the averages for males. Gravid females maintain the highest body temperatures.

Snakes in northern climates usually spend the early parts of the day basking in the sun until their body temperature approaches their preferred range (Larsen 1987, Stewart 1965). Then the snakes will spend their time searching for food, cover, or shelter (Larsen 1987). Snakes are most active between 1000 h and 1600 h (Aleksiuk 1977). When sunset approaches, the snakes will perceive the lowering of their body temperature and will begin searching for suitable cover (Gregory 1984, Larsen 1987, Leavesley 1987, Vincent 1971). This search can be quite extensive. In a northern population of garter snakes, the average observed search time was 34 minutes (Larsen 1987). Cover often takes the form of other animal burrows, roots of plants, under rocks, and foundations of buildings. The continued search for areas to help regulate body temperatures is described in detail by Johnson et al. (1975) for pythons in Australia.

In their search for cover, heat is a more important factor than light. Noble and Clausen (1936) used Common brown snakes (*Storeria dekayi*) and Butler's garter snakes

(*Thamnophis butleri*) to test the relation between movement patterns and heat source. A heat gradient was set up with and without lighting. In both situations, the snakes were attracted to the warmer section of the heat gradient regardless of whether light was available. Butler's garter snake would always aggregate toward the warmer area regardless of room temperature while brown snakes would aggregate only under cooler room temperatures. Noble and Clausen concluded that temperature was of importance in directing the movement of both snake species.

Gibson and Falls (1979) found that a population of garter snakes in Ontario was not as efficient at temperature regulation as suggested by other authors. They would find snakes basking in much less desirable locations thermally and not infrequently within a metre of an area which would provide better thermoregulatory conditions. They concluded that perhaps only a transient advantage is attributable to superior basking sites. This advantage is insufficient to outweigh the effort and risk of finding them.

2.5 Summary

Road mortality of animals is an issue that is dealt with in the literature. However, literature pertaining specifically to snakes and road mortality is rare. Various mitigative techniques are discussed and many case studies involving amphibians and road mortality have been documented.

Mitigative measures have included manipulation of the road and its surroundings, and altering the use of the road. Fencing, tunnels, and traps are alterations to the road that try to provide safe routes for the animals to cross the road without disrupting the flow of traffic. Other methods which change road use by humans include road closures, reduced road speeds, and warning signs. No clear identification of an 'ideal' technique is given in any of the articles reviewed. Each of the methods recommended had drawbacks associated with their use. Pilot field tests were carried out to test some of the measures described in the literature. Testing of fence materials, culvert use, affect of artificially lighting the culvert, and use of pheromone trails are examined in Chapter 3.

Chapter 3: Methods

3.1 Literature Review

The literature review served several purposes in this project. Each facet of the project required a search of the literature to gather information regarding previous cases, experiences with similar species, and mitigative measures tried in those cases.

Literature relating to the biological characteristics and behavioral patterns of garter snakes played an important part in the research. Information regarding snake behaviour in the area was obtained from interviews with experts in the field (eg. Bill Koonz, Dr. Bob Mason, Dr. Ken Stewart). Behavioral characteristics of the snakes were investigated to find the snakes' preferences and possible reasons for their observed behaviour. Potential reactions to different environmental conditions not yet explored in the literature was also speculated on through the research. The effect of implementing certain mitigating techniques was hypothesized after studying known behavioral patterns.

Previous experience with road crossings of snakes, other reptiles, and amphibians suggested potential techniques to be investigated. The review was limited to species which are similar in behaviour to garter snakes (such as other reptiles) or in size (i.e. amphibians).

The literature on road crossings by amphibians has proven valuable to the project. Langton (1989) dealt specifically with cases where pipes from drainage systems were used as a thoroughfare for amphibians in Europe. Many amphibians are similar in size to snakes and their reasons for crossing the highway in these instances are also comparable. The roads in most cases separated their breeding grounds and summer feeding marshes (Haslinger 1989). Some of the problems with tunnel systems and fencing design are also dealt with in these articles and provide insight into possible mitigating options.

These previous experiences with snakes and other species provided suggestions for further tests to be done at NWMA. Some of the findings in the previous studies was used to form the basis for the pilot field tests carried out in the fall of 1992.

3.2 Interviews

Interviews served much the same purpose as the literature review, but they also provided information that was not readily available in the literature. Topics such as the amount of traffic on PTH 17, reactions of snakes to various stimuli, and other issues pertaining to the design of field tests was discussed. Possible mitigating techniques were discussed as well. Interviews also resulted from important findings documented in certain articles. Others interviewed included researchers who had published articles relevant to the problem as well as professionals whose work relates to the problem at hand (eg. Wildlife Technicians, Department of Highways personnel).

3.3 Pilot Field Tests

It was important that the recommended techniques were effective in reducing mortality at a reasonable cost to the public. Pilot field tests of selected mitigative measures were carried out to gain insight into various procedures required for their implementation and to acquire a better estimate of costs involved. The following field tests were carried out:

1. a fence leading to the culvert was installed to get an indication of its effectiveness in directing the snakes to use the culvert,
2. lights were placed in the culvert to observe the snakes' behaviour regarding their acceptance of the culvert as a thoroughfare,
3. a pheromone mixture was sprayed at the culvert entrance and along the fence leading to the culvert. Behaviour of snakes was observed as they encountered the culvert entrance area,
4. a new fence material was installed in two sections roughly 70 metres long parallel to the highway. Between the two sections, pheromone was applied. The usefulness of the fence and of the pheromone as an obstruction and as a means to alter the snake migration route was observed.

Behaviour of snakes encountering the various mitigative techniques was observed to see if mitigative techniques were useful in keeping snakes off the road. More importantly, the implementation of the pilot field tests provided recommendations regarding future tests of this kind including, confounding variables, difficulties in implementation, and suggestions of future tests or experiments that should be carried out.

The four techniques were chosen for various reasons. The first mitigative measure (fence leading to culvert) has been implemented over the past few seasons at the site. No formal investigation of its effectiveness has been completed to date. It was felt that observations of methods already in place should be undertaken.

The second experiment was chosen because it was felt by some researchers that the relatively darker and cooler conditions within the tunnel may be a hindrance to its acceptance by the snakes. Krikowski (1989) and Ryser (1989) felt that light conditions within a tunnel were an important consideration in their acceptance by animals (see Chapter 2). The validity of their recommendations could be tested by lighting the tunnel and noting the behaviour of snakes entering the tunnel. In this study, no attempt was made to scientifically explore the validity of their hypothesis. However, some observations were noted as an indicator of what may be expected.

The pheromone experiments were suggested by Dr. Robert Mason of Oregon State University. Trailing of snakes by other snakes is a well documented behaviour and pheromonal cues play an important role in this activity (see Chapter 2). Researchers have observed that snakes will sometimes follow trails laid down by other snakes to travel to den sites in the fall (Costanzo 1989, Mason, personal communication). The reaction of the Narcisse snakes to pheromonal cues could provide an effective method to move snakes through the culvert.

3.3.1 Road Mortality Count

To establish the year's fall mortality rate, a daily count of the number of snakes killed on the 2.34 kilometre section of PTH 17 adjacent to NWMA was kept from August 31 to October 1. The road was divided into sections using hydroelectric utility poles adjacent to the highway as indicators. The poles were between 72 and 88 metres apart. Dead snakes were removed from the road surface and their location on the road (the section in which they were found) recorded. The following day, any snakes found dead would have perished after the last count. This gave a daily count of the number of snakes killed within each section on the highway adjacent to NWMA. A sample data sheet for spring 1992 is shown in Figure 6.

Counts began at approximately 2:00 pm and were carried out by the staff of the Department of Natural Resources - Central Region. These data have been collected for the previous three seasons dating back to the spring of 1991. The numbers obtained gave some indication of the success or failure of certain techniques to be tested. Mortality counts can be compared between sections, and seasons. However, it must be noted that comparisons may not hold over the long term due to variables such as changes in the size of the population, weather conditions, etc.

3.3.2 Fence and Culvert

PTH 17 runs north-south immediately west of NWMA (Figure 6). The culvert near the north entrance lies perpendicular to the road (east-west). Two sections of fence were set up at either side of the culvert entrance. They were set at an angle with the intent of funnelling the snakes from the surrounding area into the culvert. It was suggested by Langton (1987) that an angle of less than 60 degrees is most effective in channelling amphibians and other species into tunnels. The fence used in the past was made of a reinforced plastic and was originally obtained from Manitoba Tent and Awning. During the past few seasons, this fence was set up at the culvert in an attempt to divert some of the snakes under the highway. To prevent snakes from getting under

SPRING 1992 *Snake Mortality Along Hwy. 17 (2.34 km transect), West of Narcisse Dens.*

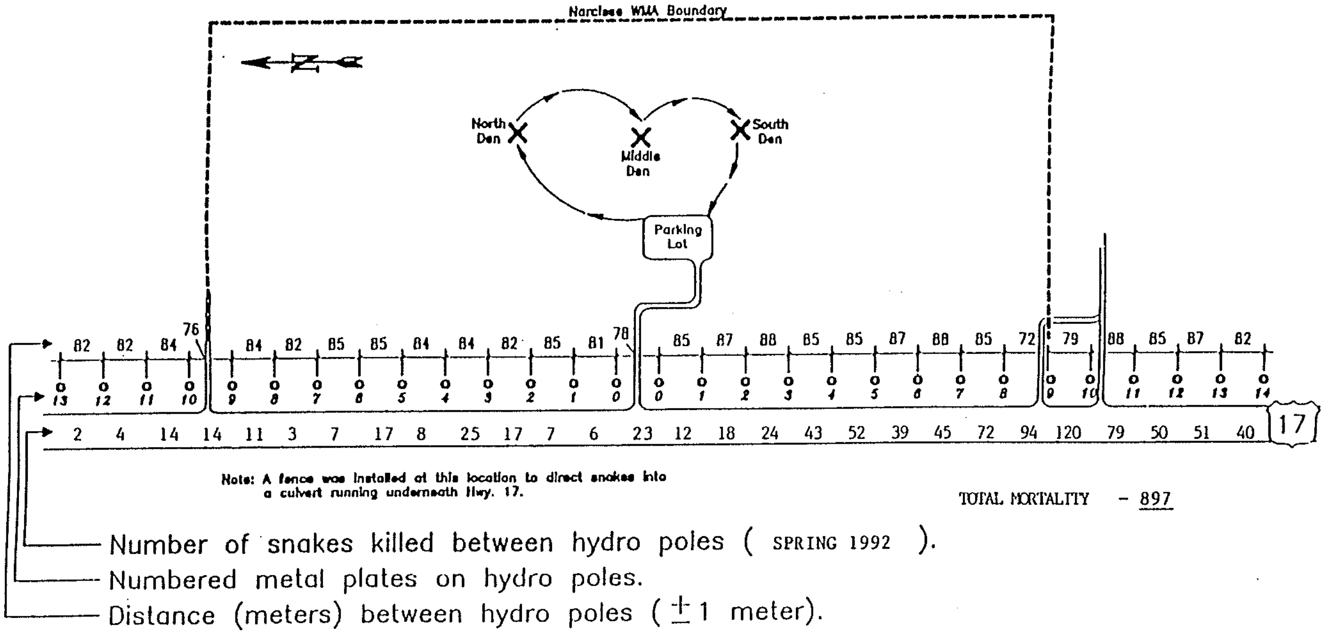


Figure 6: Provincial Trunk Highway 17 and Narcisse Wildlife Management Area (Department of Natural Resources)

the fence, a shallow trench was dug so that the bottom of the fence was covered with the surrounding organic material. The fence was set up on September 10 at approximately 12:00 pm and remained throughout the study period. It was placed on the west side of PTH 17 between hydroelectric poles 9 and 10 north of NWMA parking lot, where the culvert is located.

This test was executed to observe whether snakes would follow the fence, their rate of progress, their reaction to the culvert, and to receive an indication of the culvert's success in providing a thoroughfare for snakes. In all of the field experiments, the date, time, and weather conditions were noted. For this particular test, observations of behaviour such as stopping before entering the culvert, and activity of the snakes within the culvert were recorded. Numbers of snakes seen exiting the east end of the culvert (exit) were noted as a crude indicator of the culvert's success.

3.3.3 Lights within the Culvert

A series of three lights were placed within the culvert. It was hypothesized that the darkness and cooler temperatures within the culvert may be the cause of the snakes' hesitation as they travelled under the road. This was the hypothesis of Krikowski (1989) in reference to the migration of toads using tunnels to cross roads in Europe. A perceived advantage of the described tunnel system was that light and air could reach the tunnel through slots along the top surface (Brehm 1989).

The lights were connected to a car battery placed above the culvert. For the first trial the lights were placed at the east (exit) portion of the culvert. During the next phase, the lights were moved to the entrance. The trials took place September 13 and 14. Phase one took place between 10:00 am of September 12 and 2:00 pm September 13. Phase two ran from September 13 at 2:30 pm and September 14 at 3:00 pm. During this time, observed behaviour of the snakes was recorded. Behaviour patterns of particular interest were hesitation, attraction to the light source, speed of progress, and change in direction of movement.

3.3.4 Pheromone at the Entrance of the Culvert

The trailing of pheromones by snakes has been researched for many species. (For an extensive list see Ford 1986). Though the bulk of the research on pheromone trailing deals with sex-attractiveness pheromones (trailing of females by males), there is also evidence of snakes using pheromone trails to find their way back to hibernacula (Ford 1986, Graves et al. 1986, 1991, Costanzo 1989, Mason, personal communication).

In this experiment, garter snake pheromone was sprayed on the ground along the fencing material leading to the culvert as well as at the entrance to the culvert itself. The purpose of this was to observe behaviour of the snakes along the fence, and at the culvert entrance, and determine their receptivity of the culvert. It was hypothesized that the pheromone trail would lead snakes to the entrance. Upon arrival at the culvert, they would sense that many other snakes had supposedly arrived at that same point and be enticed to travel through the culvert.

Garter snake pheromones are components of integumental skin lipids (Mason et al. 1989). A skin lipid extract was obtained from Dr. Robert T. Mason of Oregon State

University. It was extracted using a hexane wash as described in Mason et al. (1987, 1989). The lipids sent to the researcher were concentrated requiring dilution with hexane before being applied. After dilution, the lipid, which originally had the consistency of jelly, was suspended in the hexane and applied using a back pack sprayer (used in forest fire fighting). Hexane is a highly volatile liquid that evaporates soon after application leaving only the pheromone. The mixture was applied in discrete lines to simulate high volumes of snake traffic in a defined area. The pheromone was applied on the afternoon of September 19.

