

Final Report

Indicators and Methods for Monitoring the Effectiveness of Gopher Snake Wildlife Habitat Areas

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EXECUTIVE SUMMARY

The Great Basin Gopher Snake (*Pituophis catenifer deserticola*) occupies a restricted range within arid valleys of south-central British Columbia, where its populations are threatened by habitat loss and fragmentation and by direct persecution; reflecting these threats, this subspecies is “blue-listed” provincially and “threatened” nationally. The establishment of Wildlife Habitat Areas (WHAs), anchored on communal hibernation sites, is a primary means for protecting this and other large snakes at risk under the Identified Wildlife Management Strategy.

We developed a set of habitat- and population-based indicators for assessing the effectiveness of WHAs for this species. The procedure consisted of (a) formulating monitoring objectives/questions, (b) listing threats and other stressors on the population and assessing their importance, (c) developing a conceptual model linking stressors to snake population parameters, (d) listing candidate indicators, based on pathways in the conceptual model, and (e) screening candidate indicators to arrive at a set of practical indicators with a high information content. Using this process we selected five indicators at the regional level and 12 indicators at the local level. The regional level corresponds to geographic ranges of subpopulations for this species in the province or to broad management units, whereas the local scale corresponds to individual WHAs and the area immediately surrounding them. For each indicator, the rationale for selection, description and methods, practical considerations, and criteria for action were described. The level of effort required to measure different indicators ranges from routine (for habitat indicators that can be measured from maps or other existing data sources or that require qualitative assessment in the field), to extensive (for habitat indicators that require quantitative field work), and to intensive (for indicators that require telemetry, or monitoring demographic parameters or population trends).

Paucity of information on habitat use and population parameters of the Great Basin Gopher Snake, together with inherent characteristics of the species including cryptic behaviour, extensive movements, and relatively wide niche breadth, complicate conservation efforts and the assessment of the effectiveness of WHAs. The population and habitat information collected at WHAs could serve as a baseline for examining future trends in selected indicators, evaluating their validity, and filling in data gaps. A hierarchical implementation strategy for the selected indicators is described. A pilot project at a small number of WHAs using this implementation strategy is recommended.

1.0 INTRODUCTION

The Great Basin Gopher Snake (*Pituophis catenifer deserticola*) is one of three recognized subspecies of *Pituophis catenifer* and the only extant Gopher Snake that occurs in British Columbia (the Pacific Gopher Snake, *P. catenifer catenifer* is considered extirpated). It is listed as “threatened” in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and is on the provincial blue list (vulnerable to extirpation) in British Columbia. These large snakes (adult length about 76 – 180 mm) are restricted to the warm, dry grassland valleys of the southern interior, reaching highest numbers in the Okanagan and Thompson Valleys. They require access to talus or rock outcrops for communal denning, south-facing slopes with loose, sandy soils for egg-laying, and grasslands and riparian habitat for foraging; earthen burrows are also used for denning in some areas. Their restricted distribution in British Columbia and requirements for specialized seasonal habitats and habitat features make them vulnerable to human activities and land conversions, which are expanding rapidly within the southern interior of the province.

A management strategy has been prepared for all species currently listed as Identified Wildlife in the province, including the Great Basin Gopher Snake (Bertram 2003). The Gopher Snake strategy has resulted in the preliminary selection of about 30 Wildlife Habitat Areas (WHAs) and the development of general wildlife measures for the species in publicly owned, managed forests and rangelands of British Columbia. The Wildlife Habitat Areas are anchored on hibernation sites that often are used communally and by several species of snakes. The protection of such sites is vital for the conservation of regional snake populations because a considerable portion of a population in a given area may congregate at a single site. The WHAs also are intended to protect other seasonal habitats, such as foraging and egg-laying sites, around the hibernation sites, so that all life history requirements of the snakes can be met. A RENEW (Recovery of Nationally Endangered Wildlife) Recovery Strategy is in progress for the Great Basin Gopher Snake (Sarell et al. 2003, draft).

This report describes methodologies to monitor the effectiveness of Wildlife Habitat Areas for the Great Basin Gopher Snake in reducing threats, preserving habitat quality, and helping maintain viable populations. The monitoring results are to be linked to management and can be used to re-evaluate and adjust current conservation and management measures for the species. Protecting the integrity of the WHAs from the effects of various human land uses and developments that may occur within and around these areas, including proactive measures, are handled through management; the nature and implementation of these measures form a separate issue, and are beyond the scope of this report.

2.0 OBJECTIVES

The overall goal of this study is to develop a set of indicators that can be used to assess the effectiveness of Wildlife Habitat Areas described in the Identified Wildlife

Management Strategy for maintaining and conserving populations of the Great Basin Gopher Snake in British Columbia.

The specific objectives of this study are to:

1. Review existing information on habitat requirements and management measures relevant to the selection of indicators
2. Develop monitoring goals and a list of indicators for measuring the effectiveness of WHAs, including rationale and scientific basis for their selection
3. Describe methodology for measuring selected indicators
4. Identify data gaps, research needs, and potential problems

3.0 OVERVIEW OF EXISTING INFORMATION

3.1 Distribution and life history

The Great Basin Gopher Snake is one of three species of large snakes that inhabit the dry interior belt of British Columbia; the other two are the Western Rattlesnake (*Crotalus viridis*) and the Racer (*Coluber constrictor*). These three species often hibernate together and share refuge sites, and the Racer has been observed to nest communally with the Gopher Snake in the Okanagan (Shewchuk 1996). In British Columbia there are four regional populations of the Great Basin Gopher Snake (Figure 1). The northernmost population in the Fraser, Thompson, and Nicola Valleys is geographically isolated from the three southern sub-populations (in the Grand Forks, Midway, and Okanagan/Similkameen areas), which are a part of a larger population connected south of the Canadian/United States border (Waye and Shewchuk 2002); reference to a fifth population in the Trail area in the COSEWIC report appears to be erroneous (M. Sarell, pers. comm.). The northern population occupying the Fraser, Thompson, and Nicola valleys is of special conservation significance because of its isolation from other populations and its location at the northern extremity of the species' range (Sarell et al. 2003). The Okanagan sub-population appears to be the largest, and this area represents a stronghold for the species in the province (Sarell 1993).

The Gopher Snake exists at the northern limits of its geographic range in British Columbia, and its range expansion is likely limited by constraints imposed by the climate (Shewchuk and Waye 2002). The optimum body temperature for activity of this species is around 30°C (Diller and Wallace 1996, Shewchuk 1996), and the relatively brief period available for activity in the summer is thought to limit the acquisition of energy reserves for reproduction. The species is oviparous, and suitable warm conditions are required for the incubation of eggs. The presence of suitable hibernation sites that allow the snakes to escape subfreezing conditions is particularly important for this and other snakes in northern areas, and the presence of such sites may be in short supply.

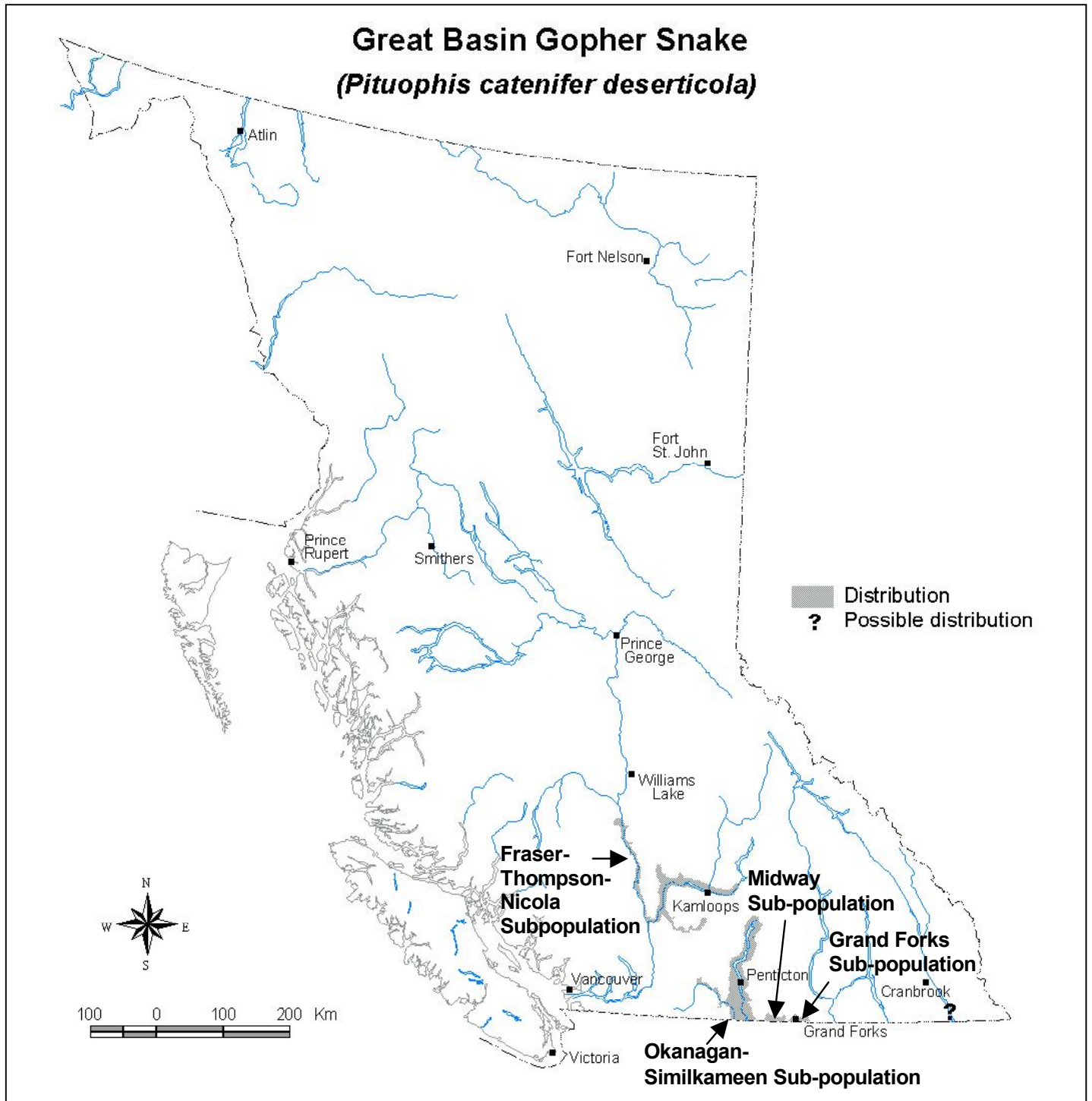


Figure 1. Distribution of the Great Basin Gopher Snake in British Columbia showing the four known sub-populations (map adapted from Sarell et al. 2003).

In British Columbia, Nelson (1992), Shewchuk (1996), and Bertram et al. (2001) studied populations of the Great Basin Gopher Snake through mark-recapture and telemetry, but many aspects of the species' life history and ecology remain poorly known. The seasonal activity pattern of the Great Basin Gopher Snake is similar throughout its range, but the timing of events differs in space and time, depending on environmental conditions (Waye and Shewchuk 2002). In British Columbia, the snakes emerge from hibernation in the spring (late March – April) and disperse to summer foraging areas shortly after; mating takes place in the spring after or during dispersal to summer ranges; females lay a clutch of eggs in a sheltered site in the summer (late June – July); the eggs hatch in the autumn (September – October); the snakes return to hibernation sites between late summer – late autumn, with males usually returning before females, and juveniles returning last. Unlike other snakes (such as the Western Rattlesnake) individual Gopher Snakes appear to spend little time around den sites both after emergence in the spring and before hibernation in the autumn (M. Sarell, pers. comm.). In Utah, the time individuals spent around den sites in the spring was variable ranging from a few days to weeks; in the autumn, the arrival times at den sites were staggered, but individuals appeared to enter the den soon after arrival (Parker and Brown 1980).

The life history of the Great Basin Gopher Snake is characterized by delayed maturity and relatively low fecundity when compared to smaller colubrid snakes (reviewed in Shewchuk 1996). These life history characteristics are often associated with unpredictable or harsh environments that favour the survival of adults over young. Survival rates of young over their first season of hibernation can be low (29% compared to 89% for adults in Utah; Parker and Brown 1980). Longevity of adults enables the population to withstand periods of unfavorable conditions for reproduction and poor recruitment of young that may occur in some years.

Many features of the life history and ecology of the Great Basin Gopher Snake in the southern Okanagan, in terms of timing of seasonal activities and reproduction, are similar to populations farther south (in Idaho and Utah), but several differences attributed to local conditions occur (Shewchuk 1996). Both the mean body size of adults at sexual maturity (females 695 mm in SVL; males 745 mm in SVL) and clutch size (mean = 4.6 eggs; range 2 – 8 eggs) were relatively small in the Okanagan population when compared to more southern populations, and females appeared to reproduce biennially or less frequently rather than annually. Clutch size in this species shows a positive correlation with the body size of females, and small clutch size in the Okanagan reflects the relatively small body size of gravid females. Apart from individuals in their first year of life, body size is an unreliable predictor of age, as the body sizes of different year classes overlap greatly. Consequently, age at sexual maturity in British Columbia populations is poorly known; females are unlikely to mature before the age of three years and may not reproduce until 5 years of age (Waye and Shewchuk 2002, M. Sarell, pers. comm. cited in above). The sex ratio of adults usually approximates 1:1, but males are often encountered more frequently than females due to differences in behaviour and activity between the sexes (Waye and Shewchuk 2002 and references therein).

3.2 Habitat use and movements

In British Columbia, the Great Basin Gopher Snake occurs in grasslands, shrub steppe, and dry open forest habitats within the Bunch Grass, Interior Douglas Fir, and Ponderosa Pine biogeoclimatic zones (Cannings et al. 1999). These ecosystems are largely maintained by wildfires, and human activities have changed both the frequency and intensity of fire events through fire suppression and other activities over the past century, in addition to direct modification of landscapes (Canadian Forest Service 2003).

The Great Basin Gopher Snake requires different habitats for its seasonal activities (hibernation, foraging, and egg-laying), and these habitats are usually spatially separated. The requirement by individual snakes for relatively large amounts of space across different habitats poses a challenge for the conservation and management of populations in human-modified and fragmented landscapes. This species shows a relatively weak association with rock habitats and has generalized habitat requirements when compared to the sympatric Western Rattlesnake (reflected in a relative wide niche breadth for habitat; Diller and Wallace 1996). As a result, habitats are more difficult to identify and protect.

Hibernation habitats:

In British Columbia, hibernacula (also referred to as dens) of the Great Basin Gopher Snake are in fissures in rock, in talus slopes, or sometimes in earthen burrows (Waye and Shewchuk 2002, Bertram et al. 2001, Bertram 2003, Sarell et al. 2003 and references therein). Dens must be sufficiently deep to allow snakes to escape subfreezing conditions and to prevent overheating on warm winter days (Cannings et al. 1999). Suitable moisture conditions are also presumed to be important (sufficient humidity to prevent dehydration). The Gopher Snake often hibernates communally, either with conspecific individuals or other species of snakes, suggesting that suitable den sites are in short supply (Waye and Shewchuk 2002). However, one study in the Thompson-Nicola region found no evidence of communal hibernation by this species (Bertram et al. 2001). Storm and Leonard (1995) noted that Gopher Snakes are seldom found aggregated in large numbers at den sites as some other snakes, such as the Western Rattlesnake.

