Inventory Methods for Beaver and Muskrat

Standards for Components of British Columbia's Biodiversity No. 22

Prepared by
Ministry of Environment, Lands and Parks
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Resources Inventory Committee

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Preface

This manual presents standard methods for inventory of Beaver and Muskrat in British Columbia at three levels of inventory intensity: presence/not detected (possible), relative abundance, and absolute abundance. The manual was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Inventory Committee (RIC). The objectives of the working group are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series which present standard protocols designed specifically for groups of species with similar inventory requirements. The series includes an introductory manual (*Species Inventory Fundamentals No. 1*) which describes the history and objectives of RIC, and outlines the general process of conducting a wildlife inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The *Species Inventory Fundamentals* manual provides important background information and should be thoroughly reviewed before commencing with a RIC wildlife inventory. RIC standards are also available for vertebrate taxonomy (No. 2), animal capture and handling (No. 3), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in inventories which involve any of these activities.

Standard data forms are required for all RIC wildlife inventory. Survey-specific data forms accompany most manuals while general wildlife inventory forms are available in the *Species Inventory Fundamentals No. 1 [Forms]* (previously referred to as the Dataform Appendix). This is important to ensure compatibility with provincial data systems, as all information must eventually be included in the Species Inventory Datasystem (SPI). For more information about SPI and data forms, visit the Species Inventory Homepage at:
http://www.env.gov.bc.ca/wld/spi/ric_manuals/

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve very quickly over their initial years of use. Field testing is a vital component of this process and feedback is essential. Comments and suggestions can be forwarded to the Elements Working Group by contacting:

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The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report “The Future of our Forests”.

For further information about the Resources Inventory Committee and its various Task Forces, please contact:

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Terrestrial Ecosystems Task Force

All decisions regarding protocols and standards are the responsibility of the Resources Inventory Committee. Background information and protocols presented in this version are based on contributions from Kim Poole (Timberland Consultants Ltd.). In addition, Colleen Bryden contributed to an earlier unpublished draft, *Standardized Inventory Methods for Components of Biodiversity in British Columbia: Beaver and Muskra,* with review comments from Maria Leung and editorial assistance from Ann Eriksson.

Editorial review and production of this manual and the associated dataforms were provided by James Quayle and Leah Westereng.

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1. INTRODUCTION

Beavers and muskrats have several traits in common. They occupy similar habitats and may be found in close association. Both are generally semi-aquatic, although in the winter they may never come ashore. The muskrat has an affinity for the habitat created by the beaver's dam-building activity. In terms of diet, the beaver is a strict herbivore and the muskrat is mainly herbivorous. As well, both have home ranges which typically centre around a house, burrow, or lodge occupied by a family unit.

In terms of inventory, the tendency of beavers and muskrats towards localized movements within a largely aquatic home range reduces the effectiveness of methods which are commonly used to inventory terrestrial furbearers (*e.g.*, baited camera sets, winter track surveys, sooted track plates). However, certain characteristics which are shared by both beavers and muskrats, particularly their construction of conspicuous homesites and their dependence on waterbodies, lend themselves well to alternative methods of inventory. Because of this, it is reasonable to follow a similar approach to inventory either of these semi-aquatic mammals.

The purpose of this manual is to recommend standard methods and describe protocols for estimating presence, relative abundance, and absolute abundance of beaver and muskrat.

2. INVENTORY GROUP

The following are brief summaries of the basic biology and ecology of the beaver and muskrat with emphasis on characteristics that are important for inventory purposes.

2.1 Beaver *Castor canadensis*

A large portion of the natural history discussion below was taken from Novak (1987). This is an excellent reference.

Description

The beaver is the largest rodent in North America and is well-adapted to the aquatic environment. It is widely-recognized by its broad, naked, and horizontally flattened tail. Fur colour ranges from black to gray or blond, although most beavers appear reddish brown. There is no sexual dimorphism in pelage, size, or external features other than the swollen nipples of lactating females (Novak 1987). The average beaver weighs more than 15 kg as an adult, although maximum weights greater than 25 kg have been recorded (Novak 1987; Rezendes 1992). Adults average about one metre in length, including the tail (Banfield 1981). The beaver's skull is massive, and the incisors are large and grow continually. Olfaction and hearing are well-developed but eyesight is poor. Few beavers live longer than ten years. Trapping is the most significant mortality factor over much of the beaver's range (Novak 1987).

A typical colony consists of a breeding pair plus young-of-the-year and juveniles from the previous spring; however, single and pair colonies are known to occur (Novak 1987). Payne (1982) found these single and pair colonies to be more common in populations which were exploited (in contrast to unexploited ones).

Habitat

Beavers inhabit slow-moving streams, rivers, lakes, ponds, and marshes in forested areas (Cowan and Guiguet 1956; Banfield 1981). They do not colonize swift-flowing streams which are subject to flash floods, or areas where the water supply fluctuates seasonally (Banfield 1981; Novak 1987). Although beavers have colonized lakes in Canada's Precambrian Shield to moderate population levels, it is generally believe that they do not prefer rocky streams or lakes with rocky shorelines, and will rarely build lodges and food caches on large lakes with excessive wave action. Beavers will also colonize artificial ponds and drainage ditches (Novak 1987).

Beaver activity has a profound and long-lasting impact on the environment, and is beneficial to a wide variety of wildlife species (Novak 1987; Rezendes 1992).