Caution must be used when preparing the hexane solution for application. Hexane is a highly volatile liquid that ignites easily. Contact with the skin, and prolonged exposure to its fumes may cause physical discomfort. It is recommended that the use of safety equipment such as gloves and a mask be used when mixing this solution.

Observed behaviour of the snakes was recorded; this time with special attention paid to instances of tongue flicking behaviour. A snake's tongue picks up and delivers odours to its vomeronasal system. Therefore the tongue's activity is often used as a measure of olfactory response (Ford 1986, Ford and Low 1984). If tongue flicking is found to be common among the snakes then it can be surmised that they are aware of the pheromone trail, and may be affected by it behaviourally.

Road counts helped to determine if any reduction in road crossing resulted. A reduction in road mortality at the section would imply that the pheromone helped to increase use of the culvert as a thoroughfare.

3.3.5 Pheromone and Fencing

A new fencing material was tested at the site and used in an experiment with the pheromone. The material is perforated and is made of jute and synthetic fibre. It was ordered by Dr. Mason from KPN International, based in Connecticut. This material has some potential advantages over the reinforced plastic fencing used at the culvert. The perforations in the material would allow wind to pass through it and likely be less susceptible to damage by strong winds which commonly occur in the area. The fence was attached to stakes driven into the ground, as with the fence at the culvert. The bottom of the fence was covered with the surrounding surface material (mainly gravel with some clay) to prevent the snakes from crawling underneath it and thereby nullifying its effectiveness as a barrier. Two sections of the fencing were placed parallel to the highway on the west side. They covered the stretch of road between poles three and four, and poles five and six, north of the main entrance roughly 20 metres from the road (see Figure 7). Between these two sections of fence (section between pole 4 and 5 north of main entrance) pheromone was applied joining the two sections of fence. This was completed on September 24 by 2:00 pm. It was thought that the snakes following the two sections of fence would follow the pheromone trail after the fence section had ended. Evidence of this behaviour was noted. The number of snakes killed on the highway at these particular sections after the alterations were done was noted during daily mortality counts. If the fencing is an effective barrier, a reduction in mortality at the corresponding sections would be expected. The same principle applies for the section with the pheromone.

Fall 1991 Snake Mortality Along Hwy. 17 (2.34 km transect), West of Narcisse Dens.

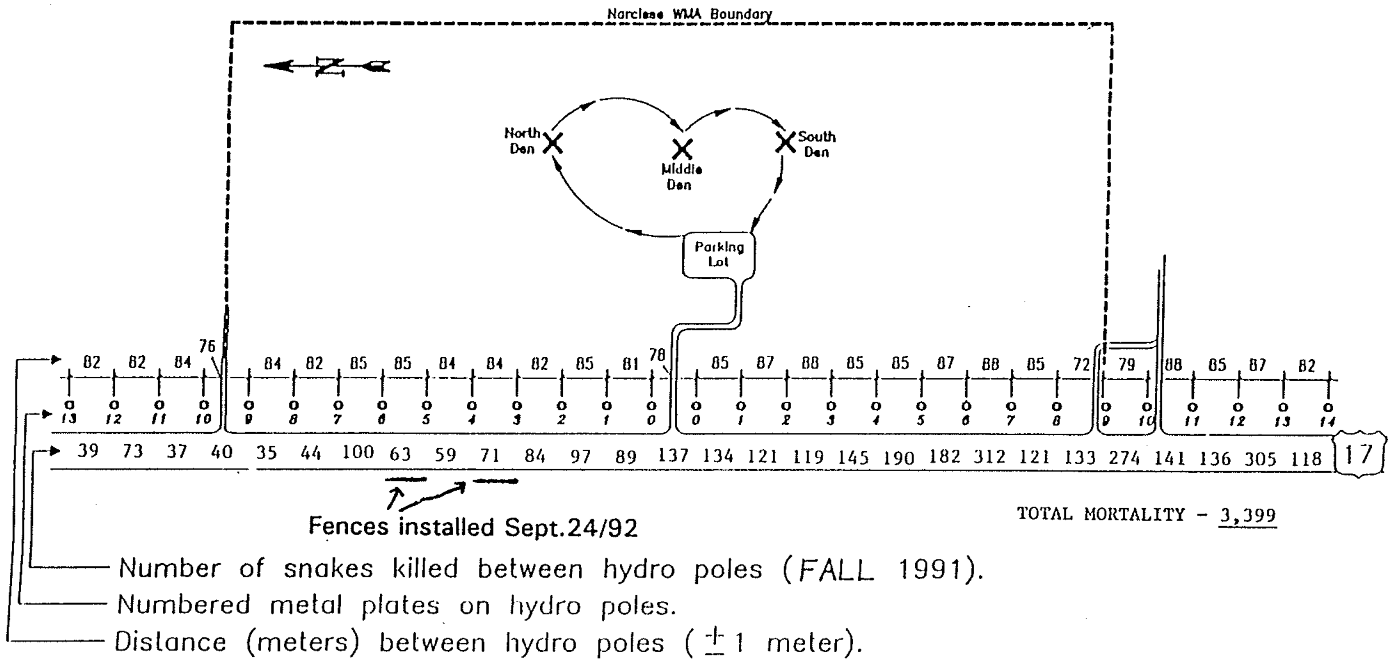


Figure 7: Position of Fence along Highway 17

Chapter 4: Observations of Pilot Field Tests

Results of pilot field tests are described in the following chapter. A brief description of procedures precedes discussion of each item in terms of how road mortality was influenced.

4.1 Road Mortality Results

The total observed mortality for red-sided garter snakes in the area of the Narcisse dens during August 31 to October 1, 1992 inclusive was 9,999. Plate 1 shows the extent of the mortality on a section of the highway before road mortality count was completed.

Plate 1: Road Mortality South of Pole 3 South of the Parking Lot Entrance on September 25, 1992

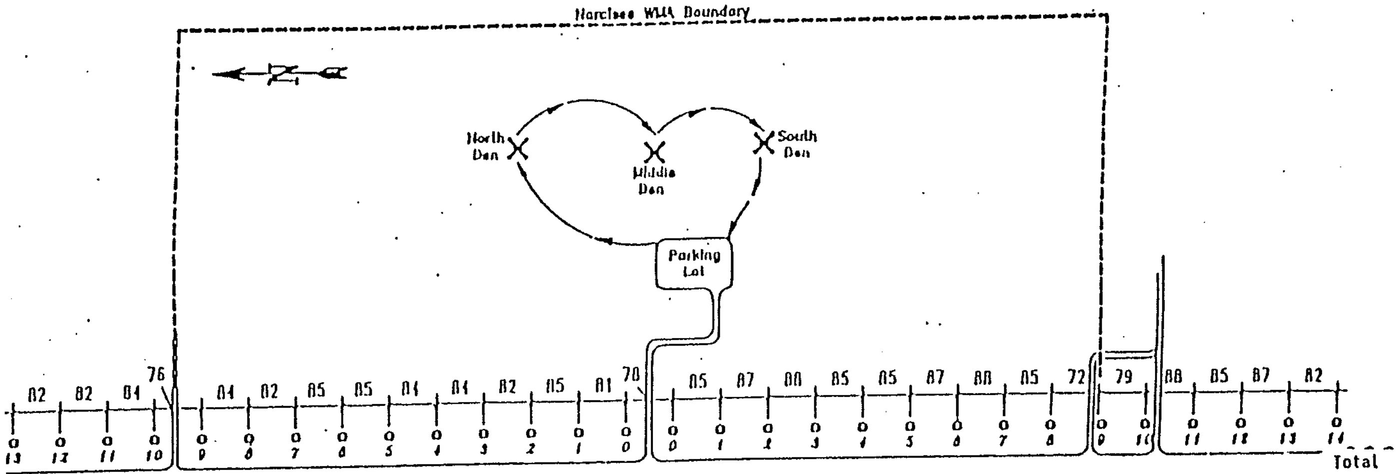
This was a dramatic increase from the previous fall season's total of 3,399. Figure 8 shows a breakdown of the daily figures and the sections on PTH 17 where mortality occurred. Fall mortality rates are much higher than those observed in the spring. Table 1 shows a comparison of the total seasonal mortality recorded since 1991. Reasons for this difference remain speculative; many theories have been put forward in an effort to explain it. In spring, the snakes will engage in mating rituals almost immediately after their emergence from the dens. As they leave the den site they are near starvation and the instinctive drive to forage may make their migration more deliberate with fewer stops. In the fall, return to the dens is less driven and appears to be interrupted by searches for basking areas, food, or shelter. In fall the snakes may spend more time basking on the road than in the spring, thereby making them more vulnerable to road mortality.

Table 1: Mortality Counts on PTH 17 at NWMA

Spring 1991	531	Fall 1991	3399
Spring 1992	897	Fall 1992	9999

Another difference between spring and fall mortality is the spatial distribution of observed mortality. Hak and Koonz (1991) reported higher numbers of dead snakes recovered at or near road approaches during the spring of 1991 (Table 2, page 45). They found 34% of all dead snakes recorded from less than 18% of the distance surveyed. A similar pattern emerged in spring 1992 where 36.8% of mortality occurred over the same area. The fall figures tell a much different story. In 1991, 21.3% of total

Snake Mortality Along Hwy. 17 (2.34 km transect), West of Narcisse Dens.



																													Total
Aug 31	2	1	0	3	0	8	3	1	3	1	2	0	0	3	1	1	1	0	2	2	0	0	1	0	1	0	2	0	38
Sept 1	3	4	2	6	4	14	11	10	8	12	4	2	6	7	5	4	3	6	4	0	3	9	4	1	1	1	1	2	137
3	3	2	4	4	1	8	3	6	1	1	4	4	3	9	4	2	3	3	5	1	0	7	3	3	0	5	3	4	96
4	6	4	4	4	2	8	7	5	7	2	3	2	7	3	4	6	2	3	10	7	3	1	7	3	1	1	3	1	116
5	7	5	0	1	0	0	2	0	3	2	2	1	2	0	0	2	3	4	5	7	8	5	3	5	1	3	2	3	76
6	0	1	0	0	1	0	4	0	0	0	1	0	0	0	0	0	0	2	0	0	1	0	1	0	1	0	1	0	13
7	3	1	2	2	3	1	2	3	2	3	0	0	3	1	1	1	4	8	6	6	2	2	2	4	4	6	0	3	75
8	7	6	5	15	8	12	9	11	5	7	7	11	8	12	6	6	5	11	22	18	14	19	4	8	3	5	8	12	264
10	0	5	0	2	8	2	3	2	1	1	0	0	2	2	4	5	5	2	11	15	1	7	6	1	5	0	9	2	101
11	5	24	11	12	14	17	18	24	20	21	19	19	18	9	8	9	5	8	13	23	15	12	9	19	7	16	18	12	405
12	9	19	17	25	24	29	33	44	37	32	46	27	19	18	20	24	15	15	23	38	35	38	23	37	24	35	33	34	773
13	9	9	10	21	9	20	11	19	30	21	11	18	16	8	8	7	11	6	10	22	21	25	24	19	20	16	20	21	442
14	21	38	20	13	17	22	17	38	39	20	24	21	22	20	22	13	20	13	22	20	38	21	22	22	21	18	14	22	620
16	18	21	18	22	26	17	20	13	36	34	26	10	20	18	17	18	16	6	17	16	31	19	11	11	11	13	7	5	497
19	28	29	25	32	21	22	35	42	28	52	35	41	39	34	51	62	75	55	70	75	59	36	33	29	35	30	18	24	1115
20	39	46	33	42	42	33	41	35	51	44	31	18	23	29	30	43	51	32	31	35	16	12	15	13	9	10	6	3	813
22	20	16	22	9	15	29	18	36	33	18	11	21	28	21	24	14	30	15	23	22	16	24	6	19	17	14	8	13	542
24	31	39	60	96	68	54	65	62	66	54	51	46	54	125	99	92	119	81	95	82	71	57	52	36	41	26	18	16	1756
25	26	26	25	43	35	33	39	35	40	23	32	31	41	75	64	76	70	46	45	40	28	18	15	11	29	13	8	13	980
Oct 1	27	43	35	74	46	45	48	33	52	32	34	41	37	101	56	67	65	45	43	59	24	29	21	13	20	18	17	15	1140
Totals:	264	339	293	426	344	374	389	419	462	380	343	313	348	495	424	452	503	361	457	488	386	341	262	254	251	230	196	205	9999

Figure 8: Daily Road Mortality for Fall 1992

mortality was recorded at or near road approaches; 16.9% in 1992. Fall migration across PTH 17 was distributed more proportionally over the 2.34 kilometre transect adjacent to the snake den area.

Table 2: Percentage of Road-kills Found at or Near Road Approaches

Season	Number Recovered at Road Approaches	Total Seasonal Mortality	Percentage of Total
Spring 1991	181	531	34.2
Spring 1992	330	897	36.8
Fall 1991	725	3399	21.3
Fall 1992	1688	9999	16.9

(Sections 9 and 10 North, 0 and 0, and 8 to 11 South of the main entrance were defined as "at or near road approaches". See Figure 8, page 44)

Another postulated pattern was a perceived increase in the number of kills along the southern portion of the road. In fall 1991, 1540 of the 3399 kills (45.3%) recorded occurred between hydro pole 6, and hydro pole 14 south of the main entrance road (See Figure 8 for location of hydro poles). In fall 1992, only 21.3% (2125 of 9999) of recorded kills occurred in this portion of the transect.