Young snakes may hibernate with adults or separately; nest sites may be too far from dens for young snakes to locate them during their first year of life (Parker and Brown 1980). Shewchuk (1996) observed that nest sites where young emerged in the autumn were located long distances from known den sites within his study area. However, very little information exists on the denning habits of young snakes.

In the Okanagan, snake hibernacula are often above the valley bottom in rugged terrain (Waye and Shewchuk 2002). Most known sites are located in the southern Okanagan, but several sites are also known from the northern Okanagan (Sarell 1993). Some hibernacula have also been identified in the Kettle Valley (Sarell et al. 1998). In contrast, only a few hibernacula have been located within the range of the northern subpopulation. In the Thompson – Nicola region, Bertram et al. (2001) located three

hibernacula used by the Great Basin Gopher Snake, each in a different habitat: in the gravel bed of a railroad track, in a rodent burrow system on the slope of a small, dry gully, and in a cavity on a steep slope of a large gully containing a creek.

Although snakes spend little time near the hibernacula both in the autumn and in the spring, the availability of sufficient vegetation and refuge sites (such as rodent burrows, rocks, or coarse woody debris) in the immediate vicinity of the hibernacula may be important in providing protection to snakes from predation. Forest succession and associated shading of the hibernacula and basking sites, in contrast, is thought to be detrimental (Waye and Shewchuk 2002).

Summer foraging habitat and diet:

In the spring, the snakes move from hibernation sites to summer foraging areas in open grasslands, meadows, and riparian areas, where they feed on mammalian prey, mostly rodents (Bertram 2003). Rodriguez-Robles (2002) reviewed the diet of the Gopher Snake in different portions of the species' range by examining stomach contents of a large number of museum specimens and records from literature. In all broad areas of the species' range, the prey consisted mostly of small mammals (3 of every 4 prey items were mammals); both adult and young snakes specialized on mammalian prey. The snakes consumed a wide variety of mammalian species. This diversity in feeding habits suggests that the snakes are opportunistic and able to switch to alternative prey if one prey species becomes scarce. The diet also included birds, bird eggs, and lizards, but in lower frequencies of occurrence; only larger individuals fed on birds. Nestling mammals and birds were more frequently consumed than were adults. In the Okanagan, most prey items were rodents (Shewchuk 1996).

The Gopher Snake can use a variety of open habitats for foraging, including human-modified areas, such as agricultural fields, where the snakes actively search for prey (Storm and Leonard 1995). The quality of summer foraging habitats presumably depends on the availability of prey, suitable thermal conditions, and shelter (Bertram 2003). Shelter sites provide both cover from predators and thermal buffering from ambient conditions. The proximity of the foraging area to other habitat features (such as oviposition sites for females) may also be important. In the southern Okanagan, radio-tagged snakes used both sand and riparian habitats for foraging, often sheltering in rodent burrows in the sandy area from where they undertook foraging forays into the riparian habitat (Shewchuk 1996). Shelter sites were often located near the top of south-facing hills, where exposed rodent burrows were most commonly found. Shewchuk (1996) speculated that elevated areas were selected because they received most exposure to direct sun. The burrow system allowed snakes to locate optimal thermal conditions underground.

In the Thompson-Nicola region, foraging areas of three snakes followed by telemetry included riparian areas or dry gullies within grassland habitats (Bertram et al. 2001). Shelters and microhabitats used by these three snakes included rodent burrows, rock features (natural and artificial), wood (such as downed trees, tree debris, dead sagebrush, and woody weeds), and various pieces of rubble from human activities,

especially near residential areas (concrete, metal, boards). Rodent burrows were the most commonly used shelter type.

Egg-laying habitats:

Egg-laying sites of the Great Basin Gopher Snake are in rodent burrows or in other sheltered sites in talus, in deep fissures in rock, or under decaying wood (reviewed in Wayne and Shewchuk 2002). Relatively open areas with exposure to the sun and lacking perennial vegetation seem to be selected. The thermal and hydric environment in the egg-laying sites is critical for the development of the embryos (Gutze and Packard 1987). In laboratory experiments with specimens from Nebraska, incubation temperatures within relatively narrow limits resulted in optimal hatching success and development of embryos, whereas moisture content of the substrate affected hatchling size and water balance; both moisture and temperature affected incubation period (Gutze and Packard 1987). In British Columbia, egg-laying sites have been found on sparsely vegetated slopes with a southern exposure and loose sandy substrates (Shewchuk 1996, Bertram et al. 2001). Rodent burrows seem to be important for this function and may be modified and enlarged by the female (Shewchuk 1996).

Loose sandy soils may be an important component of egg laying sites of this species. Egg-laying sites with loose sandy soils are selected by the Pine Snake (*Pituophis melanoleucus melanoleucus*) in New Jersey (Burger and Zappalorti 1991). These snakes dig into the loose soil to reach moist areas just below the surface. In the Okanagan, Shewchuk (1996) observed a gravid female Gopher Snake excavate a rodent burrow prior to laying eggs and speculated that snakes frequently create nesting and shelter sites by digging out and enlarging rodent burrows located in soft sandy soil. In Utah, three clutches of the Gopher Snake were located in rodent burrows in exposed grass areas (Parker and Brown 1980). One of the sites contained clutches of several females. The opening of the burrows ranged from 9 – 10 cm high and 12 – 17 cm wide, and eggs were found 34 – 43 cm below the surface within the burrows. In Oregon, a communal egg-laying site found by Brodie et al. (1969) was on an exposed, grass-covered stable talus slope with a southern aspect. Microsites with Gopher Snake eggs consisted of moist cavities within the talus; one nest was in a rodent burrow, 30.5 cm (12") below the surface.

In the southern Okanagan, females sometimes travel long distances to egg-laying sites from their summer foraging areas (Shewchuck 1996). Shewchuk (1996) located a communal egg-laying site in a rodent burrow system that was used for egg-laying by probably two female Gopher Snakes and 5 – 9 female Racers. Multiple clutches in the same location may allow eggs to remain moist and increase their chances of hatching (Shewchuk 1996). Communal nesting has also been reported for the species farther south. Brodie et al. (1969) reported on an egg-laying aggregation by several species of reptiles on a talus slope in Oregon. This site contained 112 eggs and 44 hatchlings of the Gopher Snake. Communal nesting and long movements of females to egg-laying sites suggest that habitat requirements for nesting are specific and that suitable sites may be in short supply.

Migration movements and home ranges:

In the spring and autumn, the Great Basin Gopher Snake undertakes relatively long migration movements between hibernation sites and summer foraging areas, which are often spatially separated. In southern Okanagan, the average one-way distance of nine migration movements by three individual snakes was about 0.9 km (SD = 185 m; Shewchuk 1996). The movements were rapid (completed within 1 or 2 days) and highly directional. These distances are longer than reported for the species in western United States (Utah: mean distance 0.5 km; Parker and Brown 1980) and in the Thompson – Nicola region of British Columbia (0.28 to 0.52 km for three snakes; Bertram et al. 2001). The differences may be due to local conditions and habitat availability (cliffs with hibernacula and floodplain/irrigated foraging areas in Shewchuk's study were widely separated), or simply be an artifact of small sample sizes.

In summer foraging habitats, individual snakes undertake numerous shorter movements, often returning to specific retreat sites used as a base (Waye and Shewchuk 2002). In the southern Okanagan gravid females undertook long, additional movements (several hundred metres) to egg-laying sites, often located outside centers of activity for particular individuals in summer foraging habitats (Shewchuk 1996). Summer home ranges, using the minimum polygon method, have been calculated for snakes from the southern Okanagan and Thompson – Nicola regions from telemetry locations of a small number of individual snakes. There was considerable individual variation in both studies. In the southern Okanagan, the mean home range size of females was 13.9 ha and that of males 5.3 ha (the values were not statistically different; Shewchuk 1996). In the Thompson – Nicola region, home range sizes of three individuals were 9.9 ha (non-reproductive female), 5.7 (male), and 12.5 ha (gravid female), respectively. Summer home ranges in British Columbia appear to be larger than those farther south (1 – 3 ha in Utah: Parker and Brown 1980; 95% home ranges 0.89 – 1.78 ha in California: Rodríguez-Robles 2003).

Within these large home ranges, the snakes use the habitat unevenly; there may be several centers of activity, which may shift over the summer (Waye and Shewchuk 2002). In California, movements of radio-tracked males were concentrated in several disjunct activity areas or "habitat islands" (Rodríguez-Robles 2003). The size of core areas for individual snakes (defined as the area with 50% of observations) was 0.1 – 0.29 ha, representing a fraction of the overall home range size.

Individual Gopher Snakes show fidelity to particular hibernation sites, egg-laying sites, and foraging areas (Parker and Brown 1980, Shewchuk 1996). However, fidelity to particular sites appears to be less strong than in the Western Rattlesnake, and individuals may use alternative hibernation sites (Parker and Brown 1980). In addition, individual snakes within foraging areas in southern Okanagan used particular retreat and basking sites repeatedly over the summer and over consecutive years (Shewchuk 1996).

3.3 Threats and limiting factors

The main threat for populations of the Great Basin Gopher Snake in British Columbia is from habitat loss, alteration, and fragmentation resulting from various human land uses and activities (Waye and Shewchuk 2002, Bertram 2003, Sarell et al. 2003). The geographic range of the species in the province is restricted to arid interior valleys, which are heavily modified and contain a relatively dense human population. A second threat is from direct mortality. Individual snakes traverse long distances during seasonal movements and are subject to road kill and mortality from predators. The snakes are also subject to persecution by humans who may mistakenly view these non-venomous animals as a threat. Although the snakes can tolerate some degree of habitat modification and can even benefit from increased prey base in agricultural fields, for example, these benefits are readily offset by mortality resulting from road kill and increased human encounters.

The following threats or disturbance factors have been identified (based on Waye and Shewchuk 2002, Bertram 2003, Sarell et al. 2003). Various combinations of these factors operate within WHAs and in the surrounding areas. We refer to these factors as stressors (*sensu* Noon 2003), reflecting their potentially adverse effects on populations of the Great Basin Gopher Snake. We qualitatively assessed the spatial and temporal nature of the impact of each stressor, below (widespread versus regional or local; chronic versus episodic or ephemeral) and the potential importance of each stressor to snake populations (unlikely, speculative, possible, probable). The consequences of these stressors to habitats and populations of the Great Basin Gopher Snake are summarized in Table 1.

Natural stressors:

- Climate (impacts widespread, chronic, and probable; constrain range expansion, habitat use patterns, and life history parameters)
- Vegetation succession, which contributes to forest encroachment into parkland and grassland habitats and compromises the open nature of habitats required by the Gopher Snake (impacts widespread but most prevalent in the northern part of the species' Canadian range, chronic, and probable)
- Wildfire (impacts local, episodic, and possible, depending on fire intensity; direct mortality and reduced prey availability possible following catastrophic intense fires; effects of regular, lower intensity fires are beneficial for snake habitats in fire-maintained ecosystems)
- Fluctuations in prey base (impacts widespread, chronic, and speculative or unlikely due to opportunistic feeding habits of the snakes)
- Predation by natural predators, such as skunks, raptors, and coyotes (impacts widespread, chronic, and probable)

Human-induced stressors:

- Agriculture (impacts widespread, chronic, and probable; loss and fragmentation of habitats; increased contact with humans and predators with possible increases in mortality; exposure to pesticides and other contaminants both directly and indirectly through ingestions of prey; haying, mowing, and vehicular traffic can result in direct mortality)
- Urban development (impacts local, chronic, and probable; loss and fragmentation of habitats; increased contact with humans and pets)
- Ranching (impacts widespread, chronic, and probable depending on intensity; loss of vegetation cover in heavily grazed areas; soil compaction and trampling of egg-laying habitats possible; mortality during access road construction and from traffic on roads)
- Forestry (impacts widespread, chronic, and possible depending on intensity; habitat fragmentation, possible loss of critical habitats, and direct mortality from construction of access roads)
- Road construction and improvements associated with human population expansion and resource extraction (impacts local, chronic, and probable; mortality during road construction and from traffic on roads; extraction of talus/road construction can destroy critical denning habitats and result in direct mortality)
- Fire suppression (impacts widespread, chronic, and probable; enhances forest encroachment and compromises open nature of habitats in fire-maintained ecosystems; fuel accumulation increases the probability of high-intensity, catastrophic fires)
- Persecution associated with increased contacts with humans and misconceptions (impacts widespread, chronic, and probable)
- Recreational activities that alter/destroy key habitat features or increase contacts of the public with snakes (impacts local, episodic, and possible)
- Mining and talus extraction (impacts local, episodic, and probable)
- Pesticides (impacts widespread, chronic, and speculative)
- Increase in natural predators in human-modified landscapes (impacts widespread, chronic, and speculative)
- Predation by domestic dogs and cats on young snakes (impacts local, chronic, and probable)
- Global climate change (impacts widespread, chronic, and speculative)
- Interactions among different human-induced stressors or with natural disturbances, such as land use and management practices accentuating effects of droughts (impacts widespread, ranging from chronic to episodic and from probable to speculative and unpredictable)

3.4 Conservation issues associated with approved and proposed WHAs

There are presently (January 2004) six approved WHAs for snakes within the southern interior of British Columbia, all of which contain communal hibernacula, and about 20 other WHAs are proposed. Initial inventories and habitat assessments have been conducted at these sites (Hobbs 2001, Hobbs and Sarell 2001, 2002). The Gopher Snake is known from most of these sites, but many sites require further surveys to determine the presence of additional dens and species of snakes using them. In most cases, the area within the boundaries of the WHA is likely to be too small (95 – 245 ha) to support a viable snake population, and safe access to additional foraging, egg-laying, and denning habitat outside of the boundaries of the WHA is important. Access to areas outside the WHA is also important to maintain gene flow among subpopulations within the landscape. The boundaries of WHAs are governed by the availability of crown land (extent and configuration), concerns by other stakeholders about restricting their use of crown land, and the presence of existing roads and land conversions. For these reasons, it is important to consider threats to snakes within the immediate area adjacent to the WHA, as well as conditions within the WHA itself, in evaluating its effectiveness in maintaining snake populations in the area.

Threat factors operating within or adjacent to existing and proposed WHAs include all factors identified for the species within its range in the province (see Section 3.3). Snakes dispersing from the WHA or moving to seasonal habitats outside or within a WHA may be exposed to road mortality. In some cases, there are well-used roads nearby. Road kills of the Western Rattlesnake and Gopher Snake have been found near certain WHAs.

Most existing and proposed WHAs are located in areas with grazing permits issued by the Ministry of Forests; overgrazing by livestock has been noted in some cases. Intense grazing removes security cover, potentially exposing snakes to increased predation, and may reduce the quality of foraging areas. Measures to reduce grazing within WHAs consist of removing attractants, such as artificial water sources and salt licks, and relocating corrals and staging areas.

Irrigation practices can also be a threat to snakes. In one case, a concrete aquifer was located adjacent to a WHA and was considered to have high potential for mortality of snakes in the area. Snakes could easily become trapped and die in the cold rushing water.

Many existing and proposed WHAs are within mineral claims or areas of high mineral potential. Past mining activity is evident at some WHAs, and continued exploration is possible under certain conditions. Existing WHAs commonly include a variance stating that the WHA will be eliminated or boundaries changed to accommodate future mining activity. Mining and quarrying activity can cause direct mortality, damage denning and foraging habitats, and increase human use of the area through new access roads.

Some WHAs overlap areas used for recreation, and trails may be present. Recreational use increases the probability of human encounters with snakes and may result in

disturbance or killing of snakes. There is also potential for disturbance to dens and retreat sites from high-impact activities, such as rock-climbing or ATV use – although these activities are not permitted within WHA, illegal activities may be difficult to control.

Private land lies adjacent to most existing and proposed WHAs, especially in the Okanagan Valley, and constrains the boundary configuration of WHAs. In one case a residential development is planned adjacent to a proposed WHA, which would reduce the availability of grassland foraging habitat and increase the likelihood of conflicts with people and pets. Road mortality is also a concern in the vicinity of urban developments.

3.4 Overview of inventory, management, and monitoring methods

Population studies:

The provincial RISC (1998a) standards describe survey protocols for snakes at three levels of intensity (“present/not detected”, relative abundance, and absolute abundance). For the Gopher Snake, the recommended methods include hand collecting and road surveys at the “present/not detected” level, time-constrained surveys, trapping, and quadrat or transect surveys at the relative abundance level, and mark-recapture studies at the absolute abundance level. Surveys at the “present/not detected” level are the least biased and often provide the most valid and useful information (RISC 1998a). Relative abundance measures are subject to various biases resulting from secretive habits of snakes in general and variability in opportunities for visual detection depending on habitat features, time of the year, weather, varying detection abilities of the observers, and behaviour of different components of the snake population (age/size class, sex, and reproductive status all influence detection probability). Obtaining relative abundance measures for the Great Basin Gopher Snake is problematic because these snakes are relatively mobile and dispersed over a wide area over much of the active season; in addition, they extensively use underground retreats, such as rodent burrows, where they are invisible to observers (Shewchuk 1996, Bertram et al. 2001, Sarell 2003a). Even simply ascertaining the presence of this species at particular sites can be problematic, and repeated surveys may be required (Bertram et al. 2003).

Mark-recapture methods potentially provide much information about the population but are long-term (spanning over several years) and very labour-intensive; consequently, they should be undertaken only after careful planning where multi-year funding and long-term commitment to the project are possible. Snakes for mark-recapture studies are best located when naturally aggregated, such as at communal den sites where the investigator has access to a relatively large number of snakes over a short period in the spring and autumn (RISC 1998a). Data collected at den sites are not without biases, as certain segments of the population (such as gravid females) may be easier to find at this time and over-represented in the samples (RISC 1998a). Shewchuk (1996) conducted a mark-recapture study of the Great Basin Gopher Snake in the southern Okanagan based on captures at den sites. Although much useful information about the population was obtained, the recapture rates (17%, overall) were deemed too low for estimating population size. In the Thompson-Nicola region, the Gopher Snake appears to hibernate individually or in small groups (Bertram et al. 2001). Although long-term

monitoring of snakes around hibernacula was recommended for the Western Rattlesnake in that region, this method was deemed unsuitable for the Gopher Snake. Surveying for this species both at den sites and in the summer habitat appears to be much more difficult than surveying for the Western Rattlesnake, which tends to be more aggregated at den sites and more specialized in habitat requirements (Diller and Wallace 1996, Bertram et al. 2001). Despite these difficulties, monitoring population trends at Wildlife Habitat Areas through mark-recaptures at den sites is a useful tool, if strategically used at selected sites, particularly in the Okanagan where the snakes use communal hibernacula.

Sarell (2003a) evaluated inventory needs and methods for the Great Basin Gopher Snake in British Columbia and recommended three survey techniques: stratified ground searches (hand collecting), road surveys, and radio-telemetry. These methods were intended to apply either to “present/not detected” level inventories or as an aid to locate key habitat features (see next section on habitats, below).

Road surveys conducted on foot, bicycle, or motor vehicle can be useful for surveys of both live snakes (which are attracted to the warm surface of paved roads) and dead snakes resulting from road-kill (RISC 1998a). Rosen and Lowe (1994) estimated the density of road-kill snakes (# of road-kills/km of road/year) from road survey (referred to as “quantitative road-cruising”) data within and in the vicinity of a protected area in southern Arizona. A concurrent mark-recapture study of several species allowed the comparison of road mortality to population size. This method requires repeated surveys during different seasons and can be valuable in quantifying road mortality and identifying problems from this mortality source, even where no independent population estimates are available. If problem areas are detected, drift fencing can be used to direct snakes away from roads or to special road crossing structures (CARCNET 2003; Ovaska et al. 2003).

Habitat management and monitoring:

The presence of important habitat types and certain key habitat features required by snakes for their different seasonal or life history activities can be delineated from biophysical maps or air-photos but require field visits to confirm their estimated suitability. For example, to locate den sites, Sarell and Haney (1998) selected survey sites based on biogeoclimatic zone, slope, aspect, elevation, and terrain features, followed by a site visit and assessment. Habitat suitability models for the Gopher Snake have been prepared for three areas within the Okanagan and Similkameen valleys (*referenced in* Sarell et al. 2003). A similar approach could be used at a larger scale within WHAs. Because some habitat features important for snakes cannot be resolved from maps and air-photos, it is important that site visits are conducted to locate and assess suitability of hibernation sites and other habitat features.

The Great Basin Gopher Snake requires relatively open habitats, and the degree of openness (percentage of ground covered by trees or shrubs) can be quantified from air-photos or biophysical habitat mapping, and then confirmed through field surveys within WHAs. Where forest encroachment and vegetation succession threaten the open nature of habitats, management intervention (such as controlled burning or mechanical

removal of vegetation) may be required to maintain the ecosystems and snake populations that depend on them (Johnson and Leopold 1998, Rudolph et al. 1998, Kingsbury and Gibson 2002). Controlled burning, conducted during appropriate time of the year when snakes are inactive, is an effective tool for maintaining snake habitat in early successional stages (Kingsbury and Gibson 2002). Herbicides can also be effective (Johnson and Leopold 1998), but because their effects on both snakes and their prey are largely unknown, their use in snake habitats is not without risks. Detailed descriptions of ground cover and vegetation in key habitats within the WHA can be conducted using standard plot methods (RISC 2003). However, a simplified description of vegetation, focusing on vegetation structure, is likely to be more useful and cost-efficient than the collection of detailed information on plant species composition. Vegetation surveys could be carried out concomitantly or combined with surveys for shelter sites (see below). Disturbance to vegetation or terrain can also be recorded on similar plots (e.g., evidence of grazing/browsing, presence of trails).

Cover or shelter is the most important habitat feature for snakes, and characteristics of suitable shelter include both their structural and thermal properties (RISC 1998a). The Great Basin Gopher Snake uses various types of shelters (rock, wood, burrows) during the active season, but rodent burrows appear to be especially important for various uses, including egg-laying (Shewchuk 1996, Bertram et al. 2001). The relative abundance of potential shelters for snakes (rodent burrows, rocks of specified dimensions, and coarse woody debris) in different habitats or over time could be surveyed using counts and/or percentage ground covered by each class in plots or along transects, according to standard stratified sampling designs (Krebs 1987). Bertram et al. (2001) pointed out that the role of coarse woody debris in grassland ecosystems as habitat for snakes and other animals has received very little attention when compared to forest ecosystems. Detailed, standard methods are available for quantifying coarse woody debris in forests (RISC 2003). A simplified approach based on these methods (focusing on features important for snakes) could be used to quantify coarse woody debris in snake habitats.

The availability of cover is amenable to manipulation as a part of habitat management. To increase habitat suitability, cover-objects can be added to areas that are otherwise suitable for snakes or from where they have been artificially removed (Kingsbury and Gibson 2002). The abundance of downed wood may need to be retained at relatively low abundance where fire management requires reduced fuel levels. Surface cover-objects can be removed from residential developments to reduce the use of these areas by snakes and thus encounters with humans (Bertram et al. 2001, Ovaska et al. 2003). Gopher Snakes have been reported to use crevices in building foundations in summer habitat (Shewchuk 1996), probably due to suitable thermal (cool, moist) conditions at these sites.

Because there is always uncertainty in assessing habitat suitability, particularly for species such as the Gopher Snake that do not show strong associations with a specific habitat type, it is important to test assumptions through comparisons with actual habitat use by snakes. Radio-telemetry has proven to be a valuable tool for this purpose for many species of snakes (see RISC 1998a for procedures). For example, in conjunction

with quantified habitat descriptions, tracking movements of the Massasauga Rattlesnake (*Sistrurus catenatus catenatus*) has been used to examine the effects of various habitat manipulations, including controlled burning, on habitat quality (Johnson and Leopold 1998) and effects of recreational activities on the behaviour of snakes (Parent and Weatherhead 2000). Rudolph et al. (1998) examined habitat use and behaviour of radio-tagged Louisiana Pine Snakes (*Pituophis melanoleucus ruthveni*) during prescribed burning. The snakes avoided fires by retreating underground into rodent burrows and survived low intensity, slowly advancing backfires unharmed.

The large body size of adult Gopher Snakes can easily accommodate an implanted radio-transmitter unit, the weight of which should comprise less than 5% of the body mass of the animal (RISC 1998a). Tracking movements of radio-tagged Gopher Snakes has helped locate key habitat features (hibernacula and oviposition sites) and document movement routes within and between seasonal habitats (Shewchuk 1996, Bertram et al. 2001). Together with habitat assessment, telemetry is expected to be the most valuable tool for obtaining information on the desired condition of seasonal habitats within WHAs.

Public outreach programs:

Public outreach projects can provide valuable information on distribution trends of certain conspicuous species and on human encounters with wildlife. The accuracy of such data must be carefully monitored. Bertram et al. (2001) concluded that public outreach through various means (pamphlets, one-on-one contacts, media coverage) was time-consuming and resulted in little useful data in terms of reliable distribution records for the Great Basin Gopher Snake in the Thompson-Nicola region. Incorrect identification, especially frequent confusion with the Western Terrestrial Garter Snake (*Thamnophis elegans*), made data obtained from the public unreliable. In contrast, on the Gulf Islands, one-on-one contacts with landowners at sites occupied by the Sharp-tailed Snake (*Contia tenuis*) have proven invaluable in protecting and restoring habitat for this endangered species (Engelstoft and Ovaska 2004). Similarly, close contacts with landowners in the vicinity of snake WHAs in the southern interior of the province can be valuable, especially where foraging areas or other important seasonal habitats of the snakes extend outside the boundaries of the WHA on private lands.

4.0 METHODS TO ASSESS EFFECTIVENESS OF WHAs

4.1 Approach

The key components of an ecological monitoring program include clearly stating the goals, developing a conceptual model linking relevant ecosystem components and stressors/disturbances, selection of suitable indicators to monitor, estimating their status and trend, determining values that trigger a management response, and linking monitoring results to management (Noon 2003). The selection of suitable indicators is a critical step in the above process and is especially challenging for ecological systems that are incompletely characterized, or where the system's responses to various disturbances and stressors are poorly known. While cost-efficient indicators are often structure-based, such as vegetation or terrain parameters, or characteristics of the

stressors/disturbances themselves, it is also important to incorporate population parameters in a set of indicators. Documenting and assessing population trends will guard against erroneous conclusions resulting from inappropriate selection of proxy indications (due to lack of accurate information on linkages and population responses), and from threats or responses that could not be anticipated. However, because population responses to a stressor may be delayed and are often difficult to detect promptly due to environmental “noise”, it may be difficult, if not impossible, to slow-down a population decline or reverse the trend by the time a problem is detected. Proxy indicators, on the other hand, if accurate, have the advantage of providing an early warning system, so that impending ecological problems can be addressed and potentially mitigated.

The approach used here for selecting indicators is based primarily on methods outlined in Noon (2003). The procedure consists of the following steps: (1) listing and characterizing anticipated stressors and disturbances; (2) listing ecological processes and resources affected by the above; (3) ordinal ranking of stressors/disturbances according to their expected impact; (4) developing conceptual models of the ecological system, including pathways and linkages between stressors and system components; (5) identifying candidate indicators based on the conceptual model; (6) screening of candidate indicators and selecting a set of indicators deemed optimal; and (7) establishing critical decision values for selected indicators.

4.2 Key monitoring questions

The goal of creating Wildlife Habitat Areas for the Great Basin Gopher Snake is to “maintain and link denning and foraging habitat, travel corridors, and egg-laying sites within and between adjacent populations” (p. 169, Bertram 2003). This goal emphasizes connectivity at two spatial scales, between seasonal habitats within a WHA and its immediate vicinity and with populations outside the WHA. Therefore, to be effective, WHAs are expected to contribute to conservation of both local and regional populations. The latter objective can be achieved through a network of WHAs at strategic locations and preserving connectivity of habitats outside the WHAs. Suitable indicators need to reflect connectivity at these spatial scales.

The following monitoring goals, stated in the form of questions, address the effectiveness of WHAs for the Great Basin Gopher Snake:

1. Does the WHA provide all key habitat features to meet the life history requirements of the species?
2. Are the above features receiving use by snakes?
3. Are secure travel routes available between important habitats (such as egg-laying, denning, and foraging areas) within the WHA?
4. Are secure travel routes available for dispersal of snakes to and from the WHA?
5. Does the WHA act as a mortality sink for snakes (now or in foreseeable future) and can mortality be reduced? Mortality sink is defined here as a habitat that is

attractive for snakes but where the population is maintained through immigration or where it is declining due to excessive mortality. Although areas where the probability of mortality is high are not selected as WHAs, incomplete knowledge of threats and mortality factors at the time of the selection process may inadvertently have led to the inclusion of such areas. Furthermore, threats and the role of the designated areas might change over time.

6. What is the population status and trend (stable, declining, or increasing) compared to other populations within the region, and is the population using the WHA considered to be viable over the long-term?
7. Is habitat connectivity and gene flow within regional populations maintained?
8. Do the WHAs and general measures contribute to maintaining regional snake populations?

4.3 Conceptual model and linkages

As an aid to selecting indicators for effectiveness monitoring programs, we prepared a conceptual model on the effects of various stressors on populations of the Great Basin Gopher Snake (Figures 2 and 3). This general model was broken down further to show pathways through which particular stressors identified in Section 3.3 (“Threats and limiting factors”) could affect habitat attributes and population processes of snakes (Table 1). Based on these pathways, we then listed a variety of candidate indicators for each potential effect (Noon 2003). The candidate indicators were divided into population- and habitat-based indicators, following a similar analysis by Maxcy (2003) for the Tailed Frog.

Candidate indicators are considered at two main spatial scales, at the regional (metapopulation) level and at the local (population) level. The regional level is intended to correspond to broad-scale population processes, such as metapopulation dynamics, that operate at scales much larger than the WHAs. A suitable spatial scale for measuring indicators at this level might be the range of each of the four regional subpopulations identified for the Great Basin Gopher Snake in British Columbia (see Section 3.1 “Distribution and life history”). Other broad scales (for example corresponding to management or ecological units) could also be used. This level provides a context for the management of populations within individual WHAs. The local scale is intended to correspond to the WHA itself and the area immediately surrounding the WHA. Because individual WHAs are unlikely to be large enough to support a viable snake population, it is important that areas used by snakes in their immediate vicinity will also be included (see Section 4.4, page 17, for a definition of this area).

Figure 2. Gopher Snake: Large Scale (Regional) Stressors

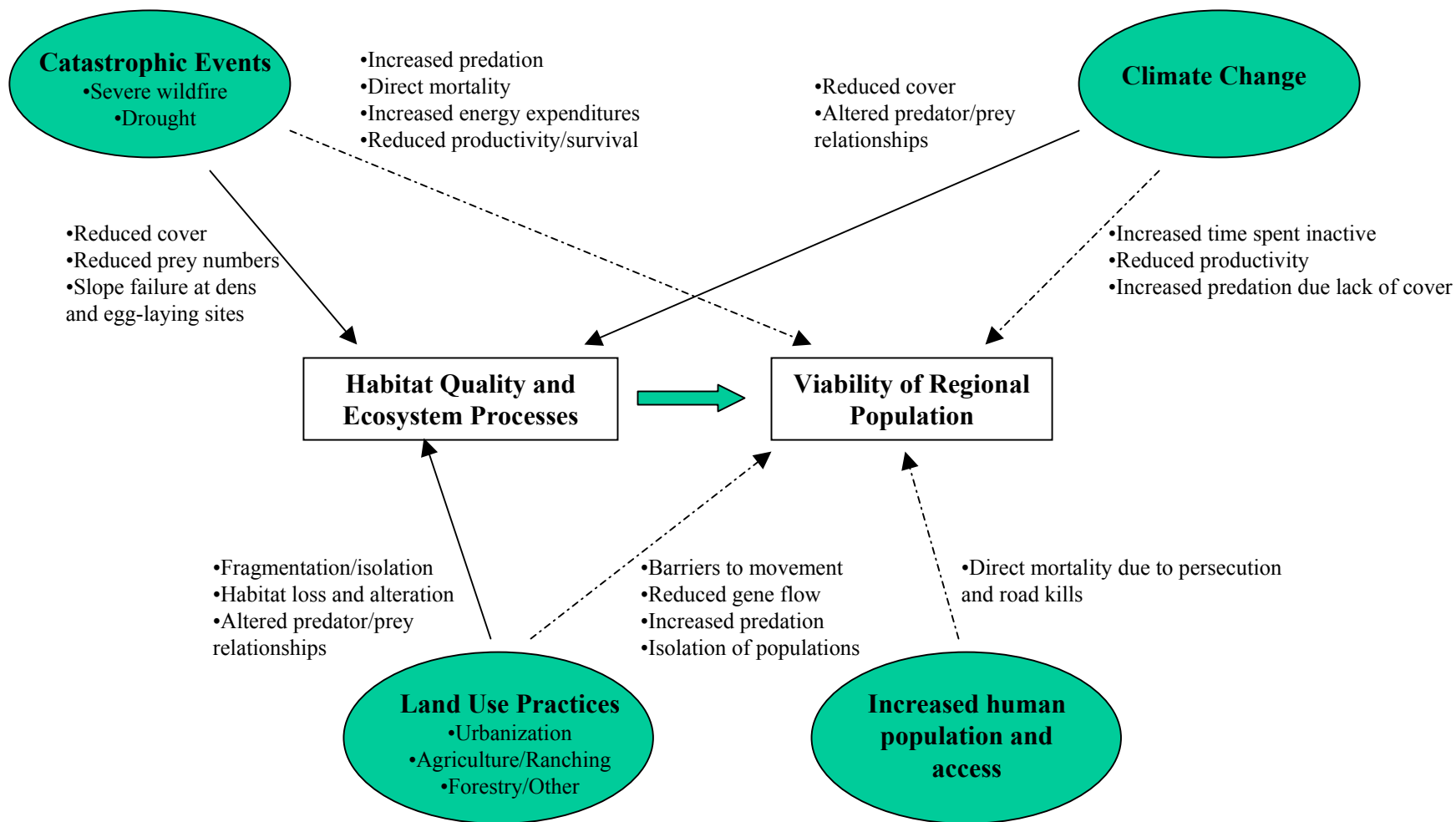
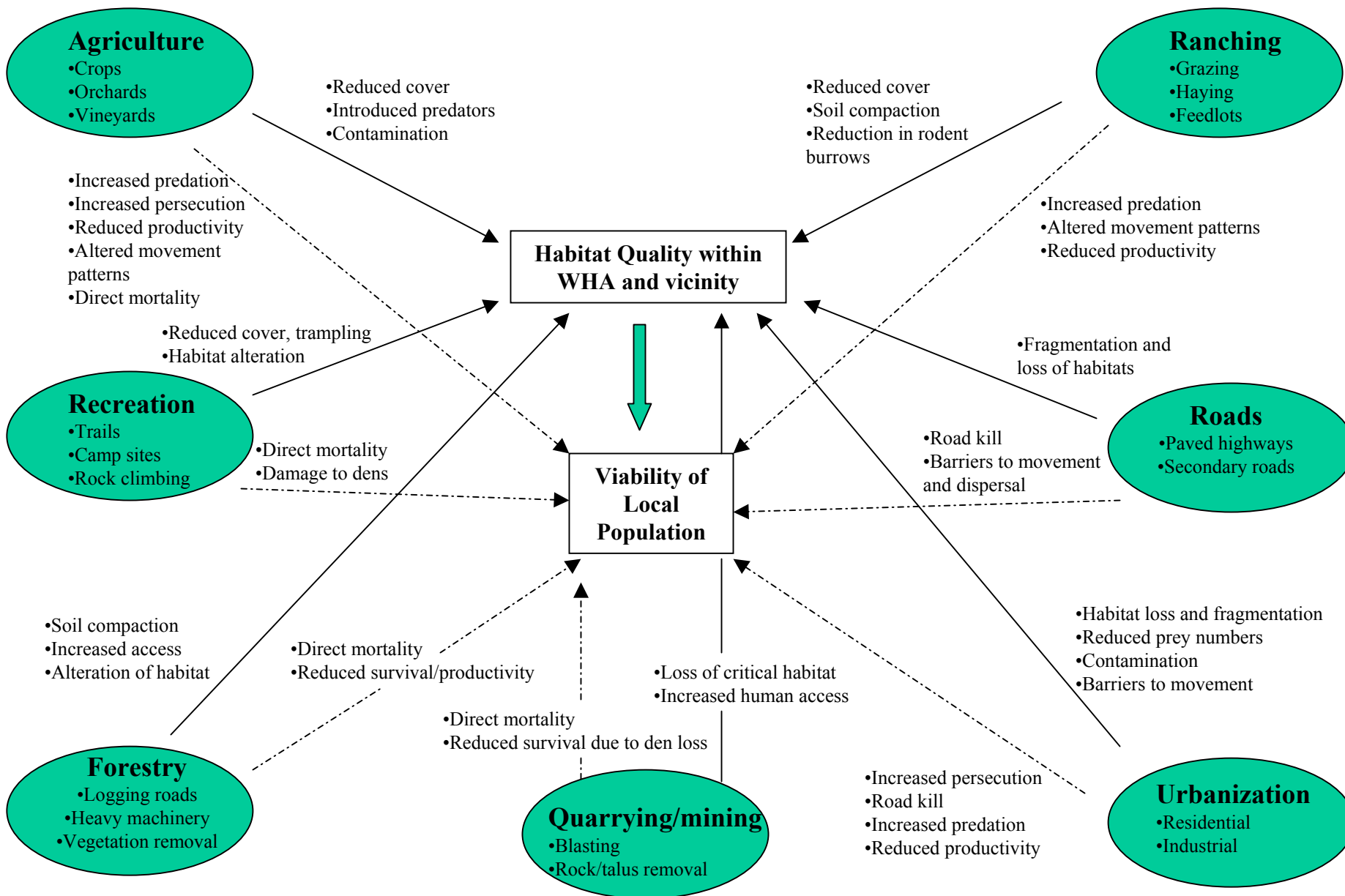


Figure 3. Gopher Snake: Landscape Scale (Local) Stressors



4.4 Screening process and selected indicators

The screening of candidate indicators is an important step in the design of an ecological monitoring program, and “the ultimate success or failure of the program may be determined by this one step” (Noon 2003, p. 43). We based the selection criteria on practicality and perceived relevance of each indicator and selected indicators using the following principles:

- Can be measured accurately and precisely
- Cost-efficient to measure
- High information content
- Clear linkages to snake biology
- Responds to a confirmed or highly likely stressor for snake populations

We selected 5 indicators at the regional level and 12 at the local level (Table 2). They were classified as threat, habitat, or population indicators, and are described in more detail in Section 4.5 (“Description of recommended indicators”). The intensity of evaluation (routine, intensive, or extensive) and perceived priority (low, moderate, high) were assessed for each indicator. The ratings for the intensity of evaluation follow the rankings developed by Forest and Range Practices Act Resource Evaluation Program (FREP 2004) and range from relatively low effort, low cost evaluations to more rigorous, cost- or labour-intensive evaluations. Population parameters are often difficult to measure with accuracy and may violate the criterion of cost-effectiveness. However, some population indicators were included, as it is important to link a measure of a population response to threat and habitat indicators.

The spatial scales for the screened indicators correspond to the two main scales described for candidate indicators (see Section 4.3 “Conceptual models and linkages”, above). The spatial scale at the local level is further subdivided into indicators that are measured within the entire WHA or within portions of it, and indicators that are measured within the immediate surrounding area. A radius of 2 km centered on hibernation sites within the WHA might provide an appropriate scale for measuring indicators outside the WHA, based on straight-line seasonal migration distances recorded for individual Gopher Snakes in British Columbia (Shewchuk 1996, Bertram et al. 2001). However, habitat evaluation may indicate that an adjustment to this area is needed for specific WHAs, depending on habitat configuration.

Candidate indicators from Table 1 that were not considered further and were eliminated from the selection process included the following (rationale in parentheses):

- Prey abundance (varies widely in space and time; the Gopher Snake consumes a wide range of mammalian prey and is able to switch to alternative prey)
- Predator abundance and predation rates (a wide range potential predators; predation rates impractical or difficult to measure)
- Contaminant levels in shed skins or tissues of snakes (no evidence that habitat or prey contamination is a problem for this species)

- Questionnaires to the public on snake encounters and their outcome (incorrect identification is a major problem)
- Temperature and precipitation patterns (clear linkages to snake biology are difficult establish at appropriate scales; mobility and behavioural thermoregulatory ability of snakes and microsite selection can greatly modify ambient regimes; long time series needed)

4.5 Description of recommended indicators

A. Regional scale

The following regional indicators were selected at the regional scale (range of each of the four regional subpopulations of the Great Basin Gopher Snake in BC or other broad scales corresponding to management or ecological units encompassing several WHAs):

- a) Road density
- b) % land base alienated
- c) Land ownership and protection level
- d) Den occupancy and regional index of abundance
- e) Spatial extent and severity of catastrophic fire events

a) Road density:

Rationale. – Road density provides an index of habitat fragmentation (EPA 2003), and roads contribute to direct mortality of snakes attracted to the warm asphalt surface or crossing roads that intersect their habitat (Rosen and Lowe 1994 and references therein). The Gopher Snake is vulnerable to road mortality because individual snakes use seasonal habitats that may be separated by long distances (see Section 3.2 “Habitat use and movements”). The snakes are especially vulnerable during migrations to and from hibernation sites in the autumn and spring, respectively, when a significant proportion of the population could be affected. In the Okanagan, Gopher snakes are known to travel from denning areas on rocky hillsides to riparian habitats within valley bottoms (Shewchuk 1996). Such movements may place snakes at risk of road mortality because major roads with high traffic volumes are preferentially built in valley bottoms due to the favourable terrain. Road mortality has been recorded for the Gopher Snake both in British Columbia (Nelson 1992, Shewchuk 1996, Bertram et al. 2001, Sarell unpubl. data) and in Alberta (Kissner and Nicholson 2003) and has been recognized as a potentially important source of mortality for this species and as a threat to populations in Canada (Waye and Shewchuk 2002).

Monitoring question(s) addressed (Question # in Section 4.2):

- Is habitat connectivity and gene flow within regional populations maintained? (#7)

Description and methods. – The methods consist of calculating the length of different types of roads within specified spatial units (such as the area occupied by each of four geographic subpopulations of the Great Basin Gopher Snake in the province or smaller

management units) using GIS methods. The densities of three types of roads are considered: primary paved roads (high traffic volumes), secondary paved roads, and unpaved access roads. Paved roads are of more concern as a source of mortality for snakes than are gravel roads, because snakes are often attracted to the warm surface (Rosen and Lowe 1994). A five-year frequency of measurement is suggested. For a finer resolution and road densities in relation to location of hibernacula, see corresponding indicator “a” under local level.

Practical considerations. – The level of effort is considered routine, as the measurements can be performed relatively easily using existing, readily available information.

Action criteria. –No specific threshold values can be set *a priori*. Rather, the trend in this measure over time will indicate how rapidly habitat is becoming fragmented. The status and trend in road density among the spatial units examined can be used to direct conservation efforts (such as establishment of additional WHAs) to those regions that are changing most rapidly, and to the initiation or expansion of snake population monitoring programs in these areas.

b) % land base alienated:

Rationale. –The geographic range of the species in the province is restricted to arid interior valleys, which are heavily modified and contain a relatively dense human population. Habitat loss, alteration, and fragmentation due to human land use conversions and activities are recognized as the main threat to the populations in British Columbia (Waye and Shewchuk 2002, Bertram 2003, Sarell et al. 2003).

Monitoring question(s) addressed (Question # in Section 4.2):

- Is habitat connectivity and gene flow within regional populations maintained? (#7)

Description and methods. – The percentage of the land base converted to different uses will be calculated within specified spatial units (such as the area occupied by each of the four geographic subpopulations or smaller management units) using GIS methods. Where information is available, the broad categories considered are (a) urban development, (b) agriculture, (c) ranching, (d) forestry, and (e) mining. Where information is available, each category can be further partitioned (such as residential versus industrial developments, type of agriculture). This subdivision is important as some types developments within a category result in more intensive use of the land than do others. A five-year frequency of measurement is suggested.

Practical considerations. – The level of effort is considered routine, as it can be performed relatively easily using existing, readily available information.

Action criteria. – No specific threshold values can be set *a priori*. Rather, the trend in this measure over time will indicate how rapidly habitat is becoming lost and fragmented. The status and trend in land conversion among the spatial units examined can be used to direct conservation effort (such as establishment of additional WHAs) to

those areas that are changing most rapidly. However, even a smaller rate of habitat loss in areas that are already heavily developed can be of concern.

c) Land ownership and protection level:

Rationale. – Information on the ownership of lands within the range of the species is required to help in determining conservation options and strategies for particular regions. As habitats continue to be lost and fragmented, protected areas (of which WHAs form one component) increase in importance.

Monitoring question(s) addressed (Question # in Section 4.2):

- Is habitat connectivity and gene flow within regional populations maintained? (#7)

Description and methods. – The percentage and spatial configuration of lands under private and public (federal, provincial, regional) ownership will be calculated within the area occupied by each of the four geographic subpopulations of the Great Basin Gopher Snake in the province using GIS methods. Similarly, the percentage of protected areas will be measured and their locations mapped. This process has already been started (Sarell 2003a), and subsequent updates can build on the existing work. A five-year frequency of measurement is suggested.

Practical considerations. – The evaluation level is considered routine, as the tasks can be performed relatively easily using existing, readily available information.

Action criteria. – The status and trend in land ownership and protected areas can be used to direct conservation efforts (such as establishment of additional WHAs where opportunities arise or the need is greatest). The establishment of additional protected areas is especially important where other regional indicators (road density, % land base alienated) denote a rapid loss and fragmentation of habitats.

d) Den occupancy and regional index of abundance:

Rationale. – Because of uncertainties inherently associated with proxy indicators, they need to be linked with direct measures of snake populations. For the Great Basin Gopher Snake, there are many such uncertainties, resulting from both paucity of available information on details of habitat requirements and characteristics of snake populations, including demographic patterns and population responses to various disturbances (see Section 6.0 “Data gaps and challenges”). Ultimately, population and distribution trends of the Great Basin Gopher Snake within different regions are the most reliable measure of whether conservation goals have been achieved.

Monitoring question(s) addressed (Question # in Section 4.2):

- What is the population status and trend (stable, declining, or increasing) compared to other populations within the region, and is the population using the WHA considered to be viable over the long-term? (#6)
- Do the WHAs and general measures contribute to maintaining regional snake populations? (#8)

Description and methods. – The first level, recommended for all WHAs, consists of surveys at the “present/not detected” level in the vicinity of den sites in the spring (the best time for detecting this species) and is intended to confirm continued use of the sites by these snakes (see indicator “f” at the local scale). Several sites within the area occupied by each geographic subpopulation (or smaller management unit) will be surveyed, and the percentage of sites occupied will be calculated. Repeated visits within the spring sampling period are recommended to confirm occupancy. This is particularly important especially in areas where the snakes occur at relatively low densities or are especially difficult to detect (Bertram et al. 2001). Once use is initially established, the recommended frequency for confirming occupancy at individual sites is 3 years.

A subset of the WHAs will be selected for intensive studies, intended to obtain an index of abundance through mark-recapture studies using standard methods (RISC 1998a). These studies are best conducted where communal use of hibernacula by this species is confirmed. Sampling is to be conducted in the vicinity of hibernacula, augmented with surveys (road-cruising or trapping) within foraging areas in the spring when snakes are most easily detected (Shewchuk 1996; see indicator “g” at the local scale). Traps together with drift fences can be effective in capturing this species (Rudolph et al. 1999).

Ideally, several sites within the range of each subpopulation will be selected, but this may not be feasible within the range of the northern subpopulation where these snakes may hibernate individually or in small groups (Bertram et al. 2001). The recommended frequency of sampling is each spring, initially, but less frequent sampling may be possible subsequently, based on modeling results from initial data.

Practical considerations. – This indicator is relatively difficult to measure and requires fieldwork by qualified professionals or advanced students. To confirm den occupancy multiple visits in spring are needed; trapping together with drift fencing can be considered to enhance detection success, especially if the number of WHAs to be surveyed is relatively small. The level of effort is rated as extensive for den occupancy surveys and intensive for mark-recapture studies. Intensive studies may be difficult to conduct in all regions and may have to be confined to WHAs within the stronghold of the species’ range in the province in the Okanagan area (Sarell 1993).

Action criteria. – Communal snake hibernacula are often used traditionally, year after year (reviewed in Waye and Shewchuk 2002), and any change in occupancy rates is a cause for concern; when statistically significant changes are detected, opportunities for conservation may already have been missed. Declines in occupancy rates that occur at more than one location within a region are to be viewed with concern and attempts should be made to determine the causes of declines, both locally and regionally. Similarly, persistent declines in abundance at more than one site per region should be viewed with concern. The first step is to examine obvious, correlated changes in habitat indicators. Declines that cannot be correlated with local factors are of particular concern. Examples of potential action include increasing size of particular WHAs,

increasing the number of protected areas within a region, or initiation of intensive studies at particular sites to elucidate causes of declines.

e) Spatial extent and severity of catastrophic fire events:

Rationale. – Whereas low intensity fires maintain habitat for snakes that depend on earlier vegetation successional stages, high intensity fires are thought to be detrimental and can result in mortality of snakes (Johnson and Leopold 1998, Rudolph et al. 1998, Smith et al. 2001). Catastrophic fires (high intensity, high spatial extent) usually result from many causes, both proximal and ultimate, which include high fuel load accumulation resulting from fire suppression policies, droughts, and inadvertent or intentional initiation by humans or by natural causes. Catastrophic fire events are predicted to increase in frequency in the future with more arid conditions associated with global climate change (Gates 1993).

Monitoring question(s) addressed (Question # in Section 4.2):

- Is habitat connectivity and gene flow within regional populations maintained? (#7)

Description and methods. – Spatial extent and severity of habitat destruction caused by fires will be determined using GIS methods for different portions of the species range in the province (the area occupied by each of five geographic subpopulations or smaller management units). The percentage of protected areas, including WHAs, affected by fires of different intensity will also be calculated. A measurement interval of 3 – 5 years is recommended; additional measurements may be required after particularly severe fire seasons.

Practical considerations. – The evaluation level is considered routine, as the tasks can be performed relatively easily using available information. Some uncertainty may exist in assessing whether a fire was severe enough to damage snake habitat and the length of time required for habitat to recover (age of burn).

Action criteria. – Further investigation is required in regions where high intensity fires cover a large proportion of protected areas or where the snake WHAs themselves are affected. Action may consist of vegetation surveys at the local level, confirming occupancy of den sites by snakes during the autumn and spring season following the fire, or documenting population parameters at mark-recapture sites.

B. Local scale

The following indicators were selected at the local scale (WHA and its immediate surroundings; 2 km radius centered on denning sites, or as determined from availability of seasonal habitats or actual habitat use patterns by snakes):

- a) Road density
- b) Road-kill mortality level
- c) Patterns of land use type and ownership, and level of protection
- d) Likelihood of major fire
- e) Movement and habitat use patterns from telemetry

- f) Occupancy of den sites
- g) Relative abundance of snakes at a WHA
- h) Reproductive and recruitment rates
- i) Condition of vegetation in key habitats
- j) Availability and quality of potential egg-laying and shelter sites
- k) Level of disturbance to key habitat features from recreation and other sources
- l) Level of mortality from human persecution

a) Road density:

Rationale. – The Great Basin Gopher Snake is vulnerable to mortality on roads that intersect their seasonal habitats or movement routes, and road mortality has been recognized as a threat to populations (Waye and Shewchuk 2002; see “Road density” under regional scale, above). Rudolph et al (1999) found that mortality associated with roads can severely depress populations of large snakes in Texas (rattlesnakes and pine snakes). Roads with moderate volumes of traffic (about 100 vehicles per day) were sufficient to cause this effect. Paved roads are located adjacent to several existing or proposed WHAs, and various access roads are present within the WHAs.

Monitoring question(s) addressed (Question # in Section 4.2):

- Are secure travel routes available between important habitats (such as egg-laying, denning, and foraging areas) within the WHA? (#3)
- Are secure travel routes available for dispersal of snakes to and from the WHA? (#4)

Description and methods. – The methods consist of calculating the length of different types of roads within varying spatial units centered on the hibernacula in the WHA, using GIS methods. Suggested spatial scales are 0.5 km, 1 km-, 2 km-, and 3 km-radius circular areas around hibernacula. The first three zones are expected to encompass migration movements of snakes between hibernacula and summer foraging ranges (Shewchuk 1996; see Section 3.2 “Habitat use and movements”). The finer scales will reveal the configuration of roads in relation to hibernacula; even one well-used road, if located in proximity to a hibernaculum or across a key migration route, can be a significant source of mortality. A 3 km-radius is expected to address dispersal movements of snakes in the vicinity of the WHA. As at the regional scale, the densities of three types of roads are considered: primary paved roads (high traffic volumes), secondary paved roads, and unpaved access roads. A five-year frequency of measurement is suggested.

Practical considerations. – The level of effort is considered routine, as it can be performed relatively easily using existing, readily available information.

Action criteria. – The presence of any paved roads within 1 km or 2 km zones around hibernacula may constitute an important source of mortality for snakes using the WHA. Where this condition applies, the required action should be further investigation, first through road-kill surveys (indicator “b”, below) to confirm the magnitude of the threat.

This action may need to be followed by telemetry surveys. The examination of the configuration of roads in relation to seasonal habitats of snakes (indicator “c”: Patterns of land use type and ownership, and level of protection) will help determine the urgency of follow-up actions. A high density of access roads within the 1 km or 2 km zones relative to other WHAs, or an increase in access road density over time, should also elicit action. This action may consist of road kill surveys. Vegetation and shelter site surveys may also be required, as habitat deterioration could occur as a result of increased public access or resource extraction.

b) Road-kill mortality level:

Rationale. – Road-kill surveys help in determining the impact of road mortality on the population using a particular WHA. These surveys also help in documenting specific localities of concern and in developing mitigation strategies.

Monitoring question(s) addressed (Question # in Section 4.2):

- Are secure travel routes available between important habitats (such as egg-laying, denning, and foraging areas) within the WHA? (#3)
- Are secure travel routes available for dispersal of snakes to and from the WHA? (#4)
- Does the WHA act as a mortality sink for snakes (now or in foreseeable future) and can mortality be reduced? (#5)

Description and methods. – The methods consist of standard road surveys, on foot, bicycle, or motor vehicle, where snakes (dead or alive) are counted along specified stretches of the road (RISC 1998a; see Section 3.4 “Overview of inventory, management, and monitoring measures”). Live snakes on the road surface are also counted, providing an indication of the use of roads and thus potential for mortality. The orientation of all snakes (dead and alive) is noted, as it may provide information on the direction of movements (Sarell 2003a). The mode of transportation will depend on the type and length of roads; for example, access roads within WHAs can be surveyed on foot, whereas surveys by motor vehicle are appropriate on longer stretches of major roads. Surveys by vehicle can be done more quickly, are more cost effective and allow more surveys to be completed for a given amount of personnel time and resources. Frequent surveys are important because snake carcasses are quickly removed by scavengers. Surveys on foot along access roads within a WHA increase the likelihood seeing snakes (dead and alive) that are hidden in vegetation along the road edges and rights of way.

The number of snakes/km of road is calculated from repeated surveys (Rosen and Lowe 1994). The surveys should be conducted both in the spring and autumn when snakes are migrating, with at least four surveys per season. The surveys should be conducted during conditions deemed optimal for snake activity (such as during warm, cloudy evenings; Nelson 1992). Snakes found dead on the road should be examined and, when possible, measurements, reproductive data, and information of stomach contents should be collected. All observations must be geo-referenced.

Practical considerations. – The level of effort is considered extensive and requires fieldwork. Initially the focus should be on covering all roads where mortality could potentially occur but specified stretches may be subsequently targeted. Personnel must have skills in basic ecological surveys and be able to identify snakes accurately.

Action criteria. – If any level of mortality of snakes is observed during these surveys, follow-up action should be undertaken. The follow-up action may consist of a) more frequent and extensive road-kill surveys to better document specific localities of concern, or b) telemetry surveys to determine movement patterns by snakes and to provide more detailed information on the location of seasonal habitats. If a high level of mortality is found at specific sites, fencing may be installed to deflect snakes away from the road to safe areas before follow-up studies are conducted. In some cases, simple measures, such as ensuring that all gaps are sealed in concrete barriers bordering roads, may be sufficient as an initial action to deter road mortality (Bertram et al. 2001). In areas of very high mortality, a system of drift fences connected to culverts or underpasses may be required to allow safe passage of snakes across roads.

c) Patterns of land use type and ownership, and level of protection:

Rationale. – The Great Basin Gopher Snake requires different habitats for its seasonal activities (hibernation, foraging, and egg-laying), and these habitats may be widely separated in space (see Section 3.2 “Habitat use and movements”). Snakes using hibernation sites and other habitats within a WHA may move beyond its boundaries into areas where they are exposed to potential mortality sources in habitats altered by various land uses. Various human activities occur also within the WHAs themselves and can adversely affect snakes (see Section 3.4 “Conservation issues associated with approved and proposed WHAs).

Monitoring question(s) addressed (Question # in Section 4.2):

- Does the WHA provide all key habitat features to meet the life history requirements of the species? (#1)
- Are secure travel routes available between important habitats (such as egg-laying, denning, and foraging areas) within the WHA? (#3)
- Are secure travel routes available for dispersal of snakes to and from the WHA? (#4)
- Does the WHA act as a mortality sink for snakes (now or in foreseeable future) and can mortality be reduced? (#5)

Description and methods. – The first step consists of calculating the percentage of land base subjected to different human uses (such as residential development, agriculture, ranching, mining, and forestry) within specified zones, using a GIS analysis. Each land use category should be further sub-divided into high, moderate, and low levels of intensity of human activity or habitat degradation. As for calculating road density, suggested spatial scales are 1 km-, 2 km-, and 3 km-radius circular areas around hibernacula. The second step consists of delineating potential foraging and egg-laying areas and probable location of travel corridors from recent air-photos or biophysical maps, and overlaying these areas with patterns of human land use. The third step

consists of a site visit to confirm evaluations of habitat and land use categories based on mapping. The percentage of overlap between estimated seasonal ranges with human activities can then be calculated (for example, 10% of potential foraging habitat within 2 km radius of hibernacula is on private lands used for agriculture). A thorough initial investigation, followed by an update every three years, is suggested.

Practical considerations. – The level of effort is routine and can be conducted based on existing information and a qualitative field assessment. Field evaluation is invaluable for locating smaller habitat patches (such as small areas of talus or sandy soils with numerous rodent burrows that could serve as egg-laying sites), which cannot be resolved from air-photos or maps. It may be difficult to evaluate potential egg-laying habitats due to paucity of information on the types of sites that the snakes use. It may be also difficult to evaluate and delineate foraging areas with accuracy because of the broad habitat requirements by this species.

Action criteria. – If a large proportion of potential foraging habitat is located outside the WHA or if the configuration of the land is such that snakes have to traverse inhospitable stretches of land (such as residential developments) to access these areas, studies on seasonal movement patterns are prompted. Options for protecting travel routes, for example by purchasing additional land, may be considered. Barrier fences may have to be constructed to keep snakes away from areas of intensive human activities or residential developments (Sarell 2003b). Where potential egg-laying habitat is discovered outside boundaries of the WHA, habitat use surveys can be conducted, and options for adding such areas to the WHA can be considered.

d) Likelihood of major fire:

Rationale. – Although fire is beneficial by maintaining the open nature of habitats for snakes, severe, high-intensity fires can result in significant mortality and habitat damage (Johnson and Leopold 1998, Rudolph et al. 1998, Smith et al. 2001; see section for indicator (e) under Regional Scale, above). Fire suppression and other factors that retard the natural disturbance regime increase the probability of large, intensive, catastrophic wild fires.

Monitoring question(s) addressed (Question # in Section 4.2):

- Does the WHA act as a mortality sink for snakes (now or in foreseeable future) and can mortality be reduced? (#5)

Description and methods. – The methods consist of estimating the likelihood of major fires within a WHA and its surroundings based on natural disturbance type for the area, stand age, disturbance history (including fire suppression activities), and other factors. Spatially explicit modelling tools (such as TELSA, Tool for Exploratory Landscape Scenario Analyses) might be suitable (Beukema et al., undated). Such models allow the simulation of the probability and extent of fire under varying scenarios at relatively fine spatial scales.

Practical considerations. – The level of effort is considered extensive initially but routine once a model is set-up.

Action criteria. – Prescribed fire may be considered in high-risk areas to reduce fuel loads and to ensure that burning does not occur during critical periods for snakes (such as when the snakes are emerging from hibernation or during nesting).

e) Movement and habitat use patterns from telemetry:

Rationale. – Telemetry is an extremely useful tool for collecting habitat use and movement information that otherwise would be difficult or impossible to obtain. Tracking movements of radio-tagged Gopher Snakes has helped locate key habitat features (hibernacula and egg-laying sites) and document movement routes within and between seasonal habitats (Nelson 1992, Shewchuk 1996, Bertram et al. 2001).

Monitoring question(s) addressed (Question # in Section 4.2):

- Does the WHA provide all key habitat features to meet the life history requirements of the species? (#1)
- Are the above features receiving use by snakes? (#2)
- Are secure travel routes available between important habitats (such as egg-laying, denning, and foraging areas) within the WHA? (#3)
- Are secure travel routes available for dispersal of snakes to and from the WHA? (#4)

Description and methods. – The method involves capturing snakes at the hibernation site or foraging areas and equipping them with surgically implanted transmitters (RISC 1998a; see “Population studies” in Section 3.4). The movements of the snakes can then be tracked to locate key habitat features and movement routes, and to delineate foraging areas. A sample size of 3 – 6 radio-tagged snakes (mainly females) per WHA might be suitable but will depend on the type of information required in particular cases. Telemetry should be conducted at WHAs where a) there is an urgent need to confirm the location of egg-laying, foraging, or hibernation sites, b) much of potential foraging habitat is outside of the WHA, c) roads intersect potential migration routes, d) road mortality has been observed and more details of migration movements are needed to direct mitigation efforts. A multi-year study (2 – 3 years duration) is preferable over studies of shorter duration to document habitat use patterns under different environmental conditions. Telemetry should be undertaken when needed and where the needs are most urgent, rather than at regular intervals.

Practical considerations. – The level of effort is intensive. Telemetry surveys should be conducted by qualified professional or advanced students. This method is particularly suitable for the Gopher Snake that is secretive and often difficult to study using other means.

Action criteria. – Depending on the purpose and findings of telemetry surveys, a variety of actions are possible. Action should be taken if snakes using the WHA are being exposed to mortality or reduced productivity resulting directly (road kills) or indirectly (degradation of habitat) from human activities. These actions include mitigation measures, such as fencing to prevent road mortality, purchase or protection of strategic

lands to increase habitat connectivity, restoration of habitat, or initiation of intensive mark-recapture studies to monitor population trends.

f) Occupancy of den sites:

Rationale. – Hibernation sites form a critical resource for the Great Basin Gopher Snake, and suitable sites within the species range in British Columbia appear to be in short supply (see Section 3.2 “Habitat use and movements”). Where hibernacula are used communally, they are of particular importance to the local and possibly also regional population. Traditional use of dens and communal hibernation is common especially in the southern portion of this species’ range in the Okanagan area (Waye and Shewchuk 2002). Occupancy of these sites over time indicates that a WHA continues to provide conditions suitable for the snakes.

Monitoring question(s) addressed (Question # in Section 4.2):

- Does the WHA act as a mortality sink for snakes (now or in foreseeable future) and can mortality be reduced? (#5)
- What is the population status or trend (stable, declining, or increasing) compared to other populations within the region, and is the population using the WHA considered to be viable over the long-term? (#6)

Description and methods. – This method consists of conducting surveys at the “present/not detected” level in the vicinity of known and suspected den sites within each WHA. Dens are considered occupied if the species is detected at den entrance or within a specified distance (such as within 50 m) from the den in the spring or autumn. Spring is the best time for detecting this species, but repeated visits are likely required to confirm its presence (M. Sarell, pers. comm.). Trapping, together with drift fencing, can be considered to enhance detection success. Unless a particular site is selected for intensive monitoring (see indicator “g”, below) or other studies, no further visits are required in a given year once the species is detected. After the presence of the Gopher Snake has been confirmed, further surveys at each WHA at intervals of 2 or 3 years might be appropriate.

Practical considerations. – The level of effort is considered extensive. Personnel must have skills in basic ecological surveys and be able to identify snakes accurately.

Action criteria. – Where the occupancy of dens by this species cannot be confirmed after several visits in a particular year, further action is elicited. Surveys to detect the species elsewhere within the WHA (e.g. through road cruising or visual searches in foraging habitat in the spring) are prompted. Obvious changes to the habitat and degradation of the den site (indicators “a” and “c”, above) are to be examined, and telemetry surveys may need to be initiated to locate possible, alternative hibernation sites. Den occupancy rates can be used as an index of the status of regional populations (see indicator “d” at regional scale).

g) Relative abundance of snakes at a WHA:

Rationale. – Because of uncertainties inherently associated with proxy indicators, they need to be linked with direct measures of snake populations (see indicator “d” at regional scale). Population trends of the Great Basin Gopher Snake at a WHA are the most reliable measure of whether conservation goals have been achieved and the WHA continues to support a viable population.

Monitoring question(s) addressed (Question # in Section 4.2):

- Does the WHA act as a mortality sink for snakes (now or in foreseeable future) and can mortality be reduced? (#5)
- What is the population status or trend (stable, declining, or increasing) compared to other populations within the region, and is the population using the WHA considered to be viable over the long-term? (#6)

Description and methods. – The methods consist of mark-recapture studies at selected WHAs using standard survey methods (RISC 1998a, Shewchuk 1996; see “Population studies” in Section 3.4). Those WHAs where evidence of communal hibernation by this species has been detected are most suitable. Sampling will be conducted in the vicinity of hibernacula and on the foraging range in the spring when the snakes can be detected most readily (Shewchuk 1996). Individual Gopher Snakes may spend little time in the vicinity of dens after emergence and appear to mate after spring dispersal (reviewed in Nelson 1992), necessitating additional surveys on the foraging range. Road-cruising and trapping can be used to facilitate detection (Rudolph et al. 1999).

The handling of snakes follows standard procedures: The snakes caught will be measured and weighed, and their sex and reproductive status of females will be determined; each snake will be marked for individual recognition and released at its original capture location. Where recapture rates are sufficient, population size can be estimated. Other population parameters including survival rates can also be estimated from mark-recapture data. Where recapture rates are too low for a formal estimation of population size, a measure of relative abundance (such as the number of individuals known to be alive at any one time) can be used. The recommended frequency of sampling is each spring, initially, but less frequent sampling may be possible subsequently, based on modeling results from initial data.

Practical considerations. – The level of effort is intensive. This indicator is relatively difficult to measure and requires fieldwork by qualified professionals or advanced students. Careful selection of WHAs for mark-recapture studies is important. Mark-recapture studies are long-term and should only be initiated where sufficient commitment of time and funding is present. Little information exists on annual population fluctuations of the Great Basin Gopher Snake, and thus distinguishing stochastic fluctuations from population declines may be difficult and requires a long time-series of data.

Action criteria. – If any declines are suspected at a WHA, the first step is to examine obvious, correlated changes in local habitat indicators. The examination of population parameters (such as reproductive and survival rates; see indicator “h” below) will also

be helpful. Examples of potential action include increasing the size of a particular WHA, or initiating studies that address specific suspected causes of declines. Persistent declines in abundance at more than one site per region should be viewed with concern (see indicator “d” at regional scale).

h) Reproductive and recruitment rates:

Rationale. – Reproductive and recruitment rates are vital population parameters, the measurement of which helps determine population status and elucidate causes of possible population declines. Reproductive frequency of female Gopher Snakes may be annual, biennial, or less frequent, depending on regional and local conditions (reviewed in Nelson 1992). In British Columbia, females of this species tend to mature later, reproduce less often, and have smaller clutch sizes than do females farther south, but limited data are available (Shewchuk 1996). Reproductive frequency is more amenable to measurement than age at first reproduction, which is another important contributor to the reproductive rate. Recruitment rates are a more direct measure of population health, but sufficient sample sizes may be difficult to obtain for a secretive species such as the Gopher Snake.

Monitoring question(s) addressed (Question # in Section 4.2):

- Does the WHA act as a mortality sink for snakes (now or in foreseeable future) and can mortality be reduced? (#5)
- What is the population status or trend (stable, declining, or increasing) compared to other populations within the region, and is the population using the WHA considered to be viable over the long-term? (#6)

Description and methods. – The proportion of females that are gravid in any one year can be used as an indicator of the reproductive frequency of females; for example, if half of adult females are gravid, females are likely to reproduce biennially (Diller and Wallace 1996, Shewchuk 1996). In turn, this measure is indicative of the condition of females and, indirectly, of habitat quality and other environmental conditions. The most reliable method of collecting data on reproductive frequency of females is through longer-term studies that monitor condition of individual females through time, and these data can be collected concurrently with the more easily obtainable data of the proportion of females gravid in any one year.

The proportion of first year young in all captures after the hibernation season in the spring can be used as an index of recruitment. The first year cohort can be identified by body size, but there is extensive overlap among subsequent age classes (Shewchuk 1996).

Information on both reproductive status of females and juvenile recruitment are to be obtained in conjunction with mark-recapture studies (see indicator “g”, above). The recommended frequency of sampling is each spring, at least initially.

Practical considerations. – The level of effort is intensive. Fieldwork by qualified professionals or advanced students is required. First year young are be difficult to find

when they emerge in early spring because juvenile snakes tend to hibernate away from communal sites used by adults (Shewchuk 1996). Effort should be spent to capture juveniles in foraging areas in May and June to account for this bias. Consistent survey methods and locations from year to year are needed to avoid sampling bias.

Action criteria. – The examination of reproductive or recruitment rates help to predict and elucidate reasons for possible population declines. Where unusually low values are observed, correlations with local conditions can be sought. Additional habitat protection or restoration measures and reduction in sources of direct mortality, such as road kills or persecution, may be required at the WHA. Where changes occur at a number of WHAs, correlations with broad environmental factors (such as droughts, length of the growing season, catastrophic fires) can be examined to explain region-wide trends.

i) Condition of vegetation in key habitats:

Rationale. – Suitable vegetation provides cover for snakes to avoid predation, maintains appropriate thermal conditions, and helps support prey populations (Waye and Shewchuk 2002; see Section 3.2 “Habitat use and movements”). The structure and ground coverage of vegetation on foraging, egg-laying, and hibernation habitats within a WHA provide information whether these areas continue to provide suitable conditions for different life history functions of the snakes. Monitoring these attributes also provides a baseline for assessing impacts from various human uses and for comparisons with future environmental changes.

Monitoring question(s) addressed (Question # in Section 4.2):

- Does the WHA provide all key habitat features to meet the life history requirements of the species? (#1)

Description and methods. – The methods consist of quantifying structure, height, and type of vegetation on standard plots using a stratified random sampling approach (see “Habitat management and monitoring” in Section 3.4). The WHA is stratified by potential habitat function and habitat type. Vegetation surveys are to be carried out in the immediate vicinity of hibernation sites (within a 200 m radius), in potential foraging habitats, and in potential egg-laying habitat, as identified for indicator “c”. Because the snakes can use a variety of foraging habitats, the areas are further stratified where required, for example, by upland versus riparian areas. Standard vegetation plots are placed in each habitat using a randomized sampling design, and the percentage of coverage by each vegetation layer and ground features (such as exposed mineral soil, bedrock, rocks, coarse woody debris) within the plots are estimated visually (RISC 2003). A simplified description of vegetation, focusing on the structure and height of ground vegetation, is recommended. Dominant plant species and selected indicator plants (such as certain invasive species) are to be recorded, but detailed information on plant species composition is both time-consuming and uninformative as an indicator of habitat use by snakes. Evidence of grazing/browsing on the plots should also be recorded.

Vegetation surveys could be carried out concomitantly or combined with surveys for shelter sites (see indicator “j”, below). Disturbance to vegetation or terrain could also be

recorded concomitantly (e.g., presence of trails or compacted soil; see indicator “k”). A sampling frequency of 3 – 5 years is recommended.

Practical considerations. – The level of effort is considered extensive. Vegetation surveys are relatively straight-forward to conduct but require careful planning, ensuring that habitats are stratified appropriately and sampled adequately.

Action criteria. – Bertram (2003) suggested that minimum understory vegetation heights above 15 cm in upland areas or above 10 cm in riparian areas are suitable for the Gopher Snake on summer foraging habitats. Values below this threshold could indicate over-grazing or other disturbances. By contrast, an increase in canopy coverage indicates a reduction in openness of the habitat and a reduction in its suitability for snakes, and may prompt management actions (such as prescribed fire). Vegetation in the vicinity of egg-laying sites is usually sparse, lacking a woody component (Shewchuk 1996; see section 3.2 “Habitat use and movements”). Shading by vegetation can render these habitats unsuitable for embryonic development; removal of excess vegetation might need to be considered where openness of the habitat is lost. Nelson (1992) speculated that some shade (for example, provided by a group of trees) around hibernacula might be beneficial in conserving moisture and preventing dehydration of snakes during hibernation. However, trees might be more detrimental than beneficial as shading reduces the availability of warm sites for newly emerged snakes attempting to gain thermal energy in the spring. There are many snake dens with no shade trees in the Okanagan (M. Sarell, pers. comm.).

j) Availability and quality of potential egg-laying and shelter sites:

Rationale. – The Great Basin Gopher Snake requires sheltered microsites with suitable structural and thermal properties for egg-laying and to provide protection from predation and unfavorable environmental conditions (Rudolph et al. 1998, Wayne and Shewchuk 2002; see section 3.2 “Habitat use and movements”). The snakes use rodent burrows extensively for nesting and as a base for foraging, but they also shelter under a variety of surface cover-objects (such as rocks and coarse woody debris; Shewchuk 1996, Bertram et al. 2001). The availability of shelter sites in the foraging and summer habitat provides an indication of habitat quality. Quantitative information on the density of shelter sites in different habitats within each WHA and the location of special features that might serve as egg-laying sites provide an important baseline for evaluating the impacts of subsequent environmental changes resulting from fires, human land uses or activities, or other factors.

Monitoring question(s) addressed (Question # in Section 4.2):

- Does the WHA provide all key habitat features to meet the life history requirements of the species? (#1)

Description and methods. – The methods consist of counting potential shelter sites for snakes, classified by type (rodent burrows, coarse woody debris, rocks, patches of talus), on sampling plots and/or along standardized transects in different habitats within the WHA and calculating their densities. Plot counts can be conducted concurrently with vegetation sampling (see indicator “i”, above). Transect counts are the preferred method

where a relatively large area needs to be sampled. The WHA will be stratified by potential use by snakes (foraging, egg-laying; see indicator “c”). Because foraging areas may encompass several different habitat types, further stratification may be necessary. Both transect and plot methods are intended to provide a rapid measure of the availability of cover for snakes; detailed measurements of the cover-objects or burrows are not required. Standard methods exist for coarse woody debris surveys in forest ecosystems (RISC 2003), but this level of detail (such as volume calculations and exact measurements of object size) is unnecessary for the present purposes, and a simplified method should be used. In addition to stratified random sampling, it may be necessary to search the entire WHA for specific, potentially rare microhabitat features, such as talus patches with appropriate exposure suitable for egg-laying. The collection of baseline data is recommended for each WHA. A sampling frequency of 3 – 5 years is recommended subsequently.

Practical considerations. – The level of effort is considered extensive. Shelter site surveys are relatively straight-forward to conduct but require careful planning, ensuring that habitats are stratified appropriately and sampled adequately.

Action criteria. – Any decline in shelter site density from the baseline should be viewed with concern, and its causes should be examined. Such declines may result from terrain erosion, declines in rodent populations (in the case of burrows), or removal of coarse woody debris or other surface cover-objects by humans or by environmental disturbances. Mitigation efforts can be appropriately directed if this information is known. The use of rare or unusual habitat features (such as talus with potential egg-laying sites) by snakes should be examined where such features are found, so that additional protection can be provided to these sites.

k) Level of disturbance to key habitat features from recreation and other sources:

Rationale. – Several snake WHAs receive recreational use and/or various other human uses (see Section 3.4 “Conservation issues associated with approved and proposed WHAs”). Monitoring the level of human activity and potential disturbance to terrain, vegetation, and key habitat features from all sources is required to ensure that the WHA continues to provide suitable habitats for all life history functions of the snakes.

Monitoring question(s) addressed (Question # in Section 4.2):

- Does the WHA provide all key habitat features to meet the life history requirements of the species? (#1)
- Does the WHA act as a mortality sink for snakes (now or in foreseeable future) and can mortality be reduced? (#5)

Description and methods. – The methods consist of visual inspection of the condition of the den site and associated features (forest encroachment, rock outcrops). The number of trails is plotted on air-photos and their densities estimated within 200 m from the den. The entire zone is to be visually examined for any disturbance to the terrain, soil, or rock formations (such as erosion or rock slides) to supplement more detailed data obtained in conjunction with vegetation plots (see indicator “i”). Photographs are to be taken of the den site. Where discrete egg-laying sites (such as patches of talus) or habitats are

delineated, a similar evaluation is to be conducted. Public access points to the WHA should be mapped and monitored.

Practical considerations. – The level of effort is considered routine but requires a field visit. A frequency of evaluation every 2 – 3 years at each WHA is recommended.

Action criteria. – If any disturbance to the key habitats is noted, its source is to be determined and mitigation measures implemented. For example, where recreational activities are resulting in damage to habitats, public access to the sites may have to be restricted, such as closing parking areas in the vicinity of the WHA. Habitat restoration may be required in some cases.

l) Level of mortality from human persecution:

Rationale. –Persecution by humans, resulting from fear of snakes or mistaking the Gopher Snake for a venomous species, is a recognized source of mortality for this species (Bertram et al. 2001, Wayne and Shewchuk 2002). Snakes can be subjected to persecution and killing either within WHAs that receive public use or when they wander outside the boundaries of WHAs to residential developments or agricultural lands. Determining the extent of this problem for snake populations within WHAs is important but difficult to address.

Monitoring question(s) addressed (Question # in Section 4.2):

- Does the WHA act as a mortality sink for snakes (now or in foreseeable future) and can mortality be reduced? (#5)

Description and methods. – The methods consist of interviews with campground facilitators, conservation officers, and other government personnel on snake encounters and persecution events in the vicinity of WHAs. Initial contacts need to be established with the above personnel; subsequent monitoring should be continuous and recorded on standardized datasheets, collected and summarized yearly.

Practical considerations. – The level of effort is considered routine. Incorrect identification of snakes is a problem with all methods that rely on input from the public (Bertram et al. 2001). Where possible, the identity of any snakes killed by the public should be verified by conservation officers and/or kept for identification by qualified personnel.

Action criteria. – The results may prompt the initiation of education programs targeted to specific groups (such as farm workers or recreational users) in specific areas near WHAs. Visitor access to particular WHAs may need to be curtailed if frequent encounters leading to persecution events occur. Barrier fences may have to be constructed to keep snakes away from residential or recreational developments (Sarell 2003b).

5.0 IMPLEMENTATION STRATEGY

Three levels of monitoring effort have been identified for assessing the effectiveness of Gopher Snake WHAs at regional and local scales, starting from an option requiring relatively low effort and proceeding to more expensive, comprehensive options (Figures 4 and 5). The different levels consist of a set of indicators grouped according to the cost, effort, and time required to measure them. Different levels of monitoring can be applied to each WHA, depending on their importance to the regional population, location, threats, and other factors. The levels are hierarchical and allow one to proceed from the low-level option to the next, where deemed appropriate.

An adaptive management approach should be followed whereby additional studies and/or protection measures are invoked and methodologies refined depending on the results of initial phases of monitoring. It is recommended that the effectiveness monitoring program begin as a pilot study of a few selected WHAs, so that the feasibility and efficacy of each indicator measured can be assessed and refined, as required.

5.1 Level I Monitoring: Effectiveness measures requiring relatively low effort

Level I monitoring can be applied to all WHAs because it uses the simplest and least costly methodology. Methods include routine analysis of threat indicators using existing databases and qualitative field surveys. It does not involve studies of demography or habitat use by snakes.

The selected indicators for Level I monitoring at regional and local scales include:

- Road density (regional)
- % land base alienated (regional)
- Land ownership and protection level (regional)
- Road density (local)
- Road kill survey (local)
- Land use type (local)
- Likelihood of major fires (local)

Level I monitoring is recommended as a first step for evaluating the effectiveness of WHAs. It can be used to predict potential problems resulting from human disturbance, habitat fragmentation, barriers to movement, and road mortality. Level 1 monitoring corresponds to an early warning system, although cost-effectiveness, rather than the type of indicator, was the primary criterion used in developing the implementation strategies. If the above indicators predict that the snakes within the WHA are exposed to a high level of threat, either direct action can be taken (if impacts are obvious and severe, such as high road mortality), or further monitoring studies (Level II or III) may be warranted.

A potential shortcoming of using Level I monitoring alone is that threats to specific WHAs may be undetected because details of habitat attributes, habitat use by snakes, and population trend data are not collected.

Level I. Methods Requiring Relatively Low Effort

Method (indicator ID letter):	Monitoring question addressed (Sec. 4.2):	Criteria for action:	Next Steps:
•Measure road density (a)	7	•High potential for impeding movements and dispersal of snakes over large areas; rapid increase in road density over time	•Consider relocation or reconfiguration of affected WHAs; additional protection and mitigation may be required; focus conservation efforts on rapidly changing areas
•Measure % of land base alienated (b)	7	•High levels of habitat fragmentation; WHAs compromised by surrounding land uses; rapid change in land base alienated	•Same as above
•Land ownership and protection level (c)	7	•Habitats adjacent to WHAs are at risk	•Same as above

Level II. Methods Requiring Moderate effort

Method (indicator ID letter):	Monitoring question addressed (Sec. 4.2):	Criteria for action:	Next Steps:
•Regional trend in den site occupancy (d)	6, 8	•Persistent decline in occupancy of den sites region-wide •Decline in occupancy of individual WHAs relative to regional trend	•Identify region-wide stressors and causes for declines; consider protection of additional den sites •Conduct further studies at affected WHAs (see local implementation strategy)
•Extent of catastrophic fires (e)	7	•Widespread deterioration of snake habitat	•Consider additional protection of snake habitat unaffected by severe fire events

Level III. Methods Requiring Intensive effort

Method (indicator ID letter):	Monitoring question addressed (Sec. 4.2):	Criteria for action:	Next Steps:
•Regional index of relative abundance (Mark recapture studies) (d)	6, 8	•Persistent decline in regional snake population •Decline in abundance at individual WHAs relative to regional trend	•Look for causes of declines; identify region-wide stressors; consider additional conservation measures for the regional population affected •Conduct further studies at affected WHAs (see local implementation strategy)

Level I. Methods Requiring Relatively Low Effort

Method (indicator ID letter):	Monitoring question addressed (Sec. 4.2):	Criteria for action:	Next Steps:
•Measure road density (a)	3, 4	• High potential for impeding movements to seasonal ranges and road mortality	•Consider modifications to WHA boundary; further study (telemetry)
•Road-kill mortality level (b)	3, 4, 5	•Evidence of road kill	•Evaluate mitigative measures such as fencing and crossing structures
•Patterns of land use type, ownership and level of protection (c)	1, 3, 4, 5	•WHA compromised by surrounding land uses	•Consider protection of additional lands or restoration; further study
•Likelihood of major fire (d)	5	•Modeling results indicate concern	•Prescribed burning

Level II. Methods Requiring Moderate effort

Method (indicator ID letter):	Monitoring question addressed (Sec. 4.2):	Criteria for action:	Next Steps:
•Occupancy of den sites (f)	5, 6	•No snakes detected after repeated visits over one year; den sites damaged	•look for causes of decline in den occupancy; increase protection of den sites
•Condition of vegetation in key habitats (i)	1	•Vegetation height below a specific threshold; excessive shading/canopy coverage	•Consider land use restrictions to reduce disturbance of vegetation; prescribed fire or other measures to reduce shading/tree encroachment
•Condition of shelter/egg-laying sites (j)	1	•Reduced number of shelter sites over time; egg-laying sites threatened	•Consider measures to increase coarse woody debris or other cover; increase protection of egg-laying sites
•Disturbance from recreation and other sources (k)	1, 5	•Trampling of vegetation or damage to dens and other key habitats	•Reduce access to site
•Level of mortality from human persecution (l)	5	•Frequent conflict with humans; mortality documented	•Reduce access to site; barrier fencing; education

Level III. Methods Requiring Intensive effort

Method (indicator ID letter):	Monitoring question addressed (Sec. 4.2):	Criteria for action:	Next Steps:
•Radio-telemetry (movement and habitat use patterns) (e)	1, 2, 3, 4	•Extensive movements to seasonal ranges outside of WHA; mortality risk high; key habitats at risk	•Additional habitat protection or restoration may be required; mitigate road kill mortality, if present
•Relative abundance of snakes (Mark recapture studies) (g)	5, 6	•Persistent decline in abundance	•Look for causes of mortality/low productivity; consider additional protection/restoration measures
•Reproductive and recruitment rates (h)	5, 6	•Persistent decline in recruitment	

5.2 Level II Monitoring: Effectiveness measures requiring moderate effort

The second level of monitoring requires more effort and resources to implement and should be used in selected WHAs, including those WHAs where problems are identified from Level I monitoring. The indicators to be measured involve more detailed habitat assessments in the field or “present/not detected” type of population measures.

The selected indicators for Level II monitoring at regional and local scales include:

- Spatial extent and severity of catastrophic fires (regional)
- Occupancy of den sites (local)
- Condition of key habitats (local)
- Availability and quality of potential egg-laying and shelter sites (local)
- Level of disturbance from recreation and other activities (local)
- Level of mortality from human persecution (local)

If serious threats are identified to key habitats, immediate protective measures should be implemented and/or additional studies involving radio-telemetry or population monitoring considered. A possible shortcoming of using Level II monitoring alone is that the ultimate effectiveness of a WHA cannot be assessed using proxy indicators, and some measure of population trend is desirable for selected WHAs.

5.3 Level III Monitoring: Effectiveness measures requiring intensive effort

Level III monitoring includes several population measures at regional and local scales. A stable or increasing population trend over the long term would indicate that the WHA continues to support a viable population. The examination of demographic parameters, such as reproductive and recruitment rates, will help determine whether the WHA is acting as a mortality sink.

Level III monitoring also includes radio-telemetry studies to identify key habitats used by snakes and to delineate seasonal movement patterns within and adjacent to the WHA. This approach requires intensive effort but will provide valuable data for evaluating whether the WHA meets all of the seasonal habitat requirements of snakes.

The selected indicators for regional and local scales include:

- Regional index of abundance and den occupancy (regional)
- Movement and habitat use patterns from telemetry surveys (local)
- Relative abundance of snakes at WHA (local)
- Reproductive and recruitment rates (local)

The shortcomings of Level III monitoring are the relatively high cost, expertise, and length of time required to obtain results. Radio-telemetry studies are highly recommended because they provide useful data on habitat requirements of snakes within the WHA and can help identify specific mitigative measures. Radio-telemetry can also be used to examine the validity of habitat-based indicators. By contrast, monitoring

of population parameters can be challenging. We therefore recommend that studies of population parameters be limited to a small number of WHAs in areas where sample sizes are expected to be greatest and where success is most likely.

6.0 DATA GAPS AND CHALLENGES TO CONSERVATION

The evaluation of the effectiveness of WHAs for the Great Basin Gopher Snake is complicated because of paucity of information on habitat use and population parameters. Inherent characteristics of the species, including cryptic behaviour, frequent use of underground refuges, extensive movements, and relatively wide niche breadth, also make sampling and conservation of key habitats challenging.

More information is needed on specific characteristics of key habitats. In particular, characteristics of egg-laying sites are poorly known, as only a few such sites have been located. Egg-laying sites, especially if used communally, are likely to be an important resource for northern populations of the Gopher Snake (Nelson 1992, Wayne and Shewchuk 2002). Without more information, potential egg-laying habitats cannot be accurately identified or their quality assessed based on habitat indicators alone. Radio-telemetry has proven a useful tool for locating both egg-laying and hibernation sites of this species, and telemetry studies at selected WHAs within each region are needed to validate monitoring programs based solely on habitat indicators. A similar approach can be used to verify the attributes used to identify foraging areas and potential travel routes.

The patterns of use of hibernacula by this species are also poorly known and appear to differ among regions or depending on local conditions. The snakes may hibernate either communally or individually. Although fidelity to specific hibernation sites has been shown, in some cases individuals may use alternative dens. Almost nothing is known of hibernation sites of the first-year young, which appear to be located in different areas than those used by adults. Telemetry is inapplicable to first-year young because of their small body size. If young snakes hibernate at scattered sites away from communal hibernacula used by adults, it may not be possible or even desirable to locate all such sites, and habitat-based correlates are the best approach. At present, based on migration distances of adults, we know only that hibernation sites of young are likely to be within about 1 km-radius of den sites of adults.

Scientifically based threshold or target values could not be determined for any of the selected indicators because of a lack of specific information on habitat or population characteristics. This problem is common to many species, especially to groups such as reptiles that are relatively poorly studied when compared to birds and mammals. For example, we do not know the range of vegetation heights that provide adequate cover for these snakes on their foraging range, or the density of burrows or surface cover-objects that allow an optimal pattern of habitat use. For some habitat attributes, this information could be gleaned from detailed examination of locations of snakes while on their different seasonal ranges; other attributes, however, are subject to much regional, local, and site-specific variation, and specific thresholds with general applicability are inappropriate. Lack of specific target values does not render monitoring efforts based on

these parameters invalid but rather emphasizes that other approaches are required to interpret the results obtained. One approach is to compare values to a baseline from the same site and involves detecting trends in selected habitat attributes. Another approach is to compare values to a baseline in areas of the same ecosystem type that are undisturbed and support healthy snake populations. In either case, a persistent change in an important habitat attribute will prompt further study by monitoring habitat use by snakes or demographic parameters.

Population size is difficult to estimate for this species and subject to several biases but should be attempted at selected WHAs, as it is the only reliable measure of the effectiveness of a WHA. We do not know how the population size of this species fluctuates in space and time, and what range of fluctuations is within acceptable limits for the system to recover. Long time-series of data are typically needed to detect statistically significant population declines.

The population and habitat information collected at WHAs could serve as a baseline for examining future trends in selected indicators, evaluating their validity, and filling in data gaps. Some of the larger, relatively undisturbed WHAs could act as benchmarks for assessing impacts from various human uses and for comparisons with future environmental changes. An alternative approach would be to obtain comparative data on population trends within large, undisturbed habitats such as in parks and other protected areas.

The indicators selected here should be applied as part of an adaptive management program, and refined and updated as new information becomes available. A pilot project at a small number of WHAs, using the implementation strategy outlined in section 5.0, would be extremely valuable.

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Table 1. Conceptual model to aid in the selection of indicators for effectiveness monitoring of the Great Basin Gopher Snake (approach modified from Maxcy 2003).

A. Large-scale; regional (metapopulation level)

Disturbance/ Stressor	Potential consequences to Gopher Snakes		Candidate indicators		Comments
	Habitat	Population	Habitat	Population	
Natural disturbances (catastrophic events)	<p><u>Intensive fire:</u></p> <ul style="list-style-type: none"> Reduction in vegetative cover for snakes Reduction in prey base <p><u>Drought:</u></p> <ul style="list-style-type: none"> Reduction in vegetative cover for snakes Reduction in prey base Reduction in rodent burrows used by snakes 	<p><u>Intensive fire:</u></p> <ul style="list-style-type: none"> Direct mortality Mortality from increased predation <p><u>Drought:</u></p> <ul style="list-style-type: none"> Reduced foraging success or increased energy expenditures Reduced reproduction Mortality from increased predation 	<ul style="list-style-type: none"> Frequency and spatial extent of wildfires Precipitation patterns Intensity of fires/droughts as reflected by vegetation characteristics Predator/prey composition and abundance 	<ul style="list-style-type: none"> Relative abundance at WHAs (regional spatial and temporal trends) 	Effects of fire depend on intensity; light fires maintain snake habitat; infrequent, intensive fires are probably harmful.
Human land use (historic and present)	<ul style="list-style-type: none"> Fragmentation of habitat Isolation of habitat patches Loss of seasonal habitats and key habitat features Reduced carrying capacity Increase in natural predators associated with disturbed habitats (coyote, fox, raven, crow, magpie, red-tailed hawk) 	<ul style="list-style-type: none"> Barriers to movements and dispersal Restricted gene flow and isolation of populations Increased mortality from predation Reduced # and size of populations 	<ul style="list-style-type: none"> % of land base modified, permanently or temporally, for different human uses Density of roads Predator/prey composition and abundance 	<ul style="list-style-type: none"> Relative abundance at WHAs (regional spatial and temporal trends) 	Interact with natural disturbances and climate

Disturbance/ Stressor	Potential consequences to Gopher Snakes		Candidate indicators		Comments
	Habitat	Population	Habitat	Population	
Climate change (increased frequency of extreme events)	<ul style="list-style-type: none"> Reduction in vegetative cover for snakes Decreased length of foraging season due to summer droughts Reduction or change in species composition of prey base Change in predator abundance/species composition 	<ul style="list-style-type: none"> Direct mortality Reduced reproduction Mortality from increased predation Longer time spent inactive due to summer droughts Decreased foraging opportunities 	<ul style="list-style-type: none"> Length of growing season Temperature and precipitation patterns Frequency and extent of wild fires/droughts/unusual weather events 	<ul style="list-style-type: none"> Relative abundance at WHAs (regional spatial and temporal trends) 	Effects speculative and likely to interact with human-induced disturbances and other factors; possible benefits (range expansion due to expanding grassland habitats) may offset negative effects

B. Landscape-scale (population level; within WHAs and immediately adjacent areas)

Disturbance/ Stressor	Potential consequences to Gopher Snakes		Candidate indicators		Comments
	Habitat	Population	Habitat	Population	
Agriculture (excluding ranching)	<ul style="list-style-type: none"> Alteration of vegetation and habitat structure Decreased cover for snakes Increase in predators commensal with humans (rats, raccoons, crows) and domestic/feral animals Change in prey base Contamination of vegetation and prey base from pesticides, herbicides, and/or 	<ul style="list-style-type: none"> Mortality from increased predation Direct mortality from persecution resulting from increased contact with humans Increased energy demands due to changed pattern of foraging movements Reduced reproduction due to declines in prey base Decreased productivity due to contaminant loads 	<ul style="list-style-type: none"> % of land base within and adjacent to WHA that is in cultivation for different purposes Types and quantities of chemical pesticides/herbicides/fertilizers applied Abundance and composition of prey populations Reduced use of modified habitats by snakes 	<ul style="list-style-type: none"> Use of agricultural lands within or in the vicinity of WHA by snakes Population trend at WHA based on relative abundance measures at den site Frequency of feeding and composition of ingested prey Contaminant levels in shed skins or tissues 	Prey base for snakes may increase or decrease in agricultural areas depending on type of agriculture and rodent control measures

Disturbance/ Stressor	Potential consequences to Gopher Snakes		Candidate indicators		Comments
	Habitat	Population	Habitat	Population	
	herbicides, and/or fertilizers	<ul style="list-style-type: none"> • Disruption of snake movements • Direct mortality from agricultural practices (e.g. land clearing, haying, tilling, mowing) 		<ul style="list-style-type: none"> • Questionnaires to farmers and agricultural workers on snake encounters and kills 	
Ranching	<ul style="list-style-type: none"> • Alteration of vegetation and habitat structure • Decreased cover for snakes • Soil compaction and loss of retreat sites • Reduction in rodent burrows available to snakes 	<ul style="list-style-type: none"> • Mortality from increased predation resulting from lack of cover/retreat sites • Reduced fitness due to change in movement patterns; decreased use of heavily grazed areas 	<ul style="list-style-type: none"> • % of landbase within and adjacent to WHA used for grazing • Intensity of grazing based on reported density of livestock • Abundance/presence of livestock attractants, corrals, or staging areas within snake habitats • Vegetation height and composition within different seasonal habitats • Density of potential retreats, such as rodent burrows • Reduced use of modified habitats by snakes 	<ul style="list-style-type: none"> • Use of grazed areas within or in the vicinity of WHA by snakes • Population trend at WHA based on relative abundance measures at den site 	Adverse effects are likely with intensive grazing; light grazing may be beneficial to snake habitats by retarding succession.

Disturbance/ Stressor	Potential consequences to Gopher Snakes		Candidate indicators		Comments
	Habitat	Population	Habitat	Population	
Roads (existing, new, improvements)	<ul style="list-style-type: none"> • Destruction of hibernacula and egg-laying sites (new and improved roads) • Habitat fragmentation • Intersection of habitats used within or between seasons, and dispersal routes 	<ul style="list-style-type: none"> • Mortality from road construction, especially at hibernacula and egg-laying sites • Mortality from road kill during seasonal migrations or dispersal movements • Mortality from road kill while thermo-regulating on road surfaces 	<ul style="list-style-type: none"> • Density of roads of different types (unpaved, paved, # of lanes) • Traffic volumes on roads within or adjacent to WHA 	<ul style="list-style-type: none"> • Seasonal movement patterns and travel routes across roads by individual snakes • Frequency and pattern of road-killed snakes • Survival rates of adult snakes • Population trend at WHA based on relative abundance measures at den site 	
Urban developments	<ul style="list-style-type: none"> • Loss of seasonally important habitats, especially hibernacula and egg-laying sites • Fragmentation of habitats • Barriers to movements • Contamination of vegetation and prey base from pesticides, herbicides, or fertilizers 	<ul style="list-style-type: none"> • Direct mortality during land development, especially at hibernacula and egg-laying sites • Direct mortality from persecution due to increased contact with humans • Direct mortality from road kill due to increased prevalence of roads (see above) • Direct mortality of young from predation by domestic or feral animals and human commensals (rats, raccoons, crows) • Decreased productivity due to habitat changes or contaminant loads 	<ul style="list-style-type: none"> • % land base in urban developments in the vicinity of WHA • density and size of housing developments • trends in size of human population • 	<ul style="list-style-type: none"> • Home range and movement patterns of individual snakes in relation to urban developments • Population trend at WHA based on relative abundance measures at den site • Questionnaires to residents on snake encounters 	

Disturbance/ Stressor	Potential consequences to Gopher Snakes		Candidate indicators		Comments
	Habitat	Population	Habitat	Population	
Mining and mineral exploration; Quarrying and talus extraction	<ul style="list-style-type: none"> Loss of critical habitat features (hibernation, egg-laying, and retreat sites) Fragmentation of seasonal habitats Increased human access 	<ul style="list-style-type: none"> Direct mortality if extraction conducted at inappropriate times Reduced winter survival where alternative hibernation sites are unavailable Decreased reproductive success where alternative egg-laying sites are of poor quality 	<ul style="list-style-type: none"> Extent of coverage of WHA and adjacent area by mineral claims; economic status of mineral resource Frequency and extent of talus extraction along roads within and adjacent to WHA Condition of identified and potential hibernation sites 	<ul style="list-style-type: none"> Population trend at WHA based on relative abundance measures at den site 	Mineral claims are prevalent in WHAs; development of claims is possible within WHA if such a variance is included during establishment of the WHA
Forestry (removal of forest cover; road construction; operation of heavy machinery)	<ul style="list-style-type: none"> Loss of hibernacula and egg-laying sites from road construction Soil compaction and loss of retreat sites due to heavy machinery action Extraction of talus for road construction Increased human access 	<ul style="list-style-type: none"> Direct mortality from road construction, especially at hibernacula and egg laying sites Direct mortality if extraction conducted at inappropriate times Direct mortality from persecution due to increased access and contacts with humans Reduced survival from disturbance to the forest floor and loss of retreat sites 	<ul style="list-style-type: none"> % land base within and adjacent to WHA logged or designated as forestry lands Frequency and extent of talus extraction along forestry roads Condition of vegetation cover within different seasonal habitats 	<ul style="list-style-type: none"> Population trend at WHA based on relative abundance measures at den site 	Forestry in general is a minor problem for snake habitats due to their location within grasslands or sparsely treed areas.

Disturbance/ Stressor	Potential consequences to Gopher Snakes		Candidate indicators		Comments
	Habitat	Population	Habitat	Population	
Recreation (trails, hiking, rock-climbing, biking, ATVs)	<ul style="list-style-type: none"> • Increased access and contact with humans • Destruction of critical habitat features from certain types of activities (rock climbing, ATVs) • Soil compaction, loss of cover and retreat sites (ATVs) 	<ul style="list-style-type: none"> • Direct mortality from persecution • Direct mortality from road and trail traffic • Reduced survival if key habitat features are disturbed or destroyed 	<ul style="list-style-type: none"> • Density of trails in different seasonal habitats • Pattern of trail use (# of users and time of use) • Intensity and type of recreational use • Condition of vegetation cover within different seasonal habitats • Condition of identified and potential hibernacula and egg-laying sites 	<ul style="list-style-type: none"> • Adult survival rates • Population trend at WHA based on relative abundance measures at den site • Questionnaires to recreational users on snake encounters 	

Table 2. Summary of indicators selected through screening progress to assess effectiveness of Gopher Snake Wildlife Habitat Areas (WHA).

Indicator	Indicator type	Spatial scale	Description	Intensity of evaluation (priority rating)	Data source	References
A. Regional scale						
a) Road density	Threat	Subpopulation/broad ecological unit; Variable zone width could be used	<ul style="list-style-type: none"> Length of roads per zone by road type (paved highway, secondary road, logging/access road) 	Routine (high)	GIS analysis from maps	
b) % land base alienated	Threat/habitat	Regional (subpopulation)	<ul style="list-style-type: none"> Measure area of existing and proposed land use types (residential, industrial/commercial, agricultural, ranching, forestry, mining, recreation) 	Routine (high)	GIS analysis; satellite imagery; land use plans and zoning maps; cadastral maps	
c) Land ownership and protection level	Threat	Regional (subpopulation)	<ul style="list-style-type: none"> Measure area of public versus private land; protected areas 	Routine (high)	GIS analysis; cadastral maps; land use plans and zoning maps	
d) Den occupancy and regional index of abundance	Population	Regional (at selected WHAs); emphasis on the two discrete Canadian populations)	<ul style="list-style-type: none"> Relative abundance of snakes at selected WHAs measured for each of 4 regional population 	Intensive (high)	Field	RISC 1998a (snakes); Sarell 1993; Shewchuk 1996
e) Spatial extent and severity of catastrophic fire events	Habitat	Regional (subpopulation)	<ul style="list-style-type: none"> Indicators of severity: % of area with mineral soil exposure, erosion, recovery potential of vegetation 	Routine (high)	Satellite imagery; GIS analysis	Canadian Forest Service 2003

Indicator	Indicator type	Spatial scale	Description	Intensity of evaluation (priority rating)	Data source	References
B. Local scale						
a) Road density	Threat	Local: Various zones up to 2 km radius from hibernacula	<ul style="list-style-type: none"> Length of roads per zone by road type (paved highway, secondary road, logging/access road) 	Routine (high)	GIS; recent air-photos; TRIM maps	
b) Road-kill mortality level	Population	Up to 2 km radius from hibernacula	<ul style="list-style-type: none"> # of road-killed snakes per km of transect conducted at different times of the year 	Extensive (high)	Field	RISC 1998a (snakes); Rosen and Lowe 1994
c) Patterns of land use type, ownership, and level of protection	Threat/habitat	Within 2 km of hibernacula, outside WHA	<ul style="list-style-type: none"> % land base subjected to different human uses Assess snake habitat quality for different seasonal uses (foraging, egg-laying, hibernation, travel routes) based on site visit 	Routine (high)	Recent air-photos, maps, land use plans and zoning maps, field	
d) Likelihood of major fire	Threat/habitat	Within 2 km of hibernacula, including WHA	<ul style="list-style-type: none"> Likelihood of major fire, based on natural fire regime for the area, present stand age, and fire history (including fire suppression activities) 	Routine (high)	Satellite imagery; GIS analysis	Canadian Forest Service. 2003; Beukema et al. (undated) Biodiversity Guidebook 1995
e) Movement and habitat use patterns from telemetry surveys	Population/habitat	From WHA outwards; dependent on snake movements	<ul style="list-style-type: none"> Tracking seasonal movements and habitat use by radio-tagged snakes; home range size and location 	Intensive (high)	Field	RISC 1998a (snakes); RISC 1998b (telemetry); Shewchuk 1996

Indicator	Indicator type	Spatial scale	Description	Intensity of evaluation (priority rating)	Data source	References
f) Occupancy of den sites	Population	WHA	<ul style="list-style-type: none"> • Presence/not detected surveys in the immediate vicinity of den • Den site surveys within WHA 	Extensive (high)	Field	RISC 1998a (snakes)
g) Relative abundance of snakes at WHA	Population	WHA	<ul style="list-style-type: none"> • Mark re-capture studies, captured by hand or trapped near hibernacula and in foraging areas in spring 	Intensive (moderate)	Field	RISC 1998a (snakes); Shewchuk 1996
h) Reproductive and recruitment rates	Population	<ul style="list-style-type: none"> • Regional (at selected WHAs) 	<ul style="list-style-type: none"> • Mark-recapture study • % of females gravid • Recruitment pattern based on recapture rates/proportion of young in samples 	Intensive (moderate)	Field	RISC 1998a (snakes); Shewchuk 1996
i) Condition of vegetation in key habitats (can be combined with shelter site surveys)	Habitat	WHA	<ul style="list-style-type: none"> • Structure, height, and type of vegetation on sampling plots • WHA stratified by habitat type (foraging, travel, egg-laying) and subtype (e.g., upland, riparian) • Includes a measure of the openness of the habitat (% canopy coverage in each seasonal habitat) 	Extensive (moderate)	Field	RISC 2003 (ground sampling procedures for vegetation; to be tailored for Gopher Snake habitat, as needed)

Indicator	Indicator type	Spatial scale	Description	Intensity of evaluation (priority rating)	Data source	References
j) Availability and quality of potential egg-laying and shelter sites (combined with vegetation surveys)	Habitat	WHA	<ul style="list-style-type: none"> Counts of potential cover for snakes (rodent burrows, CWD, rocks, talus, along transects stratified by habitat Assess availability of potential egg-laying sites 	Extensive (moderate)	Field	
k) Level of disturbance to key habitat features from recreation and other sources	Habitat	WHA (within 200 m from den site and within entire WHA)	<ul style="list-style-type: none"> Assess condition of den site Count trail densities; assess soil compaction and vegetation disturbance Assess availability of access points for public 	Routine (moderate)	Field	
l) Level of mortality from human persecution	Population	WHA and surrounding area	<ul style="list-style-type: none"> Interviews or questionnaires with campground facilitators, conservation officers, and other government personnel on persecution events 	Routine (low)	Field	