Food habits

Beavers are herbivores. Their main food is the bark of deciduous trees, preferably aspen, but beavers will also eat willow, cottonwood, and other deciduous trees. Conifers are also occasionally cut (Banfield 1981), but deciduous trees and shrubs are especially important, and beavers cannot survive without them for long (Novak 1987). In the summer, beavers also eat pond vegetation, such as duckweed and cattails. Each colony caches a winter food supply of cut deciduous branches in deep water near their lodge, or burrow during the fall. Beavers feed in the water or in their lodge (Banfield 1981).

Behaviour

The beaver is well known for building dams. The dam is built high enough to hold back water at a depth of 2-3 m, so that the beavers can swim freely under the winter ice (Banfield 1981). The resulting pond ensures that the beavers have aquatic access to their food supply. Beavers may build canals to access food farther from the pond shores (Banfield 1981). Alder is the most common species used for construction of dams and lodges (Novak 1987).

Lodges may be built in the middle of the beaver pond, or along the bank. Bank lodges are usually built where the water is deep or fast, and may include an underground tunnel system (Novak 1987). A lodge may be occupied for several years in a row (Banfield 1981), and there may be more than one lodge per colony (Hay 1958; Slough and Sadleir 1977). There is usually only a single nest chamber in a lodge with one or two exits (Novak 1987). Beavers may dig bank burrows on large lakes and rivers in addition to, or instead of, a lodge (Banfield 1981).

All colonies, whether they are bank or lodge dwellers, normally construct a single food cache in the fall, except where winters are mild (Swenson *et al.* 1983; Novak 1987). The start of cache building is correlated with the first heavy frost (Novak 1987). Preferred food is collected together under a raft, usually constructed from branches of less preferred food species (*e.g.*, alder). The raft forces the branches beneath it to sink and, subsequently, remain below any ice and available for winter feeding (Slough 1978).

Beavers are generally crepuscular and nocturnal; however they may also be active during the day in the late afternoon or when it is cloudy (Banfield 1981; Novak 1987). Although they are rarely active above the ice in temperatures below -10°C (Novak 1987), beavers remain active all winter long beneath the ice and in their lodges (Banfield 1981).

Beavers communicate by means of scent, tail-slapping, vocalizations, and body movements. Anal gland secretions give the animal’s fur a water-repellent quality as well as providing scent cues to other beavers. Castor sac secretions (castoreum) are also used in olfactory communication in the form of scent mounds established on dams, lodges, and along trails. Scent mounds may have a territorial function (Novak 1987).

Reproduction

Beavers are monogamous and the pair-bond is long term. Beavers mate during February and March in northern and montane regions, while in middle North America this occurs earlier, in January-March. Gestation lasts 105-107 days with the kits being born after the spring period. Females usually first breed at 21 months, but this may be delayed in high density populations. Males reach sexual maturity at about the same age as females. There is one litter per year and average litter size in North America is 3-4 kits (Novak 1987).

Movements, home range and territoriality

The home range and territory of beavers have not been precisely defined and there is little information on how a colony site is selected. Home range is greatly affected by the water system in which the colony lives with colonies in the best habitat occurring as close as 300 m apart. Beaver families may relocate if food supplies are depleted, or if their dam and lodges have been destroyed. Subadults generally leave the colony during the spring before the new kits are born (Novak 1987).

Distribution and abundance

The beaver is abundant across much of North America. They are generally absent north of the tree line, in peninsular Florida, in small portions of the U.S. Midwest and in arid regions of the southwestern U.S.. In Mexico there are isolated and decreasing populations along the U.S. border (Novak 1987).

The beaver is found throughout British Columbia including parts of the Queen Charlotte Islands where it was introduced sometime around 1950 (Cowan and Guiguet 1956; Banfield 1981). Beavers will enter saltwater and have reached most suitable islands off the mainland coast (Cowan and Guiguet 1956). The beaver is found in all ecoprovinces, and the only biogeoclimatic zone in which the beaver do not occur is Alpine Tundra. They are also not found in the parkland subzones of the Englemann Spruce-Subalpine Fir Zone and the scrub subzones of the Spruce-Willow-Birch Zone (Stevens 1992).

The most recent B.C. population estimate of 400,000 to 600,000 beavers is from 1979 (Munro and Fyfe 1979; Hatler 1988).

There is no evidence that beaver populations are cyclic (Novak 1987).

Status

Beaver populations were exterminated or reduced over much of their North American range by 1900 because of over-harvesting. Their distribution has returned to approximate that of pre-settlement times and their numbers are increasing or have peaked by the late 1900’s as a result of better management (Novak 1987).

The beaver is on the provincial yellow list (1997).

2.2 Muskrat *Ondatra zibethicus*

Description

The muskrat is a large vole adapted to aquatic conditions. Adults weigh about 1 kg and average around 50-60 cm in length, including the long scaly tail (Dozier *et al.* 1948; Banfield 1981). The muskrat’s tail is laterally compressed (Banfield 1981). Pelage varies in colour from light brown to black (Boutin and Birkenholz 1987). Olfaction and hearing are well-developed, but eyesight is poor (Rezendes 1992). Both male and female muskrats have anal glands which emit a strong musky odour during breeding season. Muskrats are thought to live about three years in the wild (Banfield 1981). The mink (*Mustela vision*) is probably the most serious predator of muskrats (Banfield 1981), other than humans.