The 1991 and 1992 mortality also differed in the timing of its occurrence. In 1991, 50.3% of total fall mortality was recorded by September 3. In 1992, 52.3% of kills were recorded after September 20 (see Figure 9, Table A2 - Appendix A). The data for fall 1991 ended on September 16, thereby making this comparison potentially misleading. However, if the 1992 count ended on September 16 (total = 3653), only 7.4% of the total would be recorded by September 3, 1992; whereas 63.8% of kills

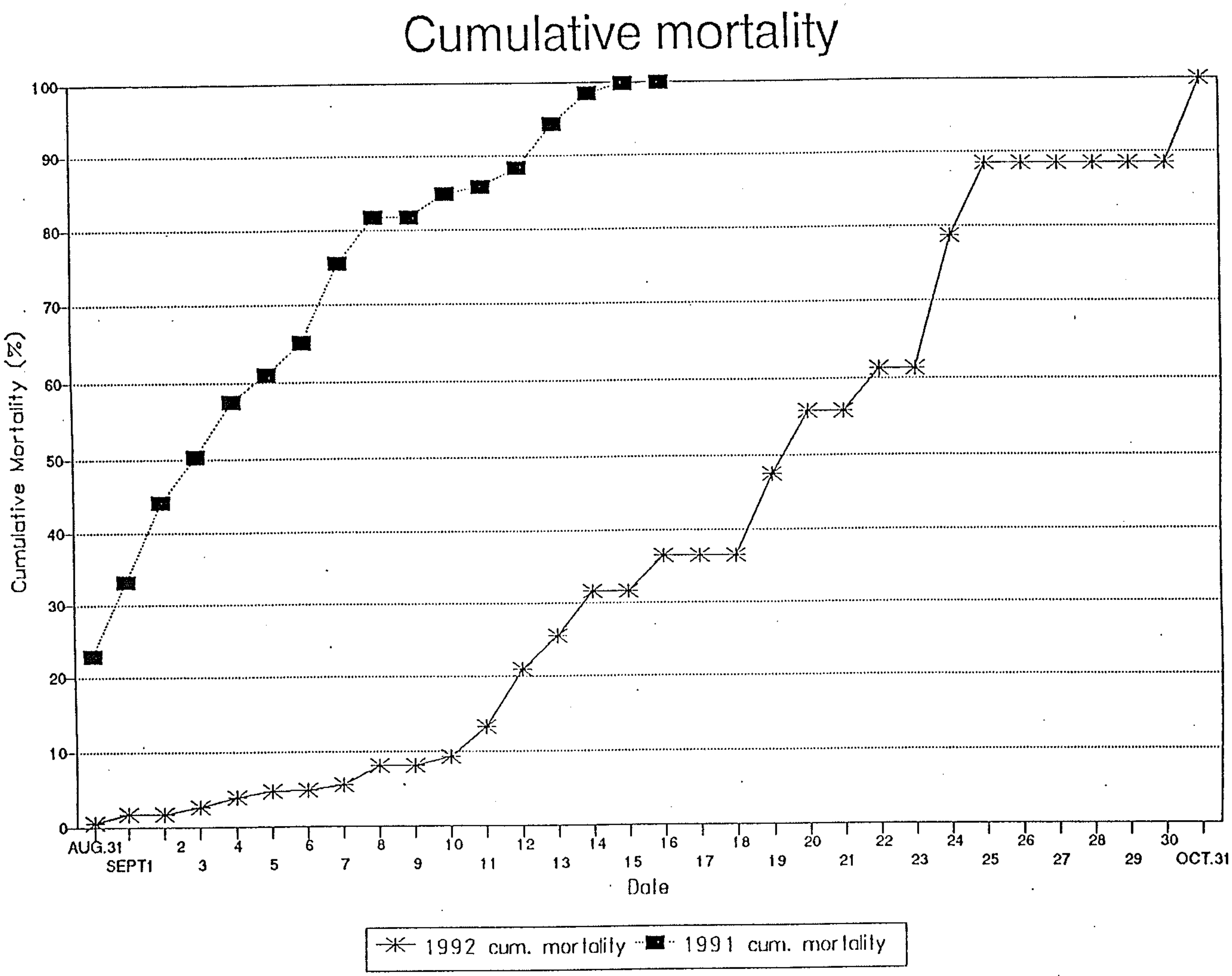


Figure 9: Percentage of Cumulative Mortality for Fall 1991 and 1992

occurred after September 12. In either case, the peak migration period in 1992 was delayed in comparison with 1991.

Unfortunately, there is no documented answer for why this shift occurred. Many speculate that the cool, wet summer and fall of 1992 delayed the migration (Koonz, personal communication, Roberts, personal communication). However, it is necessary to compare the amount of mortality with weather, amount of traffic, population size, and other variables before any real conclusion can be drawn and this data is not available for past seasons.

4.2 Culvert and Fence

The reinforced plastic fence was installed September 10 and remained throughout the study period. The fence was a reinforced polyethylene sheeting approximately 30 inches (75 centimetres) high. The two sections of the fence, each approximately 25 metres long were placed at an angle extending from each side of the culvert. This was described as a "swallow-tail" by Langton (1987). Plate 2 depicts this set up in the spring time. In the fall, the fence was set up in similar fashion west of the road. The culvert is located between hydro poles 9 and 10, north of the parking lot entrance (Figure 8, page 44). The culvert, measuring 92 centimetres high and 146 centimetres wide, is made of corrugated steel pipe constructed in an arch shape.

Overall activity of the snakes was minimal before 11:00 am. During the study period, less than five snakes were observed at the culvert area before that time. From 11:30 till 5:00 pm snake migration was at its highest. The exact timing of peak

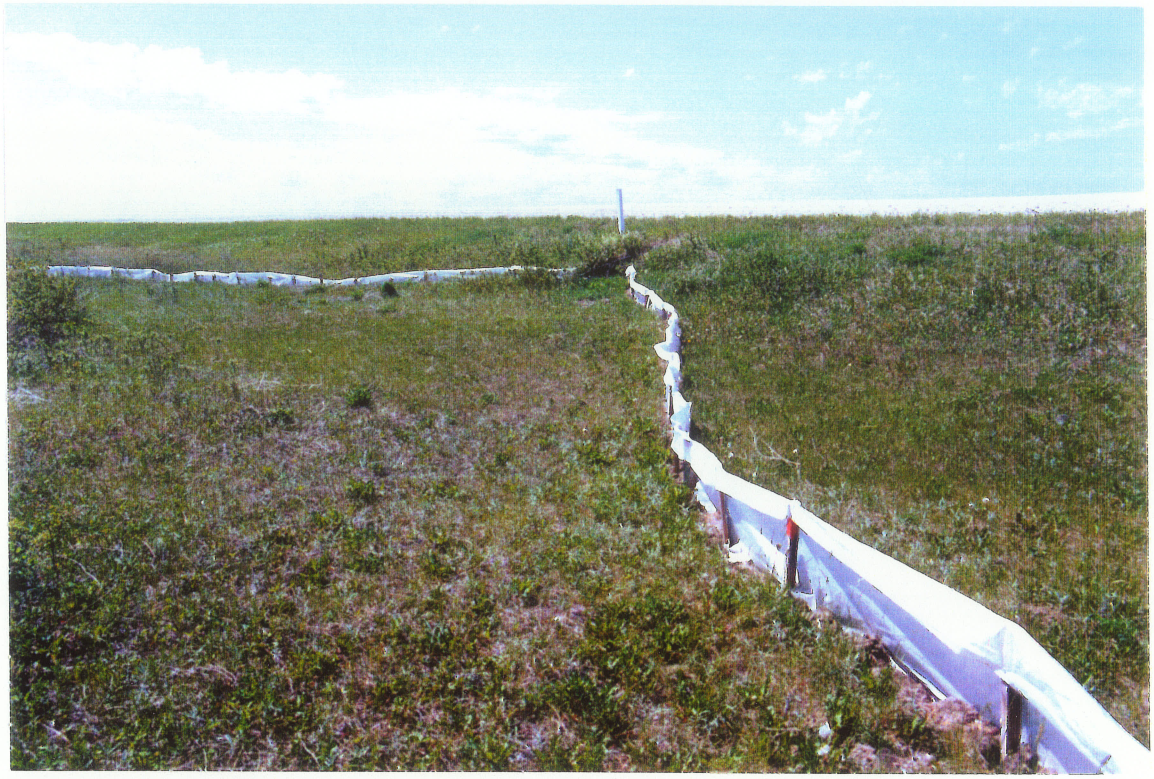


Plate 2: Position of Fence at Culvert during Spring 1992

movement periods would vary according to temperature and cloud cover conditions. This coincides with Larson's (1987) findings.

Snakes generally move slowly and cautiously and this did not change noticeably when they approached the fence. Snakes were seen following both sides of the fence; the inside of the fence which funnelled them into the culvert area, and the outside of the fence, facing the road. Snakes on the outside would follow the fence till they reached a small opening between the fence and the culvert. They would crawl through the opening and enter the culvert entrance area. When the snakes finally did reach the culvert entrance, they would hesitate before entering the culvert. Most snakes observed would spend between 10 seconds and one minute nearly motionless besides tongue flicking at the entrance of the culvert. Often, they would circle back out to the entrance area (Table A1 - Appendix A). However, evidence of snakes successfully using the culvert was found, with 54 snakes observed exiting at the east end of the culvert during the sampling period. Several were encountered in the middle of the culvert as lights were being installed for the next field test.

While moving through the culvert, snakes would tend to use the sides rather than travel along the middle. The middle of the culvert is covered with woodchips in an attempt to make travel easier for the snakes. However, almost all snakes observed would travel along the edges where metal of the culvert was exposed (Plate 3).

Snakes exhibited a strong tendency to use the edges of the culvert entrance area for basking. On sunny days, up to a dozen snakes at a time were seen basking at this location. At the exit end basking also occurred, but because of the aspect of the sun less of the area was exposed to its rays. Instead, a small bush near the entrance proved to be the preferred basking spot for snakes encountered at the east end of the culvert.

Strong winds often caused problems with the fence. On several occasions, sections of it were blown out of the ground allowing snakes to cross underneath it. One advantage that the fence did have was that snakes were easier to locate as they travelled along the fence. Snakes would make slight sounds as they slithered against the plastic material. On windy days the material would shake quite violently. However, this did not seem to deter snakes from following it.

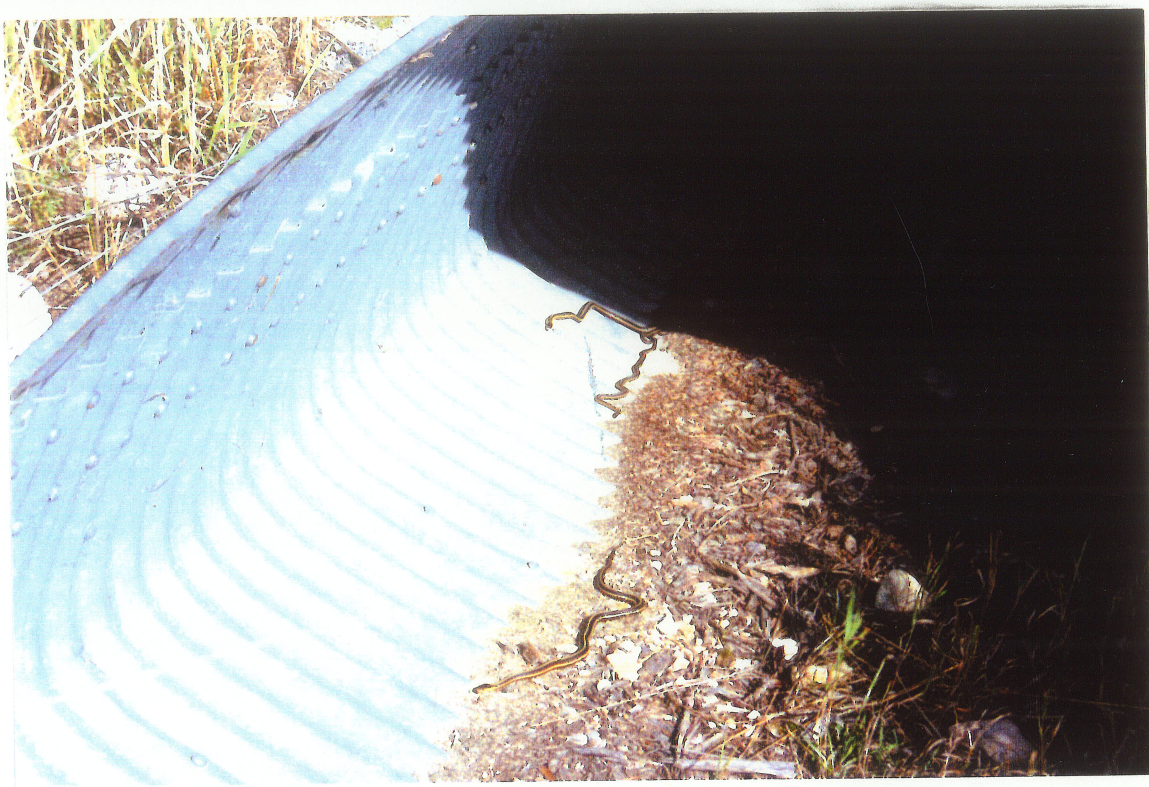


Plate 3: Snakes Travelling Along the Edges of the Culvert

4.3 Culvert and Lights

Two lights used for automobile turn signals, and a hand held emergency light were used in this pilot field test to illuminate the culvert. Trials took place from September 12 to 14. Timing of the trials was restricted by availability of the researcher, and the limited output of the automobile battery used to power the lights. The battery began to weaken after approximately four hours of use and had to be recharged nightly. Phase 1 entailed placing the lights in the culvert near the exit. The signal lights were placed before the brighter emergency lamp in the culvert to give a gradual increase in light intensity ultimately leading to the culvert exit. For both trials the lights were attached to the end of wooden sticks approximately 1 metre long. These sticks were propped up against the sides of the culvert therefore allowing illumination of one side of the culvert. The lights were placed along the culvert roughly 1 metre apart from each other. The light farthest from the culvert opening was placed approximately halfway between the entrance and exit in both cases. At the exit, the north side of the culvert was illuminated. When snakes came within 4 metres of the exit, none were observed to turn back regardless of the usage of the lights. The snakes seemed to move directly to the exit. Upon exiting, some would bask for 3 to 5 minutes before moving in the direction of the dens.

In phase 2 the lights were moved to the entrance end of the culvert. At the entrance, the south side of the culvert was illuminated. Regardless of the activity of the lights, the majority of snakes used the north side of the culvert to travel. Only a few snakes were observed lingering beneath the lights for brief moments before continuing. The presence of the lights had little noticeable effect on snake behaviour. Behaviour of snakes in the culvert did not noticeable change regardless of the presence or absence of illumination. Therefore, it is speculated that lighting may not play as important a role in guiding the migration of snakes as in other species.

As sunset approached, illumination of the culvert from the west side improving visibility within it. However, at this time, very few snakes were seen migrating. The majority of snakes had presumably found shelter for the evening. Snakes that were spotted in the culvert during sunset usually behaved in much the same way. Some actually used the culvert as shelter for the evening.

4.4 Pheromone and Culvert

The pheromone mixture obtained from Dr. Mason was diluted with 5 litres of hexane. The diluted mixture was sprayed along the ground near the fencing material and at the entrance of the culvert. The total distance sprayed was about 60 metres. The pack sprayer used had no markings to indicate the amount of liquid remaining in the storage container. Therefore estimation of the amount sprayed is very difficult. The pheromone was sprayed in fairly distinct lines between three to four centimetres wide at the suggestion of Dr. Mason. After spraying, weather conditions generally improved so it is difficult to assess whether or not a perceived increase in activity at the culvert area was due to the presence of the pheromone or because snake activity had increased as a result of the warmer weather. When compared to the mortality of adjacent sections, mortality at the section containing the culvert (between hydro poles 9 and 10 north of the parking lot entrance - see Figure 8, Page 44) had increased after spraying occurred. This may suggest the increased attractiveness of the area to snakes while use of the culvert was still minimal. Snakes would be attracted to the culvert area but would find a way to get past the fencing and eventually reached the road.

The delay in receiving the pheromone severely limited the time frame for testing its effect along the fences and at the culvert. The pheromone was applied at the culvert on September 19.

4.5 Pheromone and Fencing Material

Transportation problems were also encountered in obtaining the new perforated synthetic fencing material, which did not arrive until late September. The material, called "TerraJute" by its manufacturer (KPN International), was a woven, photodegradable polypropylene fabric (see Plate 4). Its intended use is as a cover for seeds and soils on slopes and ditches. It protects the soil from erosion while letting sunlight to pass through. It was erected parallel with the road surface and pheromone was sprayed between two sections of it. The fence was set up between sections 3 and

Plate 4: Garter Snake Moving Along the Terrajute Fencing Material

4, and 5 and 6 north of the parking lot entrance. Pheromones were sprayed between these two fenced sections, between poles 4 and 5 (see Figure 8, page 44, and Figure 7, page 41).

The fence was more resistant to wind damage and did not get pulled out of the ground on any occasion, though the material was stretched. When initially set up, the material was pulled taut between wooden stakes placed approximately two metres apart. The fence was installed on September 24. By October 1, the material between the stakes had noticeably loosened. At one location in the fence, a small snake was observed crawling through a hole created where the material had been stretched. The snake then proceeded to follow the side of the fence facing the road. As with the plastic fence at the culvert, snakes were commonly seen following both sides of it. As snakes approached the end of a fenced section, many would simply go around the last stake and follow the side of the fence facing the road. With the snakes' ability to get around the fence, and their tendency to follow it on the side facing the road, mortality could still be considerable at the fenced sections despite the fence's ability to keep snakes from initially crossing the road. Not many snakes continued to follow the pheromone trail when encountering the end of the fence. However, on one occasion, a snake was observed travelling south, parallel with the road after the fence section 3 and 4 had ended. This snake literally bumped into another snake following the same path in the opposite direction. After passing each other, the snakes continued on their way. The northbound snake was seen following the "trail" until meeting the fence at which point it continued its journey along the fence.

4.6 Summary

A dramatic increase in mortality from 1991 to 1992 was observed. Fall mortality is much larger than that observed in the spring. Mortality tends to be more concentrated around road approaches in the spring than in fall. The bulk of mortality was recorded before September 3 in 1991 while mortality in 1992 was delayed with peak numbers occurring late in the second week of September.

Both fencing materials were successful in diverting snakes. Observed snakes were not able to crawl over either fence. The "wall seeking" behaviour described in the literature was evident in the behaviour of the snakes encountering the fences. The material at the culvert had the disadvantage of being resistant to the wind. Strong winds blew sections of this fence out of the ground rendering it useless at those areas unless occasional maintenance was done. The Terrajute fence was less susceptible to wind damage. Although the material began to stretch it was never pulled out of the ground giving it an advantage over the plastic fence.

Few snakes were seen travelling the entire length of the culvert. The snakes, upon arriving at the culvert area were often reluctant to travel through the culvert and more often than not, circled back, out of the culvert after entering for a short period of time. Lighting the culvert does not appear to significantly increase use of the culvert by snakes. Any further studies should attempt testing with higher intensity lamps.

The pheromone was applied late in the season and because time was relatively limited, little can be drawn from the results outside of personal observations. There was little evidence that the pheromone was effective as a barrier to movement. This was evident at the gap between the two sections of fences where all but two snakes passed the area sprayed with pheromone without hesitation.

Other mitigative measures are potentially useful at the study site. Although time and monetary constraints prevented their testing these measures are discussed in greater detail in Chapter 5.

Chapter 5: Discussion of Other Mitigative Techniques

Four mitigative measures were included in the pilot field testing. In addition, examination of other mitigative measures was possible through investigation of past cases of usage in the literature, and by estimation of implementation costs that can be compared to the field tested materials. Potential advantages and disadvantages of these techniques were also investigated and discussed.

5.1 Fencing

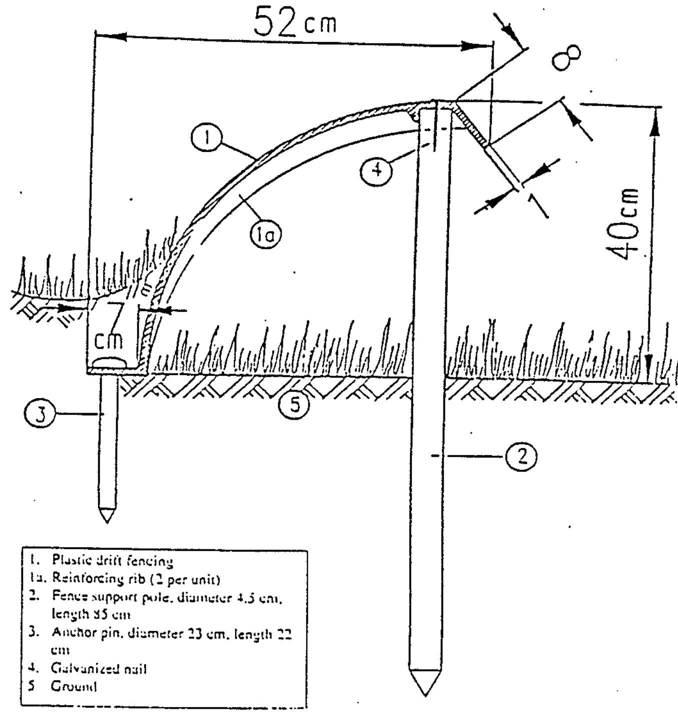
The goal of fencing is to direct snakes to a particular area for collection or to deliver them to a system (such as a culvert) which will allow them to cross the road safely. Many materials have been used for this purpose. Materials used for fencing in the pilot field tests included TerraJute fabric and reinforced plastic. Snake pheromone can also be described as a "chemical" fence as it uses chemical attraction or repulsion to direct the snakes in the same way that physical barriers direct them. Discussion of this technique is reserved for later. Materials used by researchers in past experiments include window screening and hardware cloth. Materials not yet tried at the site are plastic mesh netting (discussed in section 5.1.4), and the ACO fence. Naturally occurring barriers were used by Fitch (1951) and Stewart (personal communication) for collection directing snakes and frogs into traps. Objects such as fallen logs and large rock outcroppings were used as fences. The roadside ditches along PTH 17 adjacent to NWMA are devoid of any significantly large barriers and therefore this option is not relevant to the local situation.

The various materials are reviewed with reference to their effectiveness (observed or potential), maintenance requirements, preparation needed, and cost. It should be noted that cost of material was calculated based on the price per distance covered along the highway as opposed to cost per area of material (i.e. per square metre of fabric) because of the varying widths and lengths of the rolls of material. Costs were compared on a "cost to cover one metre" basis regardless of how high the fence would be (width of the material). Most materials studied could be used to make fences close to 24 inches (60.96 centimetres) high. In all cases, complete rolls were less expensive to purchase than cuts of specific lengths. Another item of note is that materials are often measured in imperial units. In most instances, an imperial measure is followed by the metric equivalent in parentheses.

5.1.1 ACO Fence System

As mentioned previously, the ACO fence system (Figure 10a) has been used extensively in Europe to direct migrating amphibians to tunnels that cross beneath the road, or to traps that allow volunteers to transport them. The fence is made of recycled plastic and comes in one metre long sections.

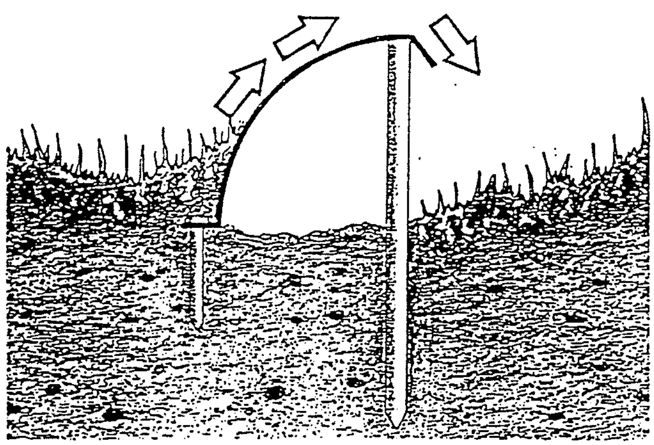
The fence's advantages were discussed earlier in Chapter 2 (section 2.2.4.2). The fence design allows animals that manage to cross or get access to the road to climb up over the curve of the fence and drop safely on the other side (Figure 10b). This way, animals which find their way onto the road are not trapped. It has been highly successful



a) ACO Specifications

Amphibian Fence

The ACO amphibian fence is a recycled plastic moulding which creates a concave barrier to approaching amphibians. This prevents amphibians climbing up over the wall. The curved fence also ensures that animals which do manage to either cross or get access onto the road are not trapped by the fence – they can climb up the curve and drop to safety on the other side. A recycled plastic pole is used to support the fence at the front. Each fence piece has a socket and spigot attachment to ensure a secure seal between pieces. Amphibian fence units are easy to cut with a wood saw.



b) ACO fence system advantage

Figure 9: The ACO Fence System - Specifications and Advantage

with amphibians, however, its use with snakes has not been investigated. Therefore, its potential effectiveness at NWMA is unknown.

The ACO fence is intended to be a permanent structure left standing year round. Therefore, maintenance requirements are minimal. Its performance in extreme winter conditions is unknown and maintenance could be required as a result of the effects of cold temperatures on the plastic material. The bottom of the fence is imbedded in the ground and hence, a shallow trench would have to be dug to install the fence sections.

If used at NWMA, enough material would have to be purchased to cover both sides of the road to mitigate mortality in both spring and fall. The ACO fence is only available from England and its price makes it quite improbable for usage at Narcisse. The material for the fence costs £14.45 per metre or approximately $26.99 per metre Canadian. This price does not include the cost of the specially made fence posts and nails totalling $6.01 per metre.

In comparison to the two materials tested, the ACO fence holds few advantages. It requires less maintenance as it is a permanent structure. Its rounded shape allows animals trapped on the road back over the fence. However, its price and shipping costs as well as unproven success with snakes make it an undesirable option. An additional disadvantage is its unknown durability in extremely cold climates.

5.1.2 Hardware Cloth

Hardware cloth has been used by researchers for enclosing dens for mark and recapture studies (Stewart, personal communication) and for cylinders in funnel traps

(Gregory 1974). It is a perforated cloth, and looks like window screening except that it is much more pliable. Hardware cloth has not yet been used for an application of this magnitude which involves distances of over 50 metres. Its durability in the long term is also unknown. The cloth would be attached to wooden stakes similar to the reinforced plastic fence system used at the culvert at Narcisse. The bottom of the fence would have to be covered by surrounding earth to prevent snakes from crawling beneath it. It could be moved from one side of the highway to the other depending on the direction from which the snakes are migrating.

The material comes in three foot widths (91.44 cm). This width can be cut in half to form two fence sections of 18 inches (45.72 cm) which should be sufficient to prevent most snakes from climbing over it. (The reinforced plastic fence and the "TerraJute" fence are 30 inches (76.2 cm) and 25 inches (63.5 cm) high respectively and were able to keep all snakes observed from climbing over it).

The material is sold at $1.49 per foot ($4.49 per metre). Its coverage is doubled after dividing the material in half and its effective price becomes $2.45 per metre (not including the cost of cutting).

5.1.3 Window Screening

Window screening has also been used to surround dens in mark-recapture studies. It has the advantage of being perforated and therefore resistant to damage by strong winds. It is manufactured in either fibreglass or aluminum with the former being the less costly material. As with the hardware cloth, window screening has only been used in small scale experiments. Its ability to withstand repeated folding, storage, and re-use is not as favourable as fabric or plastic fences (this is especially the case for the aluminum screening). Also, their durability over long term usage is unknown. If used in the same manner as the hardware cloth, it will have to be moved and re-installed twice per year. This would increase wear on the material and potential for damage in the re-installation process.

Both fibreglass and aluminum window screening are sold more cheaply when purchased in 100 foot (30.48 m) rolls. The rolls come in two widths, 24 inches (60.96 cm) and 36 inches (91.44 cm). As in the case with the hardware cloth, the 36 inch width could be cut in half to form two shorter fences, 18 inches (45.72 cm) in height. The cost of a fibreglass roll of 36 inch window screening is $104, aluminum is $116. The cost per metre of coverage would be $1.71 for fibreglass and $1.90 for aluminum after cutting is taken into consideration. The 24 inch rolls are comparable in price at $59 per roll for fibreglass and $89 per roll for aluminum. These costs average out to $1.93 per metre for fibreglass screening, and $2.92 for aluminum. The 24 inch width would not be halved because the resulting 12 inch (30.48 cm) fence would likely be too short to prevent snakes from climbing over it.

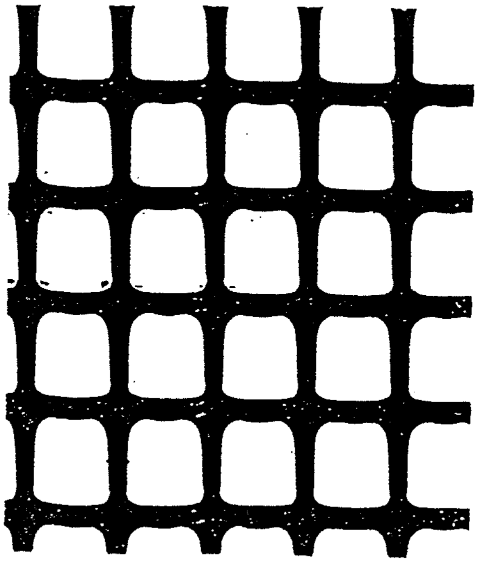
The higher cost and reduced durability of the window screening in comparison to the plastic and TerraJute fence makes it an inferior material for this purpose.

5.1.4 Plastic Mesh Netting

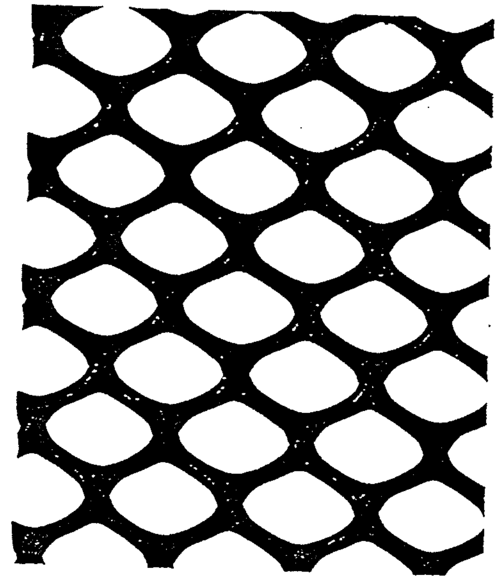
Plastic mesh netting is also perforated allowing air to pass through it. It is intended use is for predator control in the aquacultural industry. The plastic is constructed of high density polyethylene. It is non-toxic, non-corrosive, will not conduct electricity, and operates well in a wide range of temperatures. The material is manufactured by Internet Incorporated of Minneapolis, Minnesota and is distributed locally by Gerard Oval Strapping of Winnipeg. It comes in both square and diamond shaped mesh in various sizes. Figure 11 shows actual sizes of mesh evaluated.

Its effectiveness in diverting snakes is not known. One change in procedure this material would require is that staples would be better suited for attaching it to the wooden stakes than the nails presently used for all other materials. It can be rolled up and moved for re-installation in spring and fall.

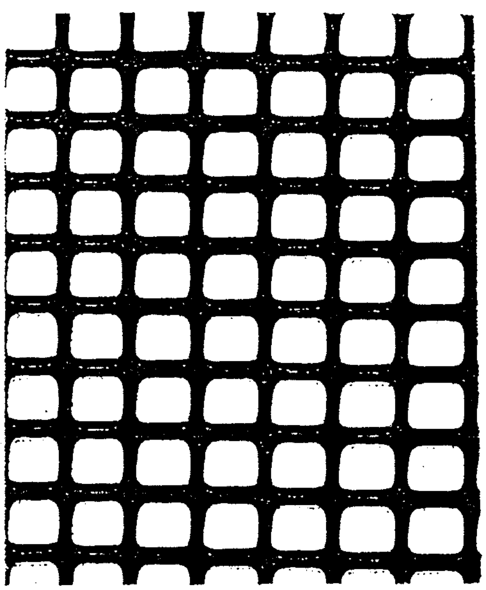
The diamond shaped, ½ inch mesh (product number XB-1132) is less expensive than the similar sized square mesh (product number XV-1020) because it is easier to manufacture. Both are less costly per unit area if purchased in complete rolls. Rolls are 500 feet (152.4 m) long and are 49 inches (124.46 cm) wide for square and 48 inches (121.92 cm) wide for diamond shaped mesh. Prices for the rolls are $1067 for square mesh and $949.85 for diamond shaped mesh. The rolls are sufficiently wide so that they can be cut in half to form two fences, 24 inches or 24.5 inches high and 500 feet long. Therefore, effective price per metre is $3.50 for square mesh and $3.12 for diamond shaped mesh.



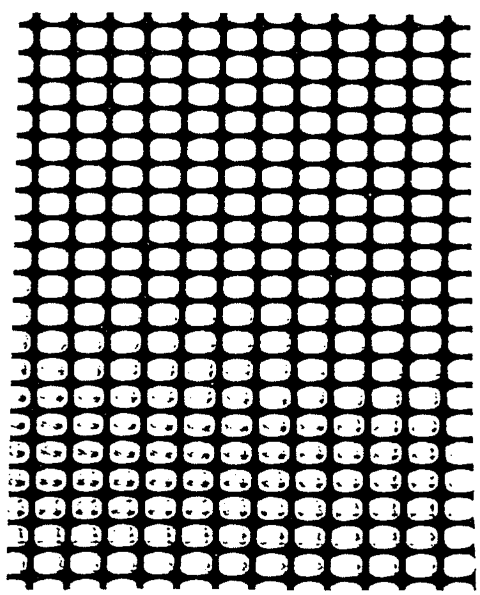
A) ½ inch square mesh
(XV-1020)



B) ½ inch diamond shaped mesh
(XB-1132)



C) ¼ inch square mesh
(XV-1170)



D) ⅛ inch square mesh
(XV-1670)

Figure 11: Internet Aquacultural Plastic Netting
(shown actual size)

Smaller sizes investigated were the ¼ inch square mesh (XV-1170) and the ⅛ inch square mesh (XV-1670). The ¼ inch square mesh rolls are 49 inches (124.46 cm) wide, the ⅛ inch square mesh rolls are 39.5 inches (100.33 cm) wide. Again, these rolls can be divided in half to double the total amount of area covered per roll. The ¼ inch rolls cost $823.50 making effective coverage price $2.70. The ⅛ inch square mesh rolls cost $388 making effective coverage price $1.27. The XV-1670 is the lightest of the four meshes potentially making it less durable. However it is also the least expensive of the plastic meshes evaluated.

Plastic mesh has been used in large scale projects and has proven durable. Its success in diverting snakes is yet to be seen. Its pliability makes it easy to store and handle. Its ability to stand despite strong winds is probably its most attractive feature. The price of the plastic mesh is a disadvantage of this material in comparison to the two materials tested.

5.1.5 Reinforced Plastic

The fencing used at the culvert area over the past few seasons is made of reinforced polyethylene sheeting. It was obtained from Manitoba Tent and Awning and the material resembles that which is used for tent floors. An advantage is its slippery surface that provides little in the way of traction so that snakes are unable to crawl over it. A disadvantage of this material is its susceptibility to wind damage. Sections of the fence have been pulled up out of the ground thereby reducing its effectiveness as a barrier and increasing maintenance requirements.

The fence currently used is about 25 inches high. The material itself is approximately 30 inches wide, however the top of it is folded over and the bottom is buried in a shallow trench. The material is attached to wooden stakes and designed to lead snakes toward the culvert. It is moved across the road after spring for use in the fall season. The fence is usually stored at the Chatfield Field Station.

The plastic comes in various strengths measured in ounces. The 2.7 ounce (76.5 g) material comes in 180 inch (457.2 centimetre) rolls which are 480 metres long. It costs $4.85 per metre. If a roll were cut into 6 equal widths of 30" (76.2 centimetres) the cost of covering a metre would be $0.81. Total coverage of the roll would be 2880 metres which is more than the length of the section of highway. A roll of 3.3 ounce (93.55 g) material is 60 inches wide and costs $1.77 per metre if an entire roll is purchased. When this width is cut in two, the cost per metre covered would be $0.89. One roll would cover 960 metres.

5.1.6 TerraJute Material

The "TerraJute" fence material obtained by Dr. Mason from KPN International has worked well during pilot testing. Some stretching of the material was observed although the fence does not blow out of the ground. Snakes were seen travelling along the fence without any difficulty.

The material is a woven, photodegradable, polypropylene fabric weighing approximately 2.5 ounces (70.87 g) per square yard. The material comes in rolls of two widths, 6 feet 3 inches (190.5 centimetres) or 12 feet 6 inches (381 centimetres). The length of the rolls for both sizes is 432 feet (131.67 metres). Dr. Mason purchased a 12 foot 6 inch roll and had it cut into six rolls, each 25 inches (63.5 centimetres) wide by 432 feet (131.67 metres) long. Two of the rolls were used in the pheromone and fencing pilot field test. The remaining four rolls are stored at the Chatfield Field Station.

A disadvantage of this material is fraying that resulted from cutting and sewing of the strips. This problem led to delays in the transport of the materials to Winnipeg. At last communication, a representative from KPN International mentioned that they would be searching for material that would not require cutting or sewing and that would be less expensive.

Also, the material is photodegradable, which may cause another problem. The fence would be in use for extended periods and therefore be exposed to sunlight for at least six weeks of the year. A necessary precautionary measure in storing the material would be to ensure it is housed in a dark place as soon as the migration periods in the spring and fall are completed.

As with the other materials, it can be moved for use in both spring and fall. Wooden stakes were first hammered into the ground. Then, the material was spread out along the stakes and attached using nails. The bottom flap of material was covered with dirt to prevent snakes from travelling beneath it.

The cost of the material is $0.42 (US currency) per square yard. For a 12 foot 6 inch roll (total area 600 square yards) the price would be $252 (US). One 12 foot 6 inch roll can cover 790 metres if divided into six strips. Therefore price per metre of coverage is $0.32 (US) per metre (or $0.41 Canadian). However, this price does not include the cost of cutting ($5 per cut), sewing ($0.07 per square yard), or transportation ($121 Canadian for delivery to Winnipeg from Connecticut via Roadway Express). Total cost equals $440 or $0.56 per metre US. In Canadian funds, the cost would be roughly $0.66 per metre, depending on the exchange rate. At present, the four remaining rolls would be able to cover 526.68 metres in total.

Table 3 summarizes the cost comparisons for the fence materials discussed in the preceding sections.

Table 3: Fencing Material Cost Comparison

Fencing Material	Price per metre of Coverage ($/m)
ACO Fencing System	$ 33.00/m
Hardware Cloth	$ 2.45
Window Screening - 18"	fibreglass: $ 1.71 aluminum: $ 1.90
Window Screening - 24"	fibreglass: $ 1.93 aluminum: $ 2.92
Plastic Mesh - Internet	XV-1020: $ 3.50 XB-1132: $ 3.12 XV-1170: $ 2.70 XV-1670: $ 1.27
Reinforced Plastic	2.7 ounce: $ 0.81 3.3 ounce: $ 0.89
TerraJute - 12'6" roll	$ 0.66

(Prices as of December, 1992)

5.1.7 Vertical Cuts in the Road Verge

A vertical cut in the road verge could possibly have the same effect as a fence by preventing snakes access to the road. This alteration to the road embankment would be a permanent "fence" and would have to be constructed on both sides of the road. The wall formed by the cut would have to be steep and high enough to prevent snakes from crawling over it. This would be a difficult task since the snakes are able to climb the steep walls of the hibernacula (particularly at the north den). A further problem with implementing this mitigative measure is that it will negatively effect vehicle safety. Any vehicle that veered off the road would be placed in greater danger of rolling. Harm to passengers and vehicles would increase because of the sharp drop off at the edge of the highway. The steep embankment would also promote erosion thereby endangering the integrity of the road shoulders. Manitoba Department of Highways and Transportation is opposed to any such cut in the road bank for these reasons. Therefore this option is not considered further.

5.1.8 Pheromone Usage as a "Chemical" Fence

In theory, pheromones can act as a "chemical" fence by directing snakes to a desired location. Snakes would follow the trail of pheromone in the same manner that they would follow a visible fence. Several important questions about pheromones and their usage remain unanswered. The ability and mechanism of snakes to use them for orientation, the effect of precipitation, wind, and time, and the limiting range of their effectiveness have not yet been studied in any detail (Costanzo 1989).

A future problem with the use of "chemical" fencing is finding a readily available source of the pheromone. At present, the only known source of garter snake pheromone is from dead garter snakes. No manufactured substitute has been developed and no other natural source is known to exist. Early research had linked the pheromone with vitellogenin which possibly could have been extracted from other species. However, further studies have shown that though the pheromone is chemically related to vitellogenin, it cannot be equated with it (Mason et al. 1987).

The process of obtaining the pheromone involves washing the skin of the snakes for periods of up to 12 hours. Hexane is used as the solvent to dilute the concentrated lipids. The amount of hexane used would depend upon the number of snakes used in the lipid extraction process, and the quantity used to dilute it for application. The appropriate ratio of pheromone to hexane has not been quantified. Dr. Mason suggested using the total amount of hexane available at the Chatfield Field Station (approximately five litres) for the field test. Certified grade hexane will cost $15 per 4 litre bottle.

5.1.9 Summary of Fencing

Use of fencing is critical to the success of either trapping or culvert use. Wind damage is an important factor in selecting fence material. At present, the reinforced plastic fencing needs occasional maintenance to ensure its effectiveness is not nullified by the damage. The other fencing materials reviewed are either expensive in comparison to the two tested, or have problems with handling and storage. Most are unproven in large scale use. At present, it is recommended that Dr. Mason's TerraJute fence be used to replace the reinforced plastic fence. In the meantime, a non-photodegradable alternative should be found. The plastic mesh netting has been used in large scale operations and is fairly durable. Its only drawbacks are its relatively higher cost in comparison to TerraJute and its uncertainty as an effective barrier to the snakes.

Snake pheromone trail laying and following in snakes is a research area still in its infancy. Until more research is done to improve its effectiveness, it is not recommended. An additional problem with its use lies in the source of the pheromone and the time consuming process of extracting it.

5.2 Human Assisted Crossings

Use of volunteers to carry amphibians across roads has been practised in Europe since the early 1980's (see section 2.2.3). No literature on the use of this practice for reptiles was found. In some cases, the operation merely consisted of lining up school children who would attempt to capture the nearest toad and carry it across the road. Most operations would employ traps (usually with the aid of drift fences) to gather a number of animals before transporting them across the road. Several traps would be set up along the road and would be checked regularly.

The duty of monitoring the traps could be added on to the responsibilities of Department of Natural Resources (DNR) staff hired to do the road mortality counts. A possible scenario would have staff place several traps in the morning. Then, after conducting the road mortality count, they could begin transporting the traps across the road. This would make use of traps during the snakes' peak activity periods. The traps would be in use between 10 am and approximately 3 pm. After release, the traps would be stored at the Chatfield station for use the next day. This particular method of employing traps would not eliminate road mortality along the entire length of the 2.34 kilometre section of the highway. Rather, it would attempt to reduce mortality at areas and times during which mortality is known to be high. This would lower mortality during these "peak" mortality periods.

Two very important considerations to be noted in the use of traps were identified by Gregory (1971). First, the cylinder which holds the trapped snakes must be covered by vegetation or some other substance. Desiccation of the snakes could result if this is not done. Covering the cylinder also serves the purpose of weighing down the structure. Another problem arises when the traps are placed too close to active ant mounds. Ants were observed by Gregory (1971) to attack and "chew up" any captured snakes. An active ant mound is located just west of the culvert entrance. Ants were seen attacking basking snakes on a few occasions. Snakes being attacked would begin rolling around on the ground in an effort to rub off the ants.

Several advantages are inherent in this mitigative measure. Costs of infrastructure and construction are minimal in comparison with a tunnel system. No changes to the road are needed. The only requirement would be the installation of temporary fences and placement of traps. The results of the technique are clearly visible and easy to calculate - namely numbers of animals trapped and carried across the road. It also gives an opportunity for visiting school groups and adult volunteers to actively participate in conservation biology. Lessons of conservation from the experience can be incorporated into the interpretive program.

A human assisted crossing operation is not without problems. It is labour intensive, requiring daily monitoring. When monitoring is not done the technique loses its effectiveness. It also restricts animals to crossing the road safely at certain periods of time. At other times snakes would be left to cross the roads at their own risk. Traps and drift fences are vulnerable to meddling or vandalism by travellers. This is especially true in the morning and early evening when traffic along the road is greatly reduced. In a worst case scenario, the traps could be stolen by people engaged in illegal picking who find the traps an easy means to capture snakes.

Another potential problem deals with the effects that human assisted crossings may have on the snakes' orientation abilities. Their ability to travel long distances and locate den sites is still not entirely understood. Lawson (1987) discovered that garter snakes show a strong tendency to use the position of the sun to orient themselves throughout the day. There are still questions as to whether transporting them would cause disorientation by impacting their ability to gauge distances. Their sense of direction may still be uninhibited since the trap will not be completely covered, however the effect of moving them 50 to 100 metres across the road may still affect their ability to find the dens by confusing their sense of distance. The long term effects of having this distance "removed" from their life-history is unknown.

Costs of constructing the funnel trap for human assisted crossings vary according to size. Gregory (1971) used traps with cylinders 30.5 centimetres long, 12 centimetres in diameter. His cylinders were made of hardware cloth. These were capable of holding up to 14 snakes at a time. Fitch's (1951) original design suggested a cylinder 15 centimetres in diameter, 35 centimetres long (see Figure 3, page 15). His traps were made entirely of window screening as are most traps patterned after his design. The cost estimate will be for a trap made of fibreglass window screening using sizes which make best use of the material purchased. The material is sold in two sizes. For this discussion, the 24 inch (60.96 cm) width screening sold at $0.79 per foot will be used. The purchase of complete rolls is not considered here since such large amounts are not necessary for constructing a few funnel traps. If a 24 inch wide by 1.5 foot (45.72 cm) long piece of window screening were used to construct a cylinder 19.4 centimetres in diameter by 45.72 cm long the price of materials would be $1.19.

The funnel designed by Fitch is 25 centimetres wide at the mouth. The material to construct this would be roughly 30 centimetres by 30 centimetres, or one square foot. One sheet of 24 inch screening could be used to make two funnels. Therefore each funnel could be made of $0.40 worth of material. The cap covering the end would also be a foot square to ensure coverage of the 19.4 centimetre diameter cylinder. This too would cost $0.40 to purchase. Total cost of a funnel trap would then equal $1.99 (not including taxes) using fibreglass screening.

Funnel traps are not the only type of trap used for collecting snakes and small animals but in this case they would be the most feasible. Pitfall traps which were briefly reviewed in Chapter 2 (section 2.2.2) have to be imbedded deeply enough in the ground to prevent trapped snakes from crawling out. The roadside ditches along NWMA are mainly clay and hard packed gravel. This makes digging very difficult, even for shallow trenches. For these reasons, pitfall traps will probably not be suitable for the situation at NWMA.

5.3 Tunnel Systems

Tunnel systems are used to give migrating animals a safe route to cross a road by going beneath the surface. Widespread use of tunnels to move amphibians across roads in many locations in Europe has provided many encouraging signs of their acceptance, as well as recommendations stemming from tunnel systems that have failed. Most of these were discussed in Chapter 2. An advantage tunnel systems have over human assisted crossings is the elimination of the labour intensiveness of carrying animals across roads and its potential effectiveness throughout the entire daily migration period.

In terms of tunnel design, two main options are apparent. One is a culvert similar to the one buried beneath the surface of the road between hydro poles 9 and 10 north of the parking lot entrance (Figure 8, page 44). Another option is to place the tunnel flush with the road surface with air/light slots along the top as in the ACO tunnel design. A variation of this would be to dig a shallow trench in the road and place a metal grating over top of it. Vehicles would be able to use the highway while the snakes crawl beneath the grating. Because the grates are made of metal, they are subject to expansion and contraction due to the temperature extremes experienced at the site. This likely would result in high maintenance costs to repair the surface of the road (Lund, personal communication). This factor makes the use of the grate over a trench design unlikely to receive approval from the Manitoba Highways Department.

5.3.1 ACO Tunnel System

The ACO tunnel system is manufactured from a strong polymer concrete (ACO pamphlet). It allows for installation closer to the road surface and causes less disturbance to the road bed, therefore reducing costs. An open cut of the road would be needed to install the bottom part of the tunnel. The top of the structure is constructed on site with fresh cement. Cement is poured into place on location so that the top of the tunnel will be flush with the road surface. Bird Construction Company Limited is the local distributor of the product. The dimensions of the tunnel are 0.4 metres high, 0.2 metres wide. It is sold in one metre sections at an approximate cost of $125 per metre F.O.B. Winnipeg. To cross PTH 17, approximately 10 metres of tunnel would be required adding up to a total cost of $1250, not including labour. Installation would have to be done on site to facilitate the pouring of concrete.

Brehm (1989) suggests that tunnels of at least one metre in diameter are most effective. He recommends the use of the ACO tunnel when roads are in low lying areas where installing tunnels of one metre diameter is difficult due to the problem of flooding within the tunnel. The holes in the surface of the tunnel allow light and air to penetrate the tunnel bringing the microclimate within the tunnel closer to that of the surrounding environment. This helps to counteract the problem of having such a narrow tunnel. Use of the tunnel by snakes has not been documented. However salamanders, which are similar in shape to snakes, have successfully used it in studies in the United States.

5.3.2 Concrete Culvert and Costs of Construction

The existing culvert located at the north end of the area is a corrugated steel arch 1460 millimetres wide by 920 millimetres high. Concrete is now the standard material for culvert construction on all provincial trunk highways. Chuck Lund, Highways Engineer, Arborg suggested that a multiple culvert bank of small diameter concrete pipe might receive approval from the Department of Highways and Transportation.

For any installation within the right of way limits of a road, the proponent of the installation project must enter into an agreement with the Department of Highways and Transportation regarding the recovery of all costs to the Department resulting from the installation and maintenance of the structure (Lund, personal communication). Consequently, DNR would have to pay for both the installation of the culvert and all future maintenance costs attributed to it.

Prices used in this analysis are from Supercrete Limited, Winnipeg and are in 1992 dollars. The pipes come in sections of different diameters and lengths and in classes of varying strengths. The higher pipe class the stronger and more expensive it is. For Provincial Trunk Highways, pipes of no less than class three are used. To estimate conservatively, pipes of class four are assumed to be used. Diameters of pipes assessed will be 750 mm, 1050 mm, and 1350 mm. These were chosen because they are representative of the three categories of costs for making open cuts in road surfaces.

These categories are; less than 800 mm, 800-1300 mm, and greater than 1300 mm. Of the three pipes sizes, the 1050 mm and 1350 mm diametres meet Brehm's (1989) suggested minimum pipe size of at least 1 metre diameter.

To cross PTH 17 approximately 15 metres of pipe would be required. This is more than the amount needed when using the ACO pipe because this pipe will be buried beneath the surface and therefore must stretch across the road to the sloped edges of the road embankment. The distance between the slopes varies from 12.80 and 13.41 metres. Fifteen metres of class IV pipe 750 mm in diameter costs $2076.60, 1050 mm costs $4116.15, and 1350 mm costs $6911.10.

The normal process for installing these pipes is to make an open cut in the road, dig a trench and lay the pipe down. Gravel and other materials are used to fill the area between the pipe and the road bed. After the last layer of gravel is placed, asphalt is used to cover the section, making it even with the road surface. An alternative method of installing pipes is by boring or pushing pipes through the road bed. This method is possible for smaller diameter pipes but is an expensive operation and may be infeasible for such large diameter pipes.

The average cost of an open cut are as follows: $33 per metre for pipes less than 800 mm diameter (total for 15 metres is $495), $40 per metre for pipes between 800 and 1300 mm diameter (total = $600), and $50 to $55 per metre for pipes greater than 1300 mm (total = $750 to $825). These figures are summarized in Table 4 (page 79).

Table 4: Estimated Cost of Open Cut

diameter of pipe (mm)	cost per metre ($/m)	total cost of cutting 15 metres
< 800	$33	$495
800 to 1300	$40	$600
> 1300	$50 to $55	$750 to $825

Cutting the asphalt pavement will cost roughly $10 per square metre. The area cut will depend on the diameter of pipe installed. This could vary between one and three metres. The length of pavement to be cut (width of the road) is about 10 metres including the shoulders. Thus, cost of cutting the pavement would be between $100 and $300. Shaping of the culvert bed costs $20 per metre. For a 15 metre trench, the total cost would equal $300. The area between the culvert pipe and the open cut has to be filled with gravel. Culvert gravel costs $10 per cubic metre. If it is assumed that a buffer of one foot (30.48 cm) of gravel is required around the culvert then prices and volumes for the different diameters are as summarized in table 5:

Table 5: Cost of Gravel Fill around Culvert

Diameter of Pipe (mm)	Amount of Gravel Needed (m^3)	Total Cost of Gravel
750	21.54	$215.43
1050	30.16	$301.63
1350	38.78	$387.81

These figures were calculated for a pipe 15 metres long, with the three chosen diameters, and a one foot (30.48 centimetre) buffer of gravel surrounding the culvert.

An eight inch (20.32 cm) layer of higher quality gravel is required just below the road surface. This gravel costs between \$12 and \$15 per cubic metre. The volume needed for the varying culvert sizes are between 3.048 and 6.096 cubic metres at a cost of \$36.58 to \$91.44. The costs were calculated assuming the use of a 15 metre pipe, depth of gravel at 8 inches (20.32 cm) and a trench width of one, 1.5 and two metres for the 750 mm, 1050 mm, and 1350 mm pipes respectively (see Table 6).

Table 6: Approximate Cost of High Grade Gravel

Diameter of Pipe (mm)	Approximate Volume of Gravel Needed (m^3)	Total Cost Range (\$12 to \$15/m^3)
750	3.048	\$36.58 - \$45.72
1050	4.572	\$54.86 - \$68.58
1350	6.096	\$73.15 - \$91.44

Patching of the road surface will require roughly 4 cubic metres of asphalt at a cost of \$175 per cubic metre. The total cost of patching would be about \$700. During construction, traffic signs are required to warn travellers of the construction. Also needed are workers to help control the speed of traffic. Traffic control using two workers plus signs costs about \$500 per 12 hour day. DNR staff could provide traffic control themselves, however the cost of providing would still be roughly the same. Total cost estimates for culvert installation and construction are summarized in Table 7.

This cost estimate does not consider several items. Cost of traffic control has not been included since the amount of time required to complete construction is unknown and varies according to weather conditions, amount of traffic, etc. This is a potentially significant cost factor. One week (7 days) of construction would amount to approximately $3500 in traffic control alone. Amount of time it takes to load equipment and materials, and to transport them to the site are also unknown and will vary according to the original location of each item. Materials that have to be shipped from Winnipeg

Table 7: Estimated Costs of Culvert Construction

Cost Categories	Dimensions		
	750 mm	1050 mm	1350 mm
Pipe	$ 2076.60	$ 4116.15	$ 6911.10
Open Cut of Road	495.00	600.00	750.00 - 825.00
Pavement Cut	150.00	225.00	300.00
Shaping Culvert Bed	300.00	300.00	300.00
Culvert Gravel	215.43	301.63	387.81
High Grade Gravel	36.58 - 45.72	54.86 - 68.58	73.15 - 91.44
Asphalt	700.00	700.00	700.00
Totals: Low Value	$ 3973.61	$ 6297.64	$ 9422.06
High Value	$ 3982.75	$ 6311.36	$ 9515.35

will add to the total cost of construction. Any road maintenance necessary because of the installation of the culvert would have to be included in future cost considerations.

Culverts and tunnels are the most costly mitigative measure evaluated here. Success has been variable in past cases with amphibians and can be described as moderate at NWMA. Costs and maintenance would be borne by DNR. However, at present they are the only permanent solution not requiring any drastic changes to the road surface (i.e. a bridge). More research should be done to try to improve the effectiveness of the culvert as a safe route.

5.4 Temporary Road Closure

A temporary closure of PTH 17 would eliminate road mortality during the time of closure. Road closures were recommended by Bernadino and Dalrymple (1992) to reduce road mortality of snakes in Florida. Closures do not have to last an entire day. A closure during times of high snake activity - between 1000h and 1600h (Aleksiuk 1977) - would eliminate a large portion of mortality. To further reduce the amount of time the road is closed, closure could take place over a period of one week rather than throughout the migration period.

A major problem with implementing a road closure is that PTH 17 is a main access road to Winnipeg for northern communities such as Fisher Branch and north Interlake First Nation reserves. There are alternative routes to use but all are either far enough away to be inconvenient or they are unable to handle the loads carried by PTH 17 which is frequented by large trucks. Unlike other cases where road closures are successfully used, there are no easily accessible alternative routes. Traffic control would be a potential problem in such a remote location. Therefore, the use of road closures is highly impractical.

5.5 Summary

The mitigative measures examined were funnel traps and tunnel systems. Both require the use of fences to direct the snakes to a desired area. The types of materials available vary in characteristics. It is preferable that the material be resistant to wind damage and can be easily stored and moved. Most of the materials meet this requirement. In terms of cost, the TerraJute material and the reinforced plastic have an advantage over the other materials. Several rolls of the TerraJute material remain unused from the amount purchased by Dr. Mason.

Funnel traps are low in cost and easy to manufacture. The main problem regarding their use is the amount of time, effort, and labour required in operating a trapping program and maintaining traps. Also, the technique's effect on the snakes' orientation and sense of distance is unknown and requires more research. This technique has the potential to be very devastating to the population if the snakes are unable to locate the dens after being transported across the road.

Culvert construction is the most costly solution examined. It involves the cooperation of the Manitoba Department of Highways and Transportation, temporary disturbance of traffic, and transport of materials and labour to the site. It does however provide a possible long term solution that requires less labour to operate. It also causes less disruption of the snakes' natural movement patterns than trapping.

Chapter 6: Conclusion and Recommendations

6.1 Conclusion

The garter snake dens at NWMA represent a unique natural phenomenon. Protection of this resource has been identified as an important undertaking (Koonz 1991). In addition to its intrinsic value as an important natural resource, the NWMA snake population is important in its role as a public education tool. Using the dens, Manitoba DNR can show the public the importance of snakes in the local ecosystem and the practice of conservation in a "hands-on" environment. Protection of the snakes is important as the quality of the viewing experience is directly related to the size and health of the population at the dens. The number of snakes killed on the highway adjacent to NWMA is large and potentially significant to the size of the population.

Mitigative techniques to help reduce the problem include fences in conjunction with traps and culverts. Various measures to help improve the effectiveness of these techniques involve use of pheromone application, lighting of culverts and use of heat gradients. Currently, a culvert at the north end of the transect of PTH 17 adjacent to NWMA offers a potential route for snakes to cross the highway but more research needs to be done to improve its effectiveness in transporting snakes across the road. The results of present studies can greatly affect the efficiency of the mitigative techniques discussed. In this sense, the mitigation of road mortality is an evolving process, one that must be continually monitored, tried and tested.

The road mortality situation at NWMA offers a unique opportunity to study, implement and evaluate mitigation techniques involving a large population of migrating snakes. In the management of the population at Narcisse, Manitoba DNR has a chance to show leadership in ensuring the protection of this important resource from road mortality.

6.2 Recommendations for Mitigating Road Mortality

A total of six recommendations are proposed. The first two are directly intended to mitigate road mortality. Recommendations 3 to 6 are suggestions for priority areas which should be researched further. Information gathered from this research will help evaluate effectiveness of the mitigative measures and also provide information for future researchers on more general aspects of the snake population at NWMA.

Mitigative Measures:

1. Fences and funnel traps should be used as a temporary measure to reduce road mortality.

This is the most cost effective mitigation measure and allows immediate action to be taken. It is recommended as a means to reduce mortality in high snake traffic areas over the short term while other techniques are being researched and improved. It is important that while research is being done to improve presently used or future techniques, that the current problem be addressed in some manner.

An important consideration in the spring is that the snakes are in a state of near starvation and will require food to survive the summer. Therefore it is important to transport the traps at least once during the day to minimize the amount of time a snake spends in the trap. The schedule of operation could be set as follows. Traps would be set out in the morning at about 10 am. Then, after the road mortality count is completed in the afternoon, the traps could be moved and snakes released. An additional release time could occur immediately before or after lunch at about 12 noon. This would help shorten the time the snakes spend in the traps. After release, the traps would be removed and stored at the Chatfield Field Station for use the following day.

Sections with road approaches; between hydro poles 0 and 0, 8 and 9, 9 and 10, and 11 and 12 south of the parking lot entrance should be targeted in spring. These areas have seen a high percentage of the total mortality in the past two spring seasons. The total distance of these sections is 317 metres. For this distance, the TerraJute material purchased by Dr. Mason will be more than adequate. Over 500 metres of it remains in complete rolls at the Chatfield Field Station. However, Dr. Mason should be consulted before using his material for this purpose. The fact that the material has already been purchased and is readily available makes it attractive for use in the upcoming spring. The material remaining can be used to extend the fence at one of the sections containing a funnel trap. In the fall, mortality is more evenly distributed and therefore the traps should also be set up along the whole length of the highway.

Fences should be set up in the "swallow-tail" design that has been past practise at the culvert. When setting up at road approaches, the fences should be placed north of the gravel roads since it is presumed that most of the snakes will be travelling southwest from the dens (Stewart, personal communication) to nearby marshes. This procedure would prevent the snakes from getting on to the gravel roads.

One consideration of note in the use of this material is the fact that it is photodegradable. To prolong the life of this material as much as possible, it should be stored in a dark place immediately after the migration period has ended. In the future, a material similar to this one could be used for channelling snakes into a culvert, but it would be preferable for it to be non-photodegradable. This would ensure a longer life for the material.

2. *Installation of culverts, preferably near road approaches pending favourable results from further research to improve culvert usage by snakes.*

In the long term, it is necessary to find a permanent solution to the problem. While funnel traps are a workable short term solution, they require labour and time that could be used elsewhere. A culvert would provide a solution that is free of labour and time restrictions. A culvert would also allow snakes to migrate with less human disturbance. The installation of more culverts along the road is imperative to provide safe passage for the snakes. By installing more culverts, snakes will not have to be diverted long distances from their intended routes by fences. It is important to allow the snakes to travel with as little diversion as possible since very little is known about the mechanisms they use for locating dens in the fall or finding feeding areas in the spring. However, it is also important that the culverts are effective in moving snakes under the road since they require the largest monetary investment of all techniques studied. The installation of the culvert should depend upon favourable results from Dr. Schwarz's suggested experiment (recommendation 3) or from other tests involving improvement of culvert acceptance by snakes (ie. temperature gradient experiment, pheromone experiment). If these tests can show that a culvert can move large numbers of snakes safely under the road then the best solution would be the installation of culverts.

The culvert should be at least one metre in diameter. The available literature has stated that tunnels are most effective if their diameter is at least one metre. The use of tunnels 0.6 metres in diameter provided poor results (Haslinger 1989) so use of the 750 mm culvert pipe may not be large enough to provide an effective thoroughfare for the snakes. Because of cost considerations, it would probably be best to attempt installation of a culvert 1050 mm in diameter. The ACO system is not considered here because of uncertainties about its use by snakes and its affect on road conditions after installation.

A culvert should be placed in the southern portion of the study area. This region has shown high levels of mortality in the past. A culvert could be placed near the parking lot road approach or the road approach at the south end of NWMA. If placed at the parking lot approach it may attract the attention of visitors and cause some problems with slow moving traffic at the entrance. This would be more of a problem in the spring when the fence is more visible along the parking lot road than in the fall when it is moved across to the west side of the highway. The sections of highest priority are road approaches because, at least in the spring time, snakes tend to use those areas more than others.

Ryser and Gossenbacher (1989) suggested that tunnels be no more than 50 metres apart so as to minimize the distance the animals would have to be diverted from their natural paths. For the 2.34 kilometre section of highway studied here, this requirement would need 46 culverts. A more practical option would be to concentrate culverts at traditionally high mortality areas, the south end of the highway and near road approaches. Culverts near road approaches should be installed so that the maximum distance of fencing can be stretched out reaching the road bank from the culvert.

Recommendations for future research

3. *Experiment with the opening and closing of the culvert.*

Tests of the culvert's effectiveness will require effort in the future. Dr. Carl Schwarz of the Statistics Department at the University of Manitoba suggests that the culvert and fence be used on a "one week on/one week off" basis as a way to statistically measure its success in moving snakes across the road. On alternate weeks, the culvert will be closed to snake usage and the fence removed. On other weeks the fence will be reinstalled and the culvert opened. The mortality figures for the section containing the culvert can be compared to those sections surrounding it. Quantities recorded during culvert closed/opened periods can be compared to note any decline in mortality attributable to usage of the culvert as a thoroughfare by the snakes. This will provide data to statistically measure the effectiveness of the culvert and also supply a standard against which all manipulations to the culvert (for purposes of increasing its use) can be compared.

The bulk of migration occurs within a three week span and therefore the testing periods should perhaps be shortened to three or four day blocks in which the culvert is either opened of closed.

4. Traffic Counters should be placed at the North and South ends of PTH 17 adjacent to NWMA to determine the effects and possible correlations of traffic volume on snake road mortality.

It is recommended that traffic counters be placed at the north and south ends of the section of highway. The counters should be checked daily to give an estimate of traffic along the section of highway each day. This information can be used to investigate any correlations between daily traffic density and daily road mortality. It will also show approximately how many people visit the dens from the south by comparing the number of vehicles travelling in the southern portion of the road with the northern section. Higher traffic volume on the southern portion of the highway may account for the larger number of kills recorded in this area in the past.

5. Extend monitoring dates of snake mortality on PTH 17 adjacent to NWMA.

Mortality counts on PTH 17 should be continued to provide future researchers with additional data to measure against their results. The mortality count for each season should ideally continue until mortality has declined to near zero. This monitoring will provide more information to better define the length of the entire migration period. The data will help to identify shifts in migration period and may help in correlating it with traffic patterns, weather conditions, or population changes. In the past, mortality counts have ended at a specified date which was set prior to the season, presumably due to monitoring staff scheduling. If the dates chosen for the monitoring of the 1992 fall season mortality were identical to those chosen for the 1991 season, the result would have underestimated the total by over 6000 snakes.

6. Continued research of ways to make mitigative measures more successful, especially culverts.

Many areas of snake behaviour and ecology remain a mystery. Most important to the problem of road mortality is research in making mitigative measures more successful in dealing with the issue. The subject of thermal gradients and snake behaviour holds promise. The possibility of using a temperature gradient to lure snakes into the culvert could vastly improve its effectiveness as a snake thoroughfare.

The study of pheromones should be further explored as they may potentially be important in understanding how snakes are able to locate dens. Future studies should be conducted over a longer period of time. This would allow for an adequate number of repetitions of the experiments and would provide more data for statistical analysis. The amount of hexane used to dilute the pheromone should also be increased to provide more of the mixture for spraying.

In the future, any testing on illumination within the culvert should use higher intensity lights. The battery used in field testing provided limited power and may not be adequate to provide power for brighter lamps. A gasoline or diesel powered electric generator may be needed to power more lamps of higher voltage.

A better estimate of the snake population at NWMA dens should be obtained. Before the road mortality survey, estimated population was between 10,000 and 20,000 snakes (Koonz, personal communication). This fall, with 9999 dead snakes counted, the estimated population of 10,000 is obviously incorrect. With a more accurate population estimate - perhaps using mark and recapture techniques - the significance of the effect of road mortality on the future viability of the population can be more accurately estimated and assessed.

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Appendix A:

Data Tables

Table A1: Observed Behaviour at Culvert Entrance and Exit

	Entrance (West of Road)		Exit (East of Road)	
Date	Entering	Exiting	Entering	Exiting
Sept.11	4	3	-	1
12	11	5	-	9
13	24	24	-	8
14	22	20	2	20
19	1	3	-	-
20	13	7	-	8
21	12	15	-	2
24	10	8	1	6
25	0	3	-	-
Total	97	88	3	54

Important Dates:

September 10: Fence installed at culvert.

13 - 14: Field test of lights within the culvert conducted.

19: Pheromone applied along the fence leading to the culvert and at the culvert itself.

24: TerraJute fence installed. Pheromone applied between the two fence sections.

Table A2: Cumulative Mortality

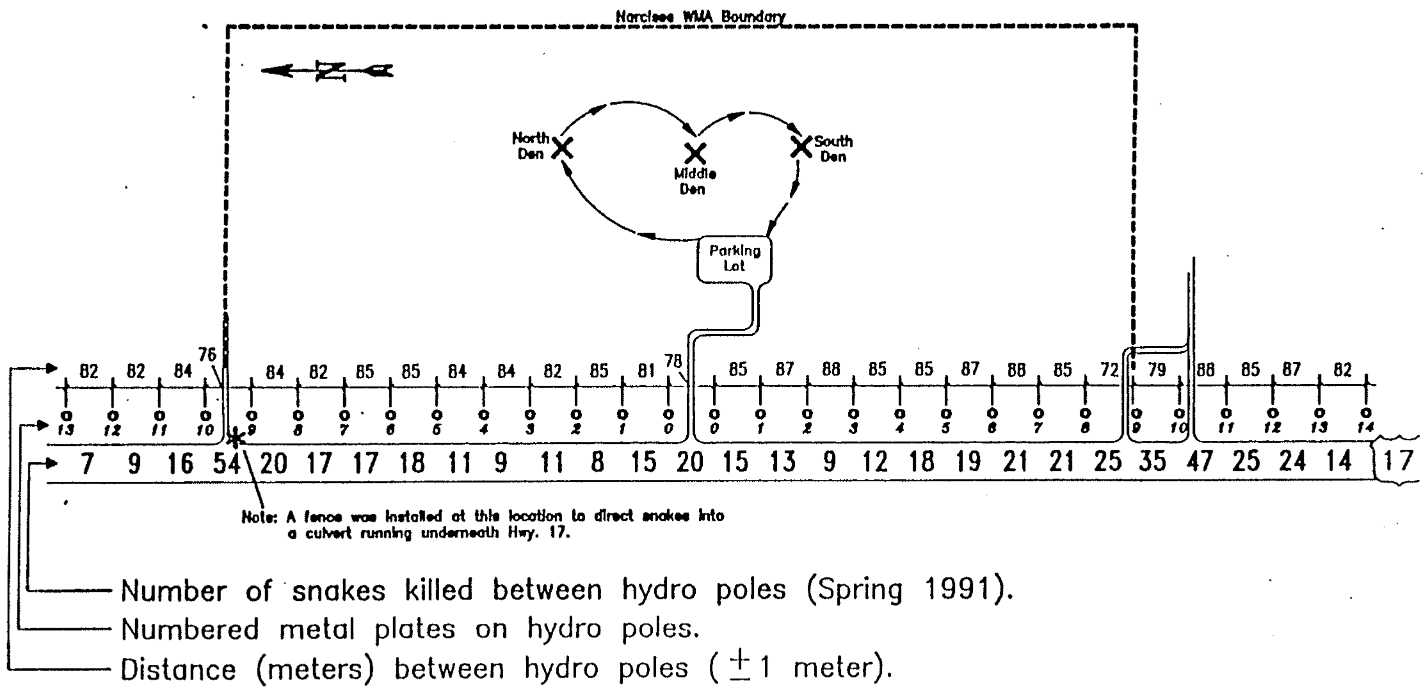
	Fall 1991		Fall 1992	
Dates	Number Dead	Cumulative % of Total	Number Dead	Cumulative % of Total
Aug. 31	777	22.9	38	0.4
Sept. 1	348	33.2	137	1.8
2	374	44.2	-	-
3	209	50.3	96	2.8
4	248	57.6	116	4.0
5	117	61.1	76	4.8
6	136	65.1	13	4.9
7	355	75.6	75	5.7
8	211	81.1	264	8.3
10	106	84.9	101	9.3
11	32	85.8	405	13.4
12	87	88.4	773	21.1
13	203	94.4	442	25.5
14	135	98.4	620	31.7
15	40	99.6	-	-
16	12	100	497	36.7
19	-		1115	47.9
20	-		813	56.0
22	-		542	61.4
24	-		1756	79.0
25	-		980	88.8
Oct. 1	-		1140	100.0

Appendix B:

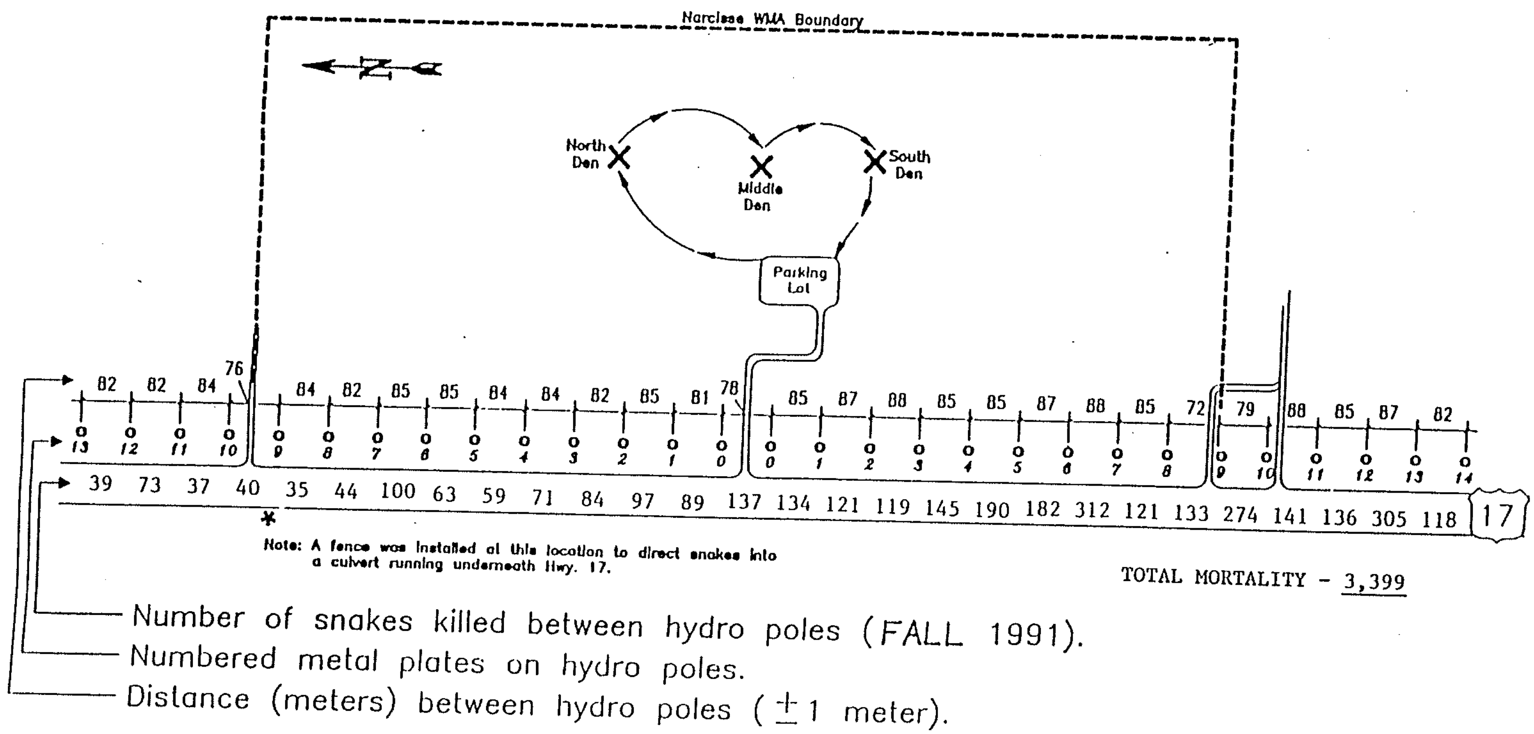
Road Mortality along PTH 17

Spring 1991 - Fall 1992

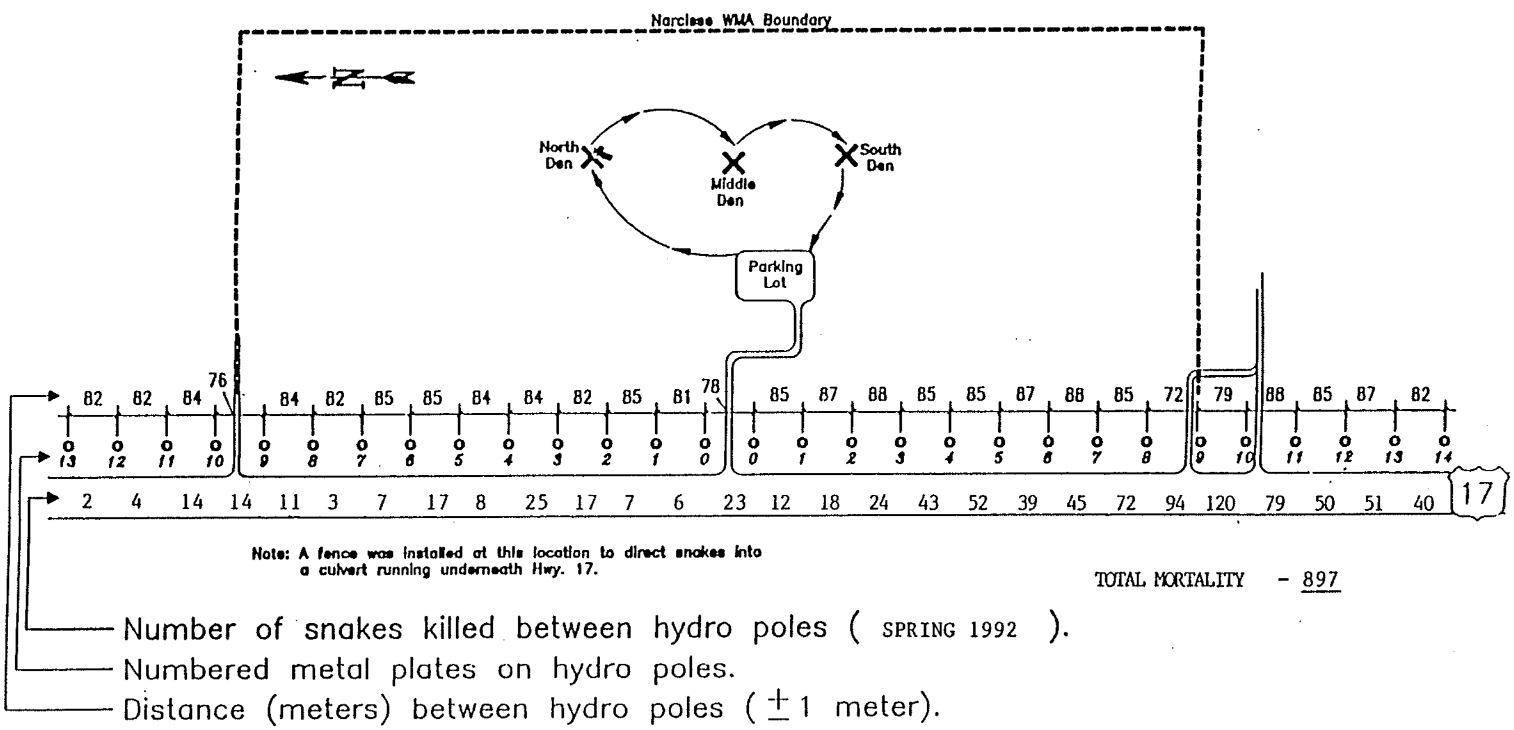
Spring 1991 Snake Mortality Along Hwy. 17 (2.34 km transect), West of Narcisse Dens.



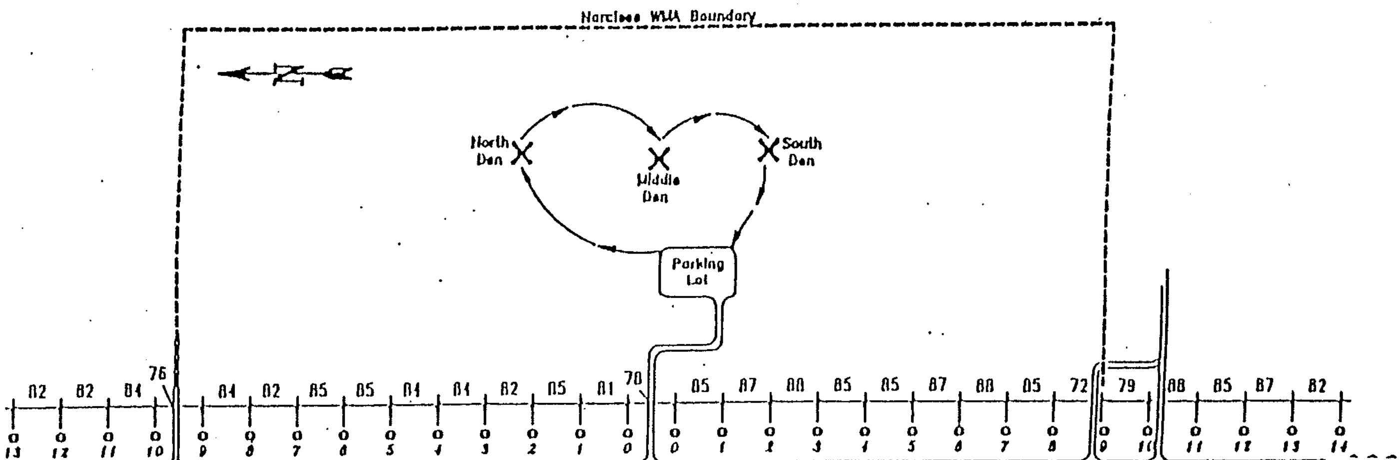
Fall 1991 Snake Mortality Along Hwy. 17 (2.34 km transect), West of Narcisse Dens.



SPRING 1992 *Snake Mortality Along Hwy. 17 (2.34 km transect), West of Narcisse Dens.*



Fall 1992 *Snake Mortality Along Hwy. 17 (2.34 km transect), West of Narcisse Dens.*



Aug 31	2	1	0	3	0	8	3	1	3	1	2	0	0	3	1	1	1	0	2	2	0	0	1	0	1	0	2	0	38
Sept 1	3	4	2	6	4	14	11	10	8	12	4	2	6	7	5	4	3	6	4	0	3	9	4	1	1	1	1	2	137
3	3	2	4	4	1	8	3	6	1	1	4	4	3	9	4	2	3	3	5	1	0	7	3	3	0	5	3	4	96
4	6	4	4	4	2	8	7	5	7	2	3	2	7	3	4	6	2	3	10	7	3	1	7	3	1	1	3	1	116
5	7	5	0	1	0	0	2	0	3	2	2	1	2	0	0	2	3	4	5	7	8	5	3	5	1	3	2	3	76
6	0	1	0	0	1	0	4	0	0	0	1	0	0	0	0	0	0	2	0	0	1	0	1	0	1	0	1	0	13
7	3	1	2	2	3	1	2	3	2	3	0	0	3	1	1	1	4	8	6	6	2	2	2	4	4	6	0	3	75
8	7	6	5	15	8	12	9	11	5	7	7	11	8	12	6	6	5	11	22	18	14	19	4	8	3	5	8	12	264
10	0	5	0	2	8	2	3	2	1	1	0	0	2	2	4	5	5	2	11	15	1	7	6	1	5	0	9	2	101
11	5	24	11	12	14	17	18	24	20	21	19	19	18	9	8	9	5	8	13	23	15	12	9	19	7	16	18	12	405
12	9	19	17	25	24	29	33	44	37	32	46	27	19	18	20	24	15	15	23	38	35	38	23	37	24	35	33	34	773
13	9	9	10	21	9	20	11	19	30	21	11	18	16	8	8	7	11	6	10	22	21	25	24	19	20	16	20	21	442
14	21	38	20	13	17	22	17	38	39	20	24	21	22	20	22	13	20	13	22	20	38	21	22	22	21	18	14	22	620
16	18	21	18	22	26	17	20	13	36	34	26	10	20	18	17	18	16	6	17	16	31	19	11	11	11	13	7	5	497
19	28	29	25	32	21	22	35	42	28	52	35	41	39	34	51	62	75	55	70	75	59	36	33	29	35	30	18	24	1115
20	39	46	33	42	42	33	41	35	51	44	31	18	23	29	30	43	51	32	31	35	16	12	15	13	9	10	6	3	813
22	20	16	22	9	15	29	18	36	33	18	11	21	28	21	24	14	30	15	23	22	16	24	6	19	17	14	8	13	542
24	31	39	60	96	68	54	65	62	66	54	51	46	54	125	99	92	119	81	95	82	71	57	52	36	41	26	18	16	1756
25	26	26	25	43	35	33	39	35	40	23	32	31	41	75	64	76	70	46	45	40	28	18	15	11	29	13	8	13	980
Oct 1	27	43	35	74	46	45	48	33	52	32	34	41	37	101	56	67	65	45	43	59	24	29	21	13	20	18	17	15	1140
Totals:	264	339	293	426	344	374	389	419	462	380	343	313	348	495	424	452	503	361	457	408	386	341	262	254	251	230	196	205	9999