1. COURSE NAME & CREDIT LOAD
COURSE CODE: FWM306
COURSE TITLE: Introduction to Forestry and Wildlife Mgt.
NUMBER OF CREDITS: 2 Credits
COURSE DURATION: Two hours per week for 12 weeks (24 hours)
As taught in (2009/2010) session.

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3. COURSE DETAILS

3.1 Course Synopses:

Organisation of Forest and Wildlife Resources. Wildlife in relation to their environment. Factors affecting distribution and abundance of wildlife. Wildlife population characteristic of mortality, movement, life cycle, food and feeding habit.Wildlfe capture techniques; objectives trap and consideration for design, immobilization by drugs. Handling, careand feeding of captured animals, field exercises of different capture methods.

3.2 Course note

WRM 306

WILDLIFE ECOLOGY AND MANAGEMENT

Introduction

The term "wildlife" in modern use includes more than animals that at one time were termed "game", such as ungulates, bears, ducks, and grouse. A broad definition would include all wild, living organisms. This latter definition has been increasingly adopted as governments move to a more broadly-based mandate associated with protection of all biodiversity. There is still greater focus on vertebrate animals by management agencies since we often know more about that

group of animals, they are considered umbrella species (rightly or wrongly) for other biodiversity, and it has greater public acceptance. The definition of "wildlife" used by the government of British Columbia

(BC) to date includes all vertebrates (excluding fish in most cases) as well as endangered and threatened species. A more workable definition in the context of this chapter is that it includes terrestrial vertebrates including mammals (excluding marine mammals), birds, amphibians, and reptiles. BC has a large percentage of the wildlife species found in Canada, although our total diversity is still small relative to more southern regions. The province covers nearly 1 million km2, and has an enormous biogeographic variation in ecoregions due to variation in climate, topography, etc. BC is home to over 440 species of terrestrial wildlife (~250 species of birds, 142 mammals, 22 amphibians, and 18 reptiles). Of those species, about 340 are forest dependent for some portion of their life cycle. The number of vertebrates that regularly occur in the province swells to about 630, when seasonal migrants are included. Over 147 species (or subspecies) of our terrestrial vertebrates are considered to be threatened or endangered (on our provincial red or blue lists). Management – ultimately a wildlife manager or a forester can usually only affect habitat type (condition) and supply. There may be occasions when more direct interventions to increase or decrease numbers of particular vertebrates may be necessary, but usually we are concerned with providing habitat that can meet a number of common needs for a range of wildlife species. Habitat refers generally to the areas used by particular species of wildlife. We refer to management at a very large scale as a coarse filter approach, i.e. that for many species some amounts of protected area and some diversity of habitats in managed forests will be sufficient to meet their needs. A successful manager is one that is able to predict accurately the outcome of a specific management action. Prediction is an important aspect of scientificallybased management, as we prefer to be able to say that such-and-such an action will result in a specific change in the population size of a particular animal. To make such predictions we need to know the habitat requirements of a species, the limitations on its populations, and its interaction with other species in the food web. Predictions are based on previous studies and management experiments in which specific hypotheses were tested to determine the mechanisms leading to a particular change. The ability to predict provides certainty to management decisions, allows for effectiveness to be carefully evaluated, and permits the consideration of alternate actions. Where outcomes do not match predictions, we can revise our predictive model and re-evaluate, the heart of adaptive management. A person responsible for wildlife management has to provide for a number of requirements of species. Individuals need to be able to have habitat in adequate supply to provide for their food supply (and that of their offspring), places where they can avoid predators, areas to avoid the high metabolic costs associated with surviving extreme conditions of winter and summer, and habitat for reproduction (e.g. nest sites, denning areas, mating areas, etc.). It is also critical that populations of sufficient size are maintained that prevent populations from experiencing the threats of local extinction associated with low numbers, genetic inbreeding, and lack of mates. All these requirements generally point to the maintenance of habitat, broadly defined, which is something a land manager has a large influence on. Direct management through culling and special protection are much more involved and problematic, and should be the approach of last resort. This chapter is divided into a series of sections on the needs of individual animals, population dynamics and community interactions, and examples of practical means of providing for particular wildlife species. Having good information on the numbers of individuals in a population and the trends in those numbers is the basis upon which decisions are made, and so there is a section at the end reviewing methods for estimation of numbers.

The individual animal

All individuals have several common needs, to eat, to avoid being eaten, and to reproduce. Animals find solutions to these needs in a variety of ways and foresters need to be able to provide for those needs at the stand and forest level. Typically this is through habitat management, either protection, creation, maintaining connectivity, or other active interventions.

Food, nutrition, and energy balance

Animals need to find sufficient food to support their basal metabolism (maintaining cellular functions, regulating body temperature, keeping heart, brain and lungs functioning, etc), growth, activity, and reproduction. Food varies in space and time (e.g. seasonally, between years). They need to be able to get enough food energy to maintain their body temperature and key physiological functions, and if there is more they can use that energy to grow and reproduce. Some foods are more digestible than others, and we can divide animals into three categories, herbivores (plants as food), carnivores (other animals as food), and omnivores (eat plants and animals). Strictly speaking, all animals are incapable of digesting cellulose, the primary constituent of plants, and therefore have to rely on specialist microbes to digest cellulose for them (either ruminants such as deer, moose, sheep, etc. Or hindgut fermenters such as rodents and rabbits). Herbivores are often described as browsers (feeding on woody tissue and leaves) or grazers (eating grasses and herbs), although many species do both. Herbivores also include species that feed on seeds and fruits, such as many birds. Acquiring energy from food is a regular activity for animals, and takes up a large portion of their lives. However, energy intake is not the only goal for most animals since they need specific nutrients that they may not be able to get solely from their regular food. For instance, calcium is a nutrient important to bone and teeth, antlers and horns, as well as for neural signalling and other physiological processes. Given that antlers (deer family: mule deer, white-tailed deer, moose, elk, caribou) are deciduous (drop off annually) and can weigh several kg, an individual needs to gain a considerable amount of calcium each year (the horns of Bovidae – sheep, goats, bison, are permanent and continue to grow through life). Calcium may be scarce in some places and animals may have to find it in "salt licks" where higher concentrations are found in the soils or rock outcrops. They can also get it from gnawing on bones and egg shells. Having a balanced diet may depend on getting all of the essential nutrients and vitamins, and not just energy intake. Therefore, protection of sites such as "salt licks" will be important to wildlife management. The metabolism of an organism varies seasonally. Birds and mammals maintain a relatively constant body temperature and there are a number of ways to reduce the magnitude of the difference between body temperature (Tb) and temperature of the surrounding environment (ambient temperature – Ta). The difference between Ta and Tb will determine how much body heat could be lost (or needs to be lost if it is too warm). Thus, when it is cold an animal may have to increase their metabolic

rate substantially to maintain their body temperature, requiring a large amount of energy. To reduce the temperature differences animals can use habitat (shelter from wind, shelter from rain or snow, thermal protection from long-wave radiation by being under closed canopy) or physiological means (thicker fur, insulating fat, raising of fur or feathers). Many animals that do not migrate and remain active through the winter are unable to maintain their body weight because of the high costs of keeping warm, low amounts of food available during winter, and the generally low quality of food available in winter (especially for herbivores). Providing habitat for winter use by animals is an important management consideration to reduce their energetic outputs at a time when resources are generally scarce.

Thermal cover is a term used to describe features of the habitat that minimise the difference between ambient temperatures and body temperatures. Thermal cover includes dens, tree cavities, closed canopy forest, insulation provided by snow or soil, etc. Another kind of cover is sometimes referred to as shelter cover, although sometimes included as thermal cover, and includes mechanisms that shelter from precipitation or wind. Since the way these affect organisms is through changes in the heat exchange mechanisms (convection, conduction, radiation, evaporation), shelter cover can be considered synonymous with thermal cover. Some mammals and birds can go into hibernation, torpor, or dormancy (all slightly different from a physiological point of view) to reduce their body temperature and thereby lose less energy. Bats, hummingbirds, and perhaps others can go into torpor during rest where their body temperatures drop considerably. Some animals hibernate, such as ground squirrels and bears, and their winter dens or burrows need to be mapped and protected. Ground squirrels and marmots may spend up to 8 months of the year in hibernation, pushing the limits for the amount of energy stored as fat prior to entering hibernation. Any additional stresses that reduce energy intake, or change the thermal properties of their dens and burrows is cause for concern (e.g. this may be implicated in the problems facing Vancouver Island marmots – see below). Amphibians and reptiles do not regulate their body temperature to a set level, and their activity is limited in part by external temperature. They also do not use as much energy as birds and mammals in order to maintain a set body temperature, allowing them to use more of their energy for growth and reproduction. These animals overwinter in a type of dormancy either in hibernacula (e.g. snake dens where many snakes may congregate), in the muddy bottoms of ponds, or underground in burrows. Protection of overwintering sites is therefore also important to maintenance of species' populations. In particular snake hibernacula can represent a very large proportion of a local population and therefore are given special protection under the Managing Identified Wildlife Strategy (one of the forest practices guidebooks). Food quantity and quality varies through time. For instance, black-tailed deer, *Odocoileus hemonius* is an herbivore that feeds on herbaceous plants, shrubs, lichens, and even conifer needles. In one study the food quantity and quality for black-tailed deer were studied throughout the year for free-ranging deer and found that the amount and nutritional value of food was lowest during the winter (Parker *et al*. 1999). These findings were consistent with the fact that deer put on relatively large amounts of fat during the summer and autumn that allow them to survive through the winter when food supply does not meet their energetic needs. Deer lose a large percentage of their body reserves during winter (Parker *et al*. 1999) and if they lose too much they can die. The same is true of many kinds of animals that are non-migratory and remain active through the winter, and this is a challenging time of year for survival of most wildlife, especially young. For a manager this means that providing good foraging areas during summer and providing thermal cover during winter and good winter range are important habitat management objectives for animals such as deer, mountain caribou, and many others. While animals are foraging or carrying out their daily activities, they are vulnerable to being seen and killed by predators. We refer to that risk as “risk of predation” and animals aim to reduce that risk by foraging in a way that allows them to be vigilant (watchful) for predators and be able to escape from the predator (e.g. Lima, 1988). Physical habitat that reduces the chance that a predator will see or capture an individual is called **security cover**. This feature of habitat may include a visual screen of vegetation, or other means of hiding or escaping predators, e.g. burrows, coarse woody debris, etc. and is an important consideration in providing for habitat through silvicultural means.

Reproduction

Reproduction replaces individuals and maintains populations, and can involve a number of strategies. Females and males find each other through a number of ways and mating is often based on one of 4 mating systems – promiscuous (e.g. frogs mating as swarms in ponds), polygynous (males have multiple partners, e.g. elk), polyandrous (females have multiple partners – rare, but occurs in phalaropes), and monogamous (or serial monogamy where there is only one partner at a time). Reproduction can be direct or delayed. Delayed implantation is a strategy possessed by a number of mammal species such as black and grizzly bears, and most of our weasels (otters, mink, fisher, wolverine, marten, etc.). This delayed implantation is a physiological adaptation that allows the embryo to suspend development until the timing is best for development, i.e. birth at an appropriate time of year. Some species of wildlife have traditional areas that they use as mating areas. Some ungulates use the same area each year for male competition and for mating. Some species of grouse meet on leks where they display. Many other species are territorial and males defend their territories against other males of their species. Disruption of territorial structure for species such as grizzly bears may have negative effects on social structure and survival of cubs (Wielgus and Bunnell, 2000) if females come into contact with aggressive males. Young animals are particularly vulnerable to predation and this is one life stage where high rates of mortality to predation and other losses can seriously affect a population's persistence in an area. Females often go to particular areas to give birth away from other members of the species, such as in caribou and other ungulates. Protection of habitat, such as nest sites and areas used by youngsters, is considered a particularly important activity and the BC government's Managing Identified Wildlife Strategy (1999) includes special provisions for nesting habitats. Tree cavities are a habitat feature used by more than 50 species of wildlife in BC (woodpeckers, songbirds, some weasels, squirrels, etc.), mostly for rearing young. Cavities typically only occur in older and larger trees, which if not provided for in stand-level plans, can disappear from intensively managed areas. This is a special attribute often associated with old growth forests and discussed further below.

Groups of animals – populations and interactions with other species

The basic group of any animal is the population, and this is usually the scale at which management takes place. This is a group of the same species that potentially interact, such as the breeding population (e.g. the group within some large watershed that rarely move outside of that geographic area). Populations may be separated by mountain ranges or other barriers that reduce movements, although not necessarily to zero (rare movements between populations allow for gene flow and colonization). Foresters need to consider sustaining populations of species such that their numbers do not drop or make them vulnerable to decrease in the long term. This usually requires management at the forest and landscape scale to maintain connectivity, habitat through which an animal can disperse effectively. The number of individuals (usually in density – numbers per some unit area) is usually set by the supply of habitat or food, something we call the *carrying capacity* of the environment. Carrying capacity (denoted K in population models) varies considerably amongst habitats and years, so it is not really a constant as some texts imply. If we know the carrying capacity we can predict the numbers of individuals across similar habitats, and this is sometimes used to generate broad estimates based on ecosystem mapping exercises, although it requires caution and many assumptions. Small, isolated populations are very vulnerable to local extinction (loss of a population, not the whole species) and a major goal of management must be to minimise the chance of driving numbers to small populations. There are several reasons. First is the simple loss of individuals and habitat that is usually progressive and deterministic. Second, there are sources of variation from year to year, known as environmental stochasticity, that could end up reducing populations (or increasing them) because of changes in food supply, predators, or even climate. Loss of several individuals from a small population will be more serious than losses of the same proportion from a large population. If there are reductions in sequential years, it could put the population into an unrecoverable decline (Gilpin and Soule, 1986). Third, as populations get smaller it is possible to get chance changes in sex ratio where all individuals are of the same gender, or at least highly skewed. There are several cases where the last five or so of a species were all the same gender and effectively extinct. And fourth, there can be genetic consequences if small populations become inbred (limited gene pool) or simply have limited genetic variation amongst them. There are many good examples of genetic problems in small populations. For all these reasons the smaller a population becomes, the risk of local extinction increases. Some species require the company of other individuals, e.g. a herd, flock, pack, etc. Rates of mortality may be higher for individual animals and reproductive (and mating) success may be lower if land management diminishes group structure. Thus, social structure within a species is an additional consideration beyond simply maintaining habitat for individual animals. There are several reasons that a group may fare better than individuals or small groups. While foraging an individual needs to maintain vigilance for predators reducing an individual's foraging time, whereas in a group, that vigilance can be shared on average allowing each individual to forage longer. Evidence indicates that as group size increases the chance of seeing and evading an approaching predator increases (the "many eyes" hypothesis). Being a member in a group may also dilute the risk of being caught by a predator if that risk is spread across all individuals and better yet if the individual can be near the middle of the group (the "selfish herd" hypothesis). In rare situations there can be group defence, such as muskox forming a ring to defend the group against wolves or birds mobbing a predator. A group may also be better able to find resources if they are patchily distributed (e.g. seed-eating birds or geese), or if hunting success increases (e.g. wolves). For these reasons and others it is important to maintain social structure and herd sizes if possible. Populations sometimes increase and individuals must leave to find a place to settle, or populations may experience declines and depend on immigration from other areas to maintain their numbers (the "rescue effect"). This movement of individuals from one area to another, more or less permanently, is called dispersal. Movements from one area to another and back (e.g. summer range and winter range) is known as migration. To maintain the ability of individuals to migrate or disperse depends on providing appropriate habitat between areas, a concept known as connectivity. The broad-scale maintainance of populations by allowing for dispersal between populations (and the rescue effect) results in a metapopulation (a "group of populations"), which is considered to be a more stable entity than individual populations, and therefore an objective of wildlife and forest management.

Interactions between species

All species are part of a biological community that includes its predators, its food, shelter (vegetative cover), competitors, parasites, and species with which it may not even interact. These interactions are important to consider in management, as an action that affects one species, may have unwanted impacts on other species, or may not work if other parts of the community are not taken into consideration. Wildlife species are susceptible to disease and parasites, and in many situations these diseases can be fatal. Wildlife can get viruses, bacteria, ticks, worms of various sorts, protozoans, fleas, etc. Some specific examples are Brucella (a bacterial disease), Pasteurella (a type of pneumonia), brainworms and lungworms (nematodes), and Leucocytozoa sp. (a blood protozoan). Most often these diseases act in a density dependent fashion. As populations increase in density, individuals may be more physiologically stressed (lower food supply, more interactions) and therefore more susceptible to disease overcoming their immune abilities. In addition, at higher densities there are more individuals and higher rates of interaction (increases as n times n-1, a geometric rate of increase) and likely more infected individuals to come in contact with. Evidence from bighorn sheep show that the prevalence of the pneumonia (Pasteurella sp.) and mortality rates are correlated with reaching high densities (Monello et al. 2001). Wildlife can also carry diseases that have impacts on humans – West Nile virus (mostly in birds such as crows and jays), Giardia ("beaver fever"), Crytosporidium, various worms from the guts and organs (mostly experienced by hunters), "Lyme" disease (caused by spirochaete bacteria, including Borrelia, the causative agent of "Lyme" disease). Wildlife can also transmit diseases into domestic livestock, such as brucellosis (caused by the bacterium Brucella) that can move from elk or buffalo into cattle, where it has more severe effects. Competition between species can occur when species share similar resources and it affects their rate of growth, survival, or reproduction. These shared resources may be for food, burrows, tree cavities, etc. The evidence to demonstrate competition is rarely sufficient to satisfy scientists completely, but most recognise that it can and probably does occur. In BC there are some examples, especially for the use of tree cavities, which can be in short supply relative to all the species and individuals that use them (Newton, 1994). Predation – there are very few species that don't have some predators, even if it's only their young that are vulnerable. Some species can be preyed upon, but ultimately have their numbers determined primarily by their food supply. In some cases predators can strongly suppress the numbers of a prey species, pushing prey numbers into what is referred to as a "predator pit". At these low densities the relatively few individuals remaining may find refuge in areas free of predators or where they can more effectively escape predation. Prey populations "escape" the predator pit because predator populations can vary through time allowing prey to increase sufficiently that predators can't increase as fast, or when resources for a prey species likewise allow more rapid increase than normal. Predators normally are larger than their prey and as a corollary (a generalisation) have slower rates of reproduction. That can result in a prey population increasing rapidly, a predator slowly catching up in terms of numbers, then being sufficiently abundant to suppress prey numbers. These kinds of interactions can cause cycles in predator-prey numbers, typically when there are few alternative prey for the predators. Two classic examples of this are for snowshoe hare and lynx interactions (Krebs et al. 1995), and moose – wolf interactions (Messier, 1991; Peterson, 1995). Most predators and prey do not show these cycles, but predation can cause problems when there are increases in alternate prey that cause increased predator numbers. For instance, the 20th century increases in moose numbers in BC are thought to have led to higher wolf population numbers, which in turn are thought to have increased predation pressure on mountain caribou, a species that appears not to withstand intensive predation. Management of predators is a controversial action that has been proposed in many forms for the protection of other species. Wolf control (culling) has been

used several times in BC to allow populations of ungulates (mostly hunted species) to increase (Seip, 1992). Other instances of predator control, including wolves, golden eagles and cougar, have been suggested for the protection of species such as Vancouver Island marmot, but to date appear not to have been implemented. Predator control is not a publicly-accepted form of wildlife management, but there are times when it may be necessary to consider this an option.

Species interact in a food web, which includes their food, predators, parasites, competitors, and other species. Interactions within foodwebs can be complex and produce complicated sets of interactions, some of which can yield "surprises" when not fully considered in management actions. Complex interactions and indirect effects are those interactions that are mediated through food web interactions and not predictable easily from the interactions of pairs of species, such as predators and prey. The snowshoe hare cycle which was thought to be predominantly driven by predation by lynx turned out to be a much more complicated set of interactions than expected, and were only realised by large-scale experimentation in the Yukon Territories (Boutin *et al*. 1995; Krebs *et al*. 1995).

Ecosystems

Some species may have an effect on their ecosystem disproportionate to their biomass, and these are known as *keystone species* (Paine, 1980; Power *et al.* 1996). Species may also be known as ecosystem engineers if their activities modify the physical environment. Beavers can be considered as a keystone species and an ecosystem engineer due to their large impact on the environment and many other species that is disproportionate to their actual biomass in the forest. A species can be an ecosystem engineer (defined as modifying the physical environment) without being a keystone species. Primary cavity nesters (in BC all are woodpeckers) may be keystone species since there are many species that depend on these species (weak primary excavators, or secondary cavity nesters) for their nest cavities (Martin and Eadie, 1999).

Management Issues, Trials, and Solutions

In addition to general measures that aim to protect wildlife, there are particular types of habitats and particular species that require more focused management. At the most broad level, the most "coarse filter" we have protected areas across the province. The intent of these protected areas (parks, special management zones, etc.) is to protect areas of habitat that serve a majority of species, but won't necessarily serve all species. Other species need particular management strategiesfor those that need particular habitats (e.g. old growth specialists, cavity nesters, riparian dependents) or need large spatial scales with particular limits on industrial activities (e.g. grizzly bears and mountain caribou). We often speak of different scales of management, the largest scale being the most "coarse filter" and usually at the level of protected areas, regional plans, and conservation plans for species such as grizzly bear. These coarse filter approaches were dealt with in the Biodiversity Guidebook of the 1995 Forest Practices Code. Sometimes protection of species with large area requirements, such as grizzly bears, are considered umbrella species for other organisms, as in an umbrella that protects all other species using the same habitat. There is little evidence that this works for all other species, but it does help many. At the next scale of management – the next "filter" – would be the Riparian Management Area Guidelines since it too protects habitats that may be useful for many species. For instance, riparian reserves serve to maintain densities of some species of small mammals (Cockle and Richardson, 2003) and amphibians. Some species pass through these habitat filters and require an even finer filter approach, i.e. a species-specific strategy, formulated by the government in their Managing Identified Wildlife Strategy. In all of these cases it is important to recognise that most of these guidelines are educated guesses and need to be rigorously tested, but some action is necessary in the short term. If these guidelines prove to be successful or inadequate, we can modify them with increased understanding.

Some classes of wildlife management issues

Old growth dependents: There are many species that are known to be dependent on oldgrowth forest characteristics for various reasons. Some of these species require that habitat for its supply of large, old trees with large branches for nests, such as the northern goshawk, northern spotted owls, and marbled murrelets. Some species appear to be associated with these oldgrowth forests because of the understory development present and the security cover it provides, e.g. northern flying squirrels. Other species that depend on old trees for cavities (see below) find those characteristics primarily in old forests. There are other characteristics of old growth forests upon which various species depend, not all of which are well understood. The amounts of woody debris and its decay class on the ground are highly dependent on the forest history. Harvesting severely reduces the amount of woody debris (an important element of habitat and cover for many species), through reducing supply and breaking up existing pieces.

Riparian dependents: Riparian areas represent a very small proportion of the forested land base, and yet >70% of species in the province are known to occur there (Raedeke 1989; Kelsey and West, 1998). These areas are usually highly productive, and provide water and additional kinds of habitats for foraging and reproduction. It is easy to think of species that are tied directly to riparian areas, such as beavers, ducks, muskrats, tailed frog, water shrew, river otters, etc. This is a huge topic and provincial guidelines for stream, lake and wetland protection are also intended to provide for wildlife habitat.

Cavity nesters: Over 50 species in BC depend on cavities for some portion of their life history requirements, often as nest sites. This includes both birds and mammals. For instance, bears (grizzly and black) make day dens in the base of old trees. Woodpeckers (12 species in BC) all nest in standing trees, either dead or dying, usually of a particular decay class (2, 3 or 4), and often of a particular minimum diameter (small diameter trees have insufficient internal space for a nest depending on the size of the woodpecker species). Many other species of birds (chickadees, tree swallows, goldeneye ducks, etc.) and mammals (red squirrels, flying squirrels, marten, etc.) either use cavities created by woodpeckers or natural holes (secondary cavity nesters). Some of these species are capable of a small amount of enlarging cavities if the wood is soft, and they are known as weak primary excavators (e.g. Martin and Eadie, 1999). In general, old, dying and dead trees are rare in most forests, so the supply of these as habitat may limit the numbers of cavity nesters (Newton, 1994). Management to maintain old and dying trees (wildlife trees) remains controversial because of the safety concerns and implications for area harvested. As the industry moves more to uneven-aged silvicultural systems this may solve the supply issue, but this needs to be carefully evaluated.

Large woody debris: Large woody debris (LWD) on the ground is used by many species as security cover, thermal cover, or simply as convenient runways through the forest. Many small mammals use

LWD for all these functions. Amphibians are often associated with LWD because of the cover and moist conditions it provides them. Forest snakes, such as the rubber boa, also make use of LWD for cover and as a place to search for prey. The amount and future supply of

LWD is reduced by forest management, because the rotation age is too short in many places to supply LARGE woody debris. In addition, existing LWD on the forest floor either decays or it may be broken up during falling or skidding operations. Small and isolated populations: Small populations have higher probabilities of going locally extinct, i.e. the population in a particular area disappears. This is also more likely to occur if there is no "rescue effect" resulting from immigration of dispersing individuals, and this is particularly likely if the population is isolated in some way. The decline or loss of these small populations is the cause of species becoming threatened or endangered in many instances. Small populations are vulnerable for several reasons. With few individuals there is a higher probability that the natural variation in population size could hit zero or near to zero, referred to in conservation biology as environmental stochasticity. Very small groups of individuals can also experience demographic effects, such as all males, or no individuals of reproductive age, etc. There are also genetic effects that have been documented for small populations, leading to decreased reproductive rates and reduced survival rates. Whenever possible, the remedy to this possibility is to maintain self-sustaining populations, ensure connectivity for immigration and emigration, and to manage for metapopulations (as opposed to isolated populations).

Problem wildlife: Some species cause problems for forestry by eating seedlings, stripping bark, eating foliage, or browsing leaders. Some examples include voles, deer, porcupines, mountain beaver, snowshoe hare, etc. Control of these species is usually not feasible through culling, as most have very high rates of reproduction and many of them are small. Various means to reduce browse damage have been tried, most with little success, such as various chemicals that may scare herbivores, either scent of predators or blood of other animals. Various chemicals that taste bad have been tried, e.g. camphor, by spraying it on seedlings (Sullivan *et al*. 2002). Silvicultural tactics to reduce damage can be used, such as increased spacing between seedlings that reduces security cover (Sullivan *et al*. 2002). Trees have been bred with higher than usual concentration of bad-tasting chemicals, and these may have some limited success in areas that are particularly affected by herbivores. Browse protectors have been used in many places with some success. These can be costly to buy, install, and maintain (e.g. from snow press or by being knocked over by ungulates). Some of these products enhance leader growth and do protect young trees to some extent. In addition to expense, these browse protectors may also lead to young trees with unwanted growth characteristics that may affect future wood quality. Problem wildlife can also include human-wildlife encounters. To a wildlife manager these may be very important, especially those that threaten human life, such as cougar and bear attacks. These are usually handled by provincial conservation officers. Other problems from wildlife include damage to crops (forage crops, apples, etc.) by deer and other ungulates. Other encounters with wildlife can include property damage, burrows that affect cattle, urban wildlife (skunks, raccoons, coyotes), etc.

Hunting and trapping: Hunting and trapping are regulated activities in BC requiring permits from the province (see http://wlapwww.gov.bc.ca/wld/hunting. htm). These permits have many restrictions and also serve to limit the numbers of individuals involved in these activities and where they hunt or trap. For hunting regulations are set for each wildlife management area, and each region may be divided into a number of wildlife management areas. Another means to control hunting is through limited entry hunts (LEHs) whereby hunters enter a lottery for a limited number of permits to hunt particular species. There are a number of other provisions that govern hunting, such as measures for fair chase (e.g. no shooting from helicopters) and for age and sex restrictions (usually biased to older males). Trapping for furbearers (marten, wolverine, hare, etc.) is a traditional First Nations activity and also carried out by non-native trappers. There are in excess of 3200 registered trap lines in BC. Trappers are given licences to particular trap lines, which they self manage. The standard layout of trap lines is to build a “no trap” buffer between trap lines that can be more than twice as wide as the actual trap line to ensure there is an area to maintain populations of furbearers. Wildlife managers are responsible for ensuring that trap lines are protected from other land use activities, and forest managers need to be aware of hunting and trapping activities in a forest district, as it affects development plans.

Wildlife viewing: Ecotourism based around watching wildlife is an important, and often underappreciated, economic activity in BC. Tourists from around the world come to experience wildlife in our province, including watching grizzly bears, eagles, salmon migrations, whale-watching, etc. Birdwatching is a major recreational activity and many residents and non-residents of the province spend money to travel and watch birds throughout the province.

Species at risk

Threatened or endangered species are designated by the province and by the federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Those species that are at highest risk of endangerment are on the "red list" and those that are vulnerable to becoming endangered are on the "blue list". In BC we have Z species on the red list and Y species on the blue list. Some of the reasons for species being at risk include a long list of human activities. Here, we consider a few particular species where forest management is thought to be a direct cause of endangerment, along with some suggestions for solutions. ***Mountain caribou*****:** This ecotype of the woodland caribou found in isolated herds in the southern mountains of BC from Prince George to the US border has a double migration each year. The world's entire distribution of this form of caribou lives in BC, Alberta, and Idaho, although the largest proportion of them are in BC. It spends summers in the alpine, autumn and early winter in valleys, winter in the subalpine (ESSF), and spring back in the valley bottoms (http://wlapwww.gov. bc. ca/wld/documents/mtcaribou_rcvrystrat02.pdf). The species is very vulnerable to predators, such as wolves, cougars, and bears. In the past decades the numbers

of these caribou have been in decline for most of the 13 herds in BC. It has been suggested that the three biggest threats are predators, loss of winter habitat, and winter recreation activities. Predator numbers are thought to be supported by the increase in moose in the past century and expose the mountain caribou to a greater predation pressure when they are in the valley bottoms than they experienced historically. Usually mountain caribou escape predation pressure during winter by being in deep snow at subalpine elevations. However, increases in snowmobile use appear to have contributed to packing of the snow and allowing predators access to subalpine areas. This is in addition to some observations of direct impacts oncaribou trying to evade snowmobilers and being trapped in avalanches. During winter caribou subsist (negative energy balance that would be worse without lichens) on arboreal lichens (*Alectoria*, *Bryoria*), a slow-growing group of species that only get to a volume or biomass worthy of consumption by mountain caribou on old growth trees. Forest harvesting in the ESSF may be reducing the overall biomass of lichens available and the rate of growth on regenerating trees.

The management for this species is highly controversial and probably requires controls on all the causal factors. Suggestions of predator control as one means of protecting them resurfaces regularly, but is not a sustainable long-term option. The province has produced a mountain caribou management strategy available at http://wlapwww.gov.bc.ca/wld/documents/mtcaribou_rcvrystrat02.pdf.

Grizzly bear: The grizzly bear requires large territory sizes and needs to be managed at a large scale. The management of grizzly bear is highly controversial for several reasons, including the absence of agreed-upon estimates of numbers, lack of a parameterised demographic population model, hunting is allowed, and its endangerment in the lower 48 states of the United States. This is a highly politicised species with several stakeholders holding very different aspirations for the species' management. The provincial government stands by its estimate of 10,000 to 13,000 grizzly bears in the province (Fuhr and Demarchi, 1990) and has allowed hunting on a limited number each year (about 240 per year in the 1990s). There have been a couple of management activities for the species, including setting aside large protected areas and building a conservation strategy. There is a proposal being considered to set a minimum protected portion of the species' populations in each of 6 regions, numbering around 100 – 250 in each region (Wielgus, 2002). These protected individuals would experience no hunting pressure and ensure that some portion of the population was better able to maintain or increase its numbers, potentially to supply excess individuals as dispersers to areas outside the protected zone. The management of this species is part of higher level plans that the forest manager needs to be aware of. At the stand level there are prescriptions for stand management to maintain good habitat, including good berry production, usually by maintaining low tree densities through thinning.

Vancouver Island Marmot: This large rodent is similar to other marmots, but as a distinct species is found nowhere else than in a few isolated alpine areas on Vancouver Island. The numbers may be fewer than 50 remaining in the wild. This species has been considered endangered for a number of years because of its declining numbers, small total numbers, isolation of populations, and the continued threat to its habitat. One of the putative causes of endangerment of this species (remember that we can't do detailed studies or experiments to test this on an endangered species) is forest harvesting and the marmots mistakenly settling into clearcut areas that in the short term resemble their alpine habitats. Recall that marmots often spend up to 8 months in hibernation and rely on their fat storage for that duration. If the insulation usually provided by deep snow is not present the burrows may be colder than those with greater snow cover at higher elevations. These colder conditions require more metabolic energy to remain above freezing than if the burrow were better insulated. Also, these sites eventually regenerateto forest and that may reduce the quality of these areas further for marmots that have mistakenly settled there. Remember that these are just hypotheses, but in

many cases with endangered species we have to take these possible explanations seriously, otherwise we run the risk of not acting soon enough to prevent the demise of a species. ***Marbled murrelet:*** The marbled murrelet is a seabird that spends a great deal of its life offshore, feeding on fish. Its connection with forestry is that it is one of the class of species that nests more or less obligately in old growth trees. The typical nesting habitat for this species are old trees with very wide side branches, usually at least 30 cm in diameter, moss-covered on which they lay their single egg each year (maybe in alternate years) in a depression in the moss. These nest platforms typically also have another large branch just above, which provides protection from some kinds of predators. The species is still relatively abundant, but strong downward trends in its numbers, and the advancing loss of old growth trees for nesting, resulted in the species being listed as threatened. The species currently receives provisions in the Managing Identified Wildlife Strategy for protection of trees where there are active nests. There are interim measures proposed for the protection of this species from forestry activities. Research on the species is ongoing and may eventually indicate why the numbers are declining as quickly as they are.

Northern spotted owl: The northern spotted owl is a species that has gained notoriety in the Pacific Northwest for its widespread impact on the forest industry. A pair of spotted owls may require an area up to 3500 ha, mostly of old growth. There is variation in the kinds of habitats used by spotted owls, shown by a very extensive body of research in the US since the mid 1980s (e.g. Noon and Franklin, 2002). The species requires old growth trees with cavities for nesting. The young owls find better protection from predators (such as great-horned owls) in old growth forests. Foraging habitat was thought to be primarily in old growth forests with extensive understory, which provides habitat for one of its main prey, the northern flying squirrel (Carey *et al.* 1995). In other parts of its range it may also prey on woodrats, some species of which are found at forest edges and second growth forests. In BC the species is found in the southwest portion of the province, mostly in the Vancouver, Chilliwack, Lilloett, and Merritt Forest Districts. Thetrend in BC appears to be strongly downward (Blackburn *et al.* 2002) although the reasons are unknown. In 1995 BC set up special management zones around the areas where the species was known to occur, with the intention that this special protection would provide high quality habitat for the owls known to occur in BC. Recent evidence indicates that even these special management areas have not stopped the decline of this species in BC. Because of the high public profile of this species and its association with old growth forest, it remains a high priority species for the provincial government.

Practical aspects of wildlife management

Identification

Putting a name to a species is critical and there are many species that look alike. It is easy to confuse species that may be endangered with ones that may be extremely common. Errors of identification can result in lost time and money, or costly lawsuits and loss of goodwill. Carry up-to-date field guides. Consult with credible biologists (those with a highly-regarded reputation).

Methods for estimating numbers, movements, and population status

One needs to know how many individuals there are of a species of interest, to determine if the numbers are going up, down, or staying relatively constant. We also need to know if a management action is having the desired effect on a population. Trapping and sampling – Methods for trapping or sampling depend on the species of interest and the information required. This information would be available from a biologist, either from one of the universities, government office, or consultants. Any kind of capture or handling of wildlife requires permits from the provincial government. There are three general classes of population estimates, each with benefits and limitations. These are indices of abundance, relative abundance, and density estimates (number per area).

Method Advantages Limitations Examples

Indices Fast, inexpensive, No actual number, Scat surveys gives trends many potential biases

Relative Inexpensive, gives No actual number, Winter bird counts, Abundance trends many potential biases hunting returns Density Actual numbers, Expensive, long-term, Mark-recapture

demographic can be biased (group or indiinformation vidual marks) or sampling The estimation of density depends to a large extent on being able to distinguish animals that have been seen previously from those not seen before. This typically means marking animals somehow. The best approach is for animals to be uniquely marked, i.e. each individual with a different number or slightly different mark (e.g. different colour combinations). Animals can be marked with ear tags (most mammals), leg bands (birds), coloured elastomer dye injections under the skin (amphibians), PIT tags (most species), hair dye or bleach (mammals), and coloured paint marks (birds and reptiles). In some cases individuals can be distinguished by careful study of individual marking patterns in their skin or by collecting bits of hair for DNA analysis. All of these methods depend on the "dilution" method, usually called capturemark- recapture (or mark-recapture) methods. In the simplest form this is based on solving a simple ratio based on catching some number of individuals (n1), marking them, and releasing them back into the population. We then resample the population, usually a day or a few days later (allowing for mixing within the population), and look at the ratio of marked to unmarked individuals. The ratio of marked to unmarked individuals in the second sample should be the same as the ratio of our initial sample to the whole population. This method depends on several assumptions, some of which we have difficulty being sure of. One assumption is that the population is "closed", i.e. immigration and emigration are very small contributors to the change in numbers between our sampling times. We also have to assume that animals that are marked keep their marks, and are no more likely or unlikely to be killed than animals that are not marked. Likewise, we have to assume that animals that have been trapped once are just as likely to be trapped again as they were the first time, i.e. they do not learn to avoid traps or go preferentially into them (they are often baited). The methods for mark-recapture estimates of numbers have become increasingly sophisticated in the past 15 years. Good sources of information on mark-recapture methods are to be found in Krebs (1999), and Anderson *et al.* (2000).

Habitat supply models

We rarely have the resources to do extensive inventories for most wildlife species, and in fact for most species we have almost no detailed information on numbers and habitats. For those species where there are estimates of population numbers for some areas, e.g. grizzly bears, habitat supply models have been used to estimate total numbers. These models typically determine the relative value of particular kinds of habitats, which may be capable of supporting some estimated density of bears (or other species). Rather than try to estimate numbers across

the whole province this habitat mapping seems like a good way to determine numbers cheaply. Habitat type or quality may be estimated by GIS, land inventory, or even by remote sensing, thereby providing extensive coverage that would not be possible from intensive surveys for population estimates. An important point to realise is that habitats are not always filled to "capacity", and in many instances even prime habitat may be vacant, depending on other influences on populations. Thus, habitat supply models may be a useful tool if used cautiously and recognising the assumptions behind the models. The estimation of numbers is how we determine the status and trends of population numbers, as well as the effect of management. Good management depends on reliable data. Other specialists: BC Ministry of Water, Land and Air Protection have the mandate to manage wildlife, as wildlife is a provincial jurisdiction. They also have staff with knowledge of many species, especially in a local context. BC Ministry of Forests also has staff that do research with wildlife and can provide advice. The Canadian Wildlife Service (CWS) of Environment Canada is the federal agency that is involved in wildlife management, particularly for migratory species and for species at risk. The CWS role in wildlife management is constitutionally intended to be to co-manage with provincial authorities. Consulting biologists may be able to provide advice.

Key concepts for forest wildlife management

Representation: Maintain elements of all ecosystem types, structure types, and BEC variants.

Remnant sizes: One size won't fit all, so ensure a variety of remnant sizes, especially some large ones.

Riparian habitats: Protect riparian habitats, especially in patches rather than thin reserves, wherever possible.

Standing dead and coarse woody debris: Maintain structural elements critical to cavity nesters and other species that use downed wood.

Connectivity: Ensure populations do not become completely isolated by forest management, including roads and other operations.

Ensure effective, self-sustaining populations are maintained: The key to longterm persistence of populations is a large enough population to maintain itself and not be vulnerable to the threats associated with small, isolated populations.

Wildlife Habitat Areas: Special designs for some species that might not be taken care of through other management efforts.

Bottom line:

Don't apply the same design to every piece of forest. Maintain diverse stand, forest, and landscape structures.

Additional information is produced and given in hard copy as handout.

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