Habitat

The muskrat can occupy a variety of aquatic habitats, but is most abundant in areas with a stable water level and rich aquatic vegetation (*e.g.*, beaver ponds, brackish and freshwater marshes and slow-flowing water courses) (Dozier *et al.* 1948; Danell 1982; Boutin and Birkenholz 1987). Ideally, water should be deep enough so that it will not freeze to the bottom in winter, but not so deep that submerged vegetation cannot grow (Banfield 1981; Boutin and Birkenholz 1987). Muskrat activity opens up dense marsh vegetation, thereby enhancing plant diversity and waterfowl habitat (Messier and Virgl 1992).

Food habits

The muskrat's summer food consists primarily of emergent vegetation (*e.g.*, cattail, sedge, bulrush and water lily). Muskrats also eat animal matter, particularly freshwater mussels (Banfield 1981). Muskrats cut off aquatic plants, but in most cases only eat part of them, leaving the remains behind (Danell 1977). High population densities have led to "eat-outs" of marsh vegetation in the southern U.S., but this has not been known to occur in Canada (Boutin and Birkenholz 1987). Winter food consists of submerged vegetation including pondweeds, water lily tuber and water milfoil (Banfield 1981). Several structures may be associated with feeding activity: feeding stations (small houses 30-40 cm high) and push-ups in the fall and winter; and feeding platforms in the spring and summer (Danell 1982; Rezendes 1992).

Behaviour

Muskrats live in burrows in areas where lake and river margins have steep banks formed of easily dug soft sediments. Where wetland margins are gently sloped and subsoil too shallow for burrowing they build houses (Danell 1982). Houses are usually built from cattails and bulrushes, and plastered with mud and pondweeds (Banfield 1981). They may be built throughout the ice-free season, but activity intensifies as winter approaches. Houses are typically around one meter high and are occupied by a family group (Danell 1982). Usually, houses are destroyed in spring floods and are not repaired. Muskrats may occupy burrows all year long in some areas and never build houses (Banfield 1981).

"Push-ups" are feeding shelters constructed after the formation of a persistent ice cover, and are supported entirely by the ice (MacArthur 1992). They consist of a dome of frozen pond vegetation over a hole in the ice in which the muskrat comes to feed (Banfield 1981).

Muskrats are primarily nocturnal, but are often seen during the day in spring and autumn (Boutin and Birkenholz 1987).

Reproduction

Muskrats breed year-round in the southern U.S., but the breeding period becomes more restricted with increasing latitude (Boutin and Birkenholz 1987). Banfield (1981) indicates that in Canada, breeding is confined to the March-September period. Breeding is initiated after waterbodies become ice-free. Females first breed as early as 6-8 weeks old in the southern U.S., but this is rare farther north (Boutin and Birkenholz 1987) where they typically first breed as yearlings (Banfield 1981). Gestation is 28-30 days (Boutin and Birkenholz 1987). Litter size is from three to nine, and a female typically has 2-3 litters per breeding season (Boutin and Birkenholz 1987). The number of litters and litter size will vary with latitude; generally, there are fewer litters farther north, but litter sizes are larger (Banfield 1981). Muskrats appear to be monogamous, and live in family groups (Sather 1958; Banfield 1981).

Movements, home range and territoriality

Muskrat home range size probably depends on habitat quality and population density and may vary seasonally. Home ranges are small, generally less than 100 m in diameter (Boutin and Birkenholz 1987). Muskrats defend their territory from neighbours (Banfield 1981).

Dispersal is most prominent during spring and fall (Boutin and Birkenholz 1987). In the fall, the young-of-the-year disperse into over-wintering habitat. Spring dispersal is associated with the breeding season (Boutin and Birkenholz 1987), and there can be much intraspecific aggression at this time (Banfield 1981). Areas may be abandoned if the water freezes to the bottom or during summer drought (Banfield 1981; Boutin and Birkenholz 1987).

Distribution and abundance

Muskrats are found throughout North America from the Mackenzie River delta to northern Mexico. They are absent from Florida, although suitable habitat appears to exist, and from parts of California, Arizona, Texas and the B.C. coast (Boutin and Birkenholz 1987; Rezendes 1992).

The muskrat's range covers all of B.C. east of the Coast Mountain Range (Cowan and Guiguet 1956; Stevens and Lofts 1988). Muskrats were introduced to Vancouver Island and the Queen Charlotte Islands (Stevens and Lofts 1988). They are found in all ecoprovinces, but are not widespread in the Coast and Mountains Ecoprovince. The muskrat is absent only from the Alpine Tundra biogeoclimatic zone (Stevens 1992).

The most recent B.C. population estimate of 3-4 million muskrats is from 1979 (Jackson *et al.* 1979).

Evidence suggests that muskrat populations in Canada are cyclic with a periodicity of 10-14 years (Boutin and Birkenholz 1987).

Status

The muskrat is on the provincial yellow list (1997).

3. PROTOCOLS

The intention of this section is to recommend inventory methods for beaver and muskrat that are appropriate for standard operational inventory rather than intensive research. To that end, the following criteria were considered: i) simplicity of equipment and design, ii) expense in terms of both time and money, and iii) applicability on a provincial basis. Table 1 contains a summary of the inventory methods recommended for Beaver and Muskrat at three levels of intensity.

The first requirement before beginning an inventory program is to clearly define the objectives. This will then determine the level of inventory that is appropriate. The protocol provides basic standards with the expectation that inventories will then be conducted in a consistent manner that will facilitate the possible comparison and correlation of inventory data throughout the province.

Table 1. Recommended inventory methods for beaver and muskrat in British Columbia at three levels of intensity.

	Recommended Method(s)		
Species	**Presence/Not Detected**	**Relative Abundance**	**Absolute Abundance**
Beaver	• Ground Physical Sign Survey	• Food Cache (Colony) Count • Ground Lodge Count	• Food Cache (Colony) Count (with estimate of colony size)
Muskrat	• Ground Physical Sign Survey	• Ground Dwelling Count	• Ground Dwelling Count (with estimate of mean number of occupants)

3.1 Sampling Standards

The following standards are recommended to mitigate several sources of bias common in surveys. Individual protocols provide more detailed standards applicable to the method(s) and design recommended.

3.1.1 Habitat data standards

A minimum amount of habitat data must be collected for each survey type. The type and amount of data collected will depend on the scale of the survey, the nature of the focal species, and the objectives of the inventory. Compulsory habitat data are outlined in the introductory manual, *Species Inventory Fundamentals* (*No.1).*

3.1.2 Survey Design Hierarchy

Beaver and muskrat surveys follow a sample design hierarchy which is structured similarly to all RIC standards for species inventory. Figure 1 clarifies certain terminology used within this manual (also found in the glossary), and illustrates the appropriate conceptual framework for an aerial food cache (colony) count survey for beavers. A survey set up following this design will lend itself well to standard methods and RIC data forms.

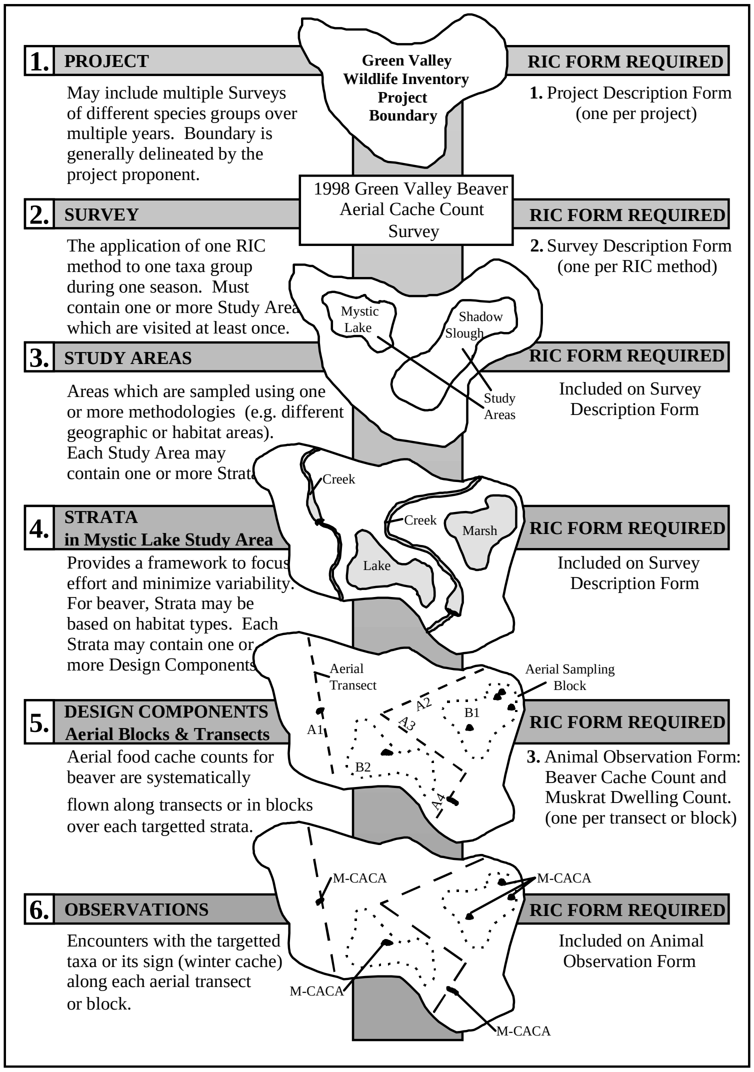

Figure 1. RIC species inventory survey design hierarchy with examples.

3.2 Inventory Surveys

The table below outlines the type of surveys that are used for inventorying beaver and muskrat for the various survey intensities. These survey methods have been recommended by wildlife biologists and approved by the Resources Inventory Committee.

Table 2. Types of inventory surveys, the data forms needed, and the level of intensity of the survey.

Survey Type	**Dataforms Required**	***Intensity**
Ground Physical Sign Survey Beaver	•Wildlife Inventory Project Description Form •Wildlife Survey Description Form - General •Animal Observation Form: Beaver & Muskrat Physical Sign	•PN
Ground Physical Sign Survey Muskrat	•Wildlife Inventory Project Description Form •Wildlife Survey Description Form - General •Animal Observation Form: Beaver & Muskrat Physical Sign	•PN
Food Cache (Colony) Count Beaver	•Wildlife Inventory Project Description Form •Wildlife Survey Description Form - General •Animal Observation Form: Beaver Cache (Colony) Count & Muskrat Dwelling Count	•RA
Ground Lodge Count Beaver	•Wildlife Inventory Project Description Form •Wildlife Survey Description Form - General •Animal Observation Form: Beaver & Muskrat Physical Sign	•RA
Ground Dwelling Count	•Wildlife Inventory Project Description Form •Wildlife Survey Description Form - General •Animal Observation Form: Beaver Cache (Colony) Count & Muskrat Dwelling Count	•RA

* PN = presence/not detected (possible); RA = relative abundance; AA = absolute abundance

3.3 Presence/Not Detected

Recommended method(s): Physical Sign ground survey for beavers and muskrats.

3.3.2 Physical Sign Survey for Beaver

Theoretically this method can be used anywhere in the province as it does not rely on an existing data base (*i.e.*, air photos) or the presence of trap lines. Ground surveys for beaver sign could be incorporated into existing aquatic inventory programs.

The presence of beavers can be signaled in a variety of ways: scent mounds, lodges, canals, slides, paths, dams, ponds, bank burrows, tracks, scats, feeding sign, sound (tail slap), smell (castoreum) and visuals, although the most reliable are observation of maintained lodges or dams, recent feeding sign, or visuals. Ground surveys of sign are most effective over small Study Areas. They may not be feasible in areas of difficult access (*e.g.*, remote areas or extensive wetlands) or large Study Areas. The alternative is to conduct aerial surveys and benefit from the additional information on relative abundance and density.

In relatively flat topography, such as in the boreal forests of the northeastern part of the province, presence of beavers can be influenced by long-term changes in water levels. Thus the researcher cannot assume that if beavers were not present in an area 10 years previously (during a dry part of the cycle), that they will not be there now.

Ground surveys for beaver sign could be combined with those for other animals occupying similar habitat (*e.g.*, muskrat).

Office procedures

- Review the introductory manual *Species Inventory Fundamentals* (*No.1).*
- Obtain relevant maps for the Project Area (*e.g.*, nautical charts, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). At minimum, a 1:50 000 map of region is needed, so that Study Areas can be delineated and the presence of beavers indicated. The detail of data recorded depends on the objectives for the Study Area and the extent of the area to be surveyed. Recent large scale (1:50 00, 1:10 000) air photos would be ideal for recording sign locations. Alternatively, large scale (*e.g.*, 1:20 000 planimetric) maps could be used. Information can be recorded directly onto the air photos in the field using a grease pencil. In some area 1:20 000 forest cover and TRIM maps show significantly more water bodies than 1:50 000 NTS maps, and may enable better delineation and coverage of a Study Area. Only used maps which are based on NAD83.
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the Project Area from maps.
- Select Study Areas that are likely to have suitable beaver habitat. Do this by stratifying the Project Area by habitat or based on expected densities. Waterbodies surrounded by significant deciduous cover should be given the highest priority.

Sampling standards

Time of year:

- Beaver sign is more likely to be encountered during the spring to fall period, when beavers are most active on shore and the types of sign are more varied.

- Surveys are generally best in the fall. Beaver sign may be most readily seen at this time because water levels are often low, lodge repair ("mudding" can be evident, and cutting activities are accelerated during cache construction.

Time of day and Weather:

- Obtaining a visuals of a beaver is most likely in the late afternoon and evening during calm weather. However, weather or time of day will have little influence if likelihood of encountering a cut tree or a lodge.

Sampling design

- Within Study Areas identify potential beaver habitat. At minimum this should involve all habitats adjacent to any water. Beavers are notorious for colonizing small streams and ponds that on first glance would appear unsuitable. Potential habitat should be identified before fieldwork begins using various information sources, including air photos and habitat, forest cover and TRIM/topographic maps.
- It is not necessary to have a rigid survey methodology when making presence/not detected assessments; however, there needs to be some means of keeping track of which areas or stream sections have been searched. To accomplish this, surveys are generally structured using infinitely-wide encounter transects. These are simply used as a means of recording survey routes and search locations, and so they do not need to be placed systematically.
- Non-random surveys would be more efficient in areas that include habitat unsuitable for beavers (*e.g.*, swift creeks). Set out transects along the perimeter of the wetlands and waterbodies or along streamsides. If the area is large select representative segments of the transects to sample; these may be chosen non-randomly in areas more likely to contain beavers. Alternatively, a large Study Area should be more effectively and efficiently surveyed by aircraft for more complete coverage..

Sampling effort

- Beavers generally produce conspicuous sign when they are present; thus, one thorough survey of an area should be sufficient to satisfy a Presence/Not Detected objective.

- If a Study Area is extensive and it is only possible to survey a portion of the total number of transect segments within suitable habitat, then an additional survey of "new" transects should be conducted during the prime fall activity period. Juvenile dispersal usually occurs during spring (Novak 1987) and surveys conducted after mid-summer should not miss newly-established individuals.

Personnel

- One or more people with expertise in detecting, identifying and interpreting animal sign, and, in particular, with the ability to recognize beaver sign from that of other aquatic or semi-aquatic animals.
- It is necessary to be able to distinguish recent beaver sign (indicative of present occupation) from old beaver sign (indicative of past occupation), and to be able to assign a relative age to that sign (*e.g.,* within the year versus historic).
- At least one person should be familiar with the collection of habitat data.

Equipment

- Waterproof marking pens
- Waterproof copies of maps or airphotos
- Waterproof field notebooks and data forms
- Clipboard
- Compass
- Binoculars or spotting scope
- Personal field gear
- Canoe or kayak with appropriate safety gear if conditions suitable

Field procedures

- Perimeter and scanning searches of wetlands and waterbodies or streamside transects can be used to look for beaver sign. Special emphasis should be placed on bays of larger lakes and side-channels of faster-flowing streams. Researchers should remember that any water can potentially harbor a beaver colony.
- All surveys are structured using infinitely-wide encounter transects showing the observer's route as a record which areas were actually searched.
- Surveys may be done on foot or by canoe or kayak if the conditions are suitable. The most thorough and efficient searches will probably be conducted by canoe or kayak if the water can be paddled. This generally allows more complete coverage of the water for lodges, caches, dams, and visual sightings, and provides better access to and vantage of shoreline for cut trees and canals/paths.

Data analysis

- As the objective of this survey is simply to evaluate the presence of beaver in different Study Areas, no statistical analysis is warranted. A table showing which Study Areas (or possibly, waterbodies) contain beaver would be appropriate. It is also generally useful to produce a map showing areas which were searched and the locations of beavers and their sign.
- Incidental observations of non-target species, especially those which are red or blue-listed are valuable and can be submitted to the province, preferably on Wildlife Sighting Forms.

3.3.3 Physical Sign Survey for Muskrats

The presence of muskrats is quite easily detected because of the variety and amount of sign they leave (Danell 1977). Muskrat sign may include: bank burrows, houses, nests (Westworth 1974), runways, feeding remains and feeding platforms, push-ups (in the winter), scats, tracks and visuals. The most obvious sign are houses and, in winter, pushups. Scat left on rocks, logs or other objects that protrude above the water (Danell 1977; Rezendes 1992) is one of the easiest types of evidence to find (Rezendes 1992).

Physical sign surveys for muskrat can be combined with those for other animals occupying similar habitat (*e.g.,* beaver).

Office procedures

- Review the introductory manual *Species Inventory Fundamentals (No. 1).*
- Obtain relevant maps for the Project Area (*e.g.*, nautical charts, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). At minimum, a 1:50 000 map of region is needed, so that Study Areas can be delineated and the presence of beavers indicated. The detail of data recorded depends on the objectives for the Study Area and the extent of the area to be surveyed. Recent large scale (1:50 00, 1:10 000) air photos would be ideal for recording sign locations. Alternatively, large scale (*e.g.,* 1:20 000 planimetric) maps could be used. Information can be recorded directly onto the air photos in the field using a grease pencil. In some area 1:20 000 forest cover and TRIM maps show significantly more water bodies than 1:50 000 NTS maps, and may enable better delineation and coverage of a Study Area. Only used maps which are based on NAD83.
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for Project Area from maps.
- Select Study Areas that are likely to have suitable muskrat habitat. Do this by stratifying the Project Area by habitat or based on expected densities. Ponds dominated by pondweed, cattail and milfoil should be given the highest priority.

Sampling standards

Time of year:

- Perhaps the easiest and most efficient way to determine simple presence of muskrats, is using winter surveys to look for push-ups. Push-ups are often readily observed during late winter when melting snows exposes them on the ice surface.
- Late spring or summer may be the best time to detect a variety of different types of sign because new vegetation growth is limited. However, house building continues until freeze-up (Boutin and Birkenholz 1987) and population levels are at their highest in the fall, suggesting that late fall surveys may have a greater chance of detecting fresh sign.
- In spring muskrat activity is intensified because it is mating season and they are active both day and night (Danell 1977). Visuals of muskrats may be most likely at this time if their houses are flooded during spring thaw (Danell 1977).
- Dispersal occurs in the spring and fall.

Time of day and Weather:

- Visuals of muskrats are greatest in the late afternoon and evening during calm weather, and they tend to be more active in the daytime during spring breeding.

Sampling design

- Within Study Areas identify potential muskrat habitat. At minimum, this should include all habitats in ponds, streams and other impoundments. Potential habitat should be identified before fieldwork begins using various information sources including air photos and habitat, forest cover and TRIM/topographic maps.
- It is not necessary to have a rigid survey methodology when making presence/not detected assessments; however, there needs to be some means of keeping track of which areas or stream sections have been searched. To accomplish this, surveys are generally structured using infinitely-wide encounter transects. These are simply used as a means of recording survey routes and search locations, and so they do not need to be placed systematically.
- Set out transects along the perimeter of the wetlands. If the area is large select representative segments of the transects to sample; these may be chosen non-randomly in areas more likely to contain muskrats. Alternatively, large Study Areas can be efficiently searched with aircraft following a systematic, transect-based survey design for more complete coverage.

Sampling effort

- Muskrats generally leave conspicuous sign to indicate their presence; thus, one thorough survey of an area should be sufficient to satisfy a Presence/Not Detected objective.
- If only a portion of the total transect segments within suitable habitat were surveyed or if the survey was conducted during spring, one more additional survey of “new” transects should be conducted during fall or winter to try to detect dispersers.

Personnel

- One or more persons with expertise in detecting, identifying and interpreting animal sign, and, in particular, with the ability to recognize muskrat sign from that of other aquatic or semi-aquatic animals.
- It is necessary to be able to distinguish recent muskrat sign (indicative of present occupation) from old muskrat sign (indicative of past occupation) and to be able to assign a relative age to that sign (*e.g.*, within the year versus historic).
- It is essential that personnel be able to determine whether or not houses and burrows are currently occupied by muskrats.
- At least one person should be familiar with the collection of habitat data.

Equipment

- Waterproof marking pens
- Waterproof copies of maps or airphotos
- Waterproof field notebooks and data forms
- Clipboard
- Compass
- Binoculars or spotting scope
- Personal field gear

- Canoe or kayak with appropriate safety gear if conditions suitable; snowshoes, skis, or snowmobile for winter study

Field procedures

- Muskrats have very flexible habitat requirements, therefore, unless habitat is clearly unsuitable for them (*e.g.*, ephemeral creeks or large open bodies of water with severe wave action) all habitat within the inventory area should be surveyed (Boutin and Birkenholz 1987).
- All surveys are structured using infinitely-wide encounter transects showing the observer's route as a record which areas were actually searched.
- Surveys may be done on foot or by canoe or kayak if the conditions are suitable. Surveys by watercraft may enable detection of muskrat sign more readily that shore-based surveys. Surveys may also be done on skis, snowshoes or by snowmobile in the winter. Remember to look for bank dwellings. Winter pushup surveys where ice forms will more readily detect muskrats regardless of dwelling type used.
- Although it is not necessary for a presence/not detected survey, information on dwelling types would be useful for any future studies.

Data analysis

- As the objective of this survey is simply to evaluate the presence of beaver in different Study Areas, no statistical analysis is warranted. A table showing which Study Areas (or possibly, waterbodies) contain beaver would be appropriate. It is also generally useful to produce a map showing areas which were searched and the locations of beavers and their sign.
- Incidental observations of non-target species, especially those which are red or blue-listed are valuable and can be submitted to the province, preferably on Wildlife Sighting Forms.

3.4 Relative Abundance

Recommended method(s): Food Cache Count (aerial, on ground or by boat) for Beaver or Ground Lodge Counts in areas where beavers do not regularly cache food (possibly coastal and southwestern B.C.; to be used with caution); Ground Dwelling count for Muskrat.

3.4.1 Food Cache (Colony) Count for Beaver

The best criteria for an active beaver colony is the presence of a fall food cache (Hay 1958; Bergerud and Miller 1977). There is one food cache per colony. There may also be fresh signs of recent activity (Potvin *et al.* 1992), for example, the lodge may have been recently plastered with mud (Banfield 1981). After comparing a number of survey techniques, Hay (1958) found aerial cache surveys to be both an accurate and practical means of determining the number of beaver colonies present in an area. Fuller and Markl (1987) suggest that colony counts are useful indices of relative abundance. They found that while mean family size per colony varies three-fold across North America, colony density may vary 10- to 100-fold among areas.

Ground or boat surveys may be alternatives to aerial cache counts, particularly if the inventory area is small or water access is especially good.

Office procedures

- Review the introductory manual *Species Inventory Fundamentals.*
- Obtain relevant maps for Study Area (*e.g.*, nautical charts , 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Various studies have used 1:50 000 topographic maps to record the location of colonies (Payne 1981; Payne 1982; Potvin *et al.* 1992). In some areas, 1:20 000 forest cover and TRIM maps show significantly more water bodies than 1:50 000 NTS maps, and may enable better delineation and coverage of the Study Area.. Air photos or forest cover/trim maps would also be useful for recording the locations of food caches, lodges and dams. Only used maps which are based on NAD83.
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for Project Area from maps.
- Select Study Areas that are likely to have suitable beaver habitat. Do this by stratifying the Project Area by habitat or based on expected densities. Waterbodies surrounded by significant deciduous cover should be given the highest priority.

Sampling standards

Time of year

- Surveys are best done after leaf-fall and before freeze-up (*e.g.*, Swank and Glover 1948; Hay 1958; Swenson *et al.* 1983; Novak 1987). The timing of this will vary annually and regionally across the province. Cache construction is accelerated as freeze-up approaches, so surveys conducted later in the fall will have greater likelihood of detecting caches. The possibility of observing caches from the air may be reduced along rivers that are narrow, or have downed trees and overhanging banks where caches may be placed, in which case, ground sign surveys could be conducted in the fall and expanded to include cache counts (Swenson *et al.* 1983).

Time of day and weather:

- Caches will be most visible under conditions of sunshine or high overcast with calm winds. Aerial surveys are much more pleasant to conduct with minimal air turbulence.

Sampling design

- Design depends on the habitat and distribution of waterbodies to be surveyed and aircraft used:
  - For gentle topography with lakes and ponds use area-based searches. These can be conducted by systematically surveying all streams, ponds and lakeshores in a given block. Accurate mapping using aerial photos or forest cover/TRIM maps can be helpful. Alternatively, Fuller and Markl (1987) surveyed 2.6 km^2 (1.0 mi^2) quadrats. Each quadrat was flown clockwise in slightly overlapping ever-decreasing concentric circles. Bergerud and Miller (1977) surveyed 2.6 km^2 blocks using a circling method. Area searches allow population estimates to be related to units of land rather than lengths of stream or water units (Bergerud and Miller 1977).
  - Where beavers inhabit river floodplains, surveys should be flown by transects (*e.g.*, Swenson *et al.* 1983). As complete coverage of meandering or multiple bed streams by fixed-wing is difficult, helicopter surveys would be more complete and accurate.
  - For rugged topography with rivers and streams use linear transect searches.
  - Survey efficiency (*i.e.*,the number of colonies present in an area that were actually found) can be assessed by re-surveying a portion of the area using twice the search intensity or an alternative survey method. With some replication, it may be possible to use the ratio of colonies counted in the initial survey to colonies counted in the subsequent, more intensive surveys as a correction factor for surveys of similar areas under similar environmental conditions.

Personnel

- Requires at least one person per flight that is familiar with identifying beaver fall and winter sign (*i.e.*, food caches and freshly mudded lodges) from the air. Aerial survey personnel should not be prone to motion sickness, as nausea makes it difficult to concentrate, to effectively spot lodges/caches, and to record data.

Equipment

- Waterproof marking pens
- Waterproof field notebooks, maps, clipboards and data forms
- Personal field gear, including binoculars if boat survey
- Aircraft or Boat as required

Field procedures

- A variety of aircraft have been used, but the most common seems to be the Super Cub (Bergerud and Miller 1977; Payne 1981; Swenson *et al.* 1983). Helicopters have been used in several studies (Payne 1981; Payne 1982; Potvin *et al.* 1992). Payne (1981) found that Super Cubs were about half as efficient as helicopters for censusing beaver colonies, although far less expensive. The Turbo Beaver was adequate for censusing, but required two observers for best results (Payne 1981). Helicopters generally provide greater survey efficiency, especially when surveying meandering channels. Choice of aircraft is a function of the available budget. Aircraft should be equipped with an intercom to facilitate communication.

- The survey should be flown at a low altitude and as slow a speed as possible within safety margins. Studies suggest an altitude of 100-200m, and an air speed of 100-130 kph (Swenson *et al.* 1983; Fuller and Markl 1987). At a search rate of 1.6-2.3 min/km^2 , Fuller and Markl (1987) believe few if any colonies were missed.
- In a Super Cub (or other two-seat aircraft), the observer is also the data recorder, navigator, and mapper, thus the pilot has to be an active, interested observer during the survey.
- Daily flight times should be kept to less than 5-6 hours/day to minimize observer fatigue.
- UTM coordinates of active lodges are required for the survey data forms, and should be recorded using the aircraft's GPS. Alternatively, if lodge locations are accurately mapped on aerial photos or forest cover/TRIM maps produced by a GIS, UTM coordinates of lodges can be obtained through post-survey processing. Regardless of how they are obtained, UTM coordinates should be georeferenced to NAD83.

Data analysis

Relative abundance can be reported as:

- # of food caches (colonies) per unit area
- # of food caches (colonies) per length of transect

It is generally also useful to include a map showing search areas and/or transects as well as the locations of caches and other beaver sign.

Estimating the Number of Individuals (optional)

Swenson *et al.* (1983) suggest that colony counts may show gross changes in beaver populations, but since variations in colony size are not evident from such counts, they would not detect changes in the number of individuals. However, unless a beaver population is being managed very intensively, cache counts alone will likely be an adequate inventory method. If an estimate of the number of individuals is considered essential, then the recommended method is to use values for mean colony size as reported for other studies, in conjunction with aerial food cache surveys. An analysis of the harvest data for use with Novak's (1977) formula is also a recommended method; however, this approach may not be feasible in some areas (*e.g.*, no active trap lines). Cache size should not be used to estimate beaver colony size, since the relationship in some areas is questionable and unproven (Osmundson and Buskirk 1993). Trapping is generally not recommended for inventory purposes unless it is part of a larger study examining population and habitat characteristics.

An estimate of the actual number of individual beavers can be determined by multiplying the number of colonies in an area by the mean colony size. This estimate relies heavily on assumption, and should be not be misinterpreted as anything but a coarse estimate of abundance. The following are three basic methods for determining mean colony size.

i) The simplest approach is to use values for mean colony size that have been reported in the literature. However, it is important to distinguish between estimates of mean colony size that include single and pair colonies with family colonies, and those that include only family colonies; and to know whether colonies were chosen at random for trapping (Payne 1982). Estimates for selected studies in mid-latitude North America range from 4.6-7.6 beavers per family colony; and 3.4-4.6 beavers per colony (Payne 1982). Banfield (1981) gives 5.7 as average colony size (includes single occupant lodges) in Canada. This approach will provide a rough estimate of the number of individuals, but obviously will not track year to year changes in abundance resulting from varying colony size.

ii) A slightly more complicated approach is to utilize information from a trapped (dead) sample of beavers to calculate mean family size and composition during the trapping season. Novak's (1977) formula is based on the assumptions that a colony has a dominant breeding pair (1.5 years or older) as its basic unit; that the age distribution of the trapped sample is representative of the population; and that there are no single occupant colonies. A record of the number of colonies trapped is not required. The limitation is obtaining an adequate sample size, particularly of reproductive organs. The yearling breeding component is a complicating factor as is knowing whether or not single occupant colonies occur.

Novak's (1977) formula:

$$\frac{\text{\%Kits + \% Nonbreeding Yearlings}}{\text{\%Adults + \%Breeding Yearlings}} = \frac{N}{\text{2.0 + Non-Breeding Adults}}$$

where N = number of kits and yearling and 2.0 is the breeding pair. Therefore, average family size = N + 2.0 + non-breeding adults (Novak 1987).

Swenson *et al.* (1983) offer a revision to this formula which includes additional non-breeding age classes present in their study area. Hay (1958) cautions that techniques based on population constants are inapplicable in the presence of factors such as animal control trapping, sudden habitat loss through logging, clearing or road building, and the effects of pollution, siltation and overuse by humans and livestock.

iii) The most complicated and expensive approach involves trapping of entire colonies to determine the mean colony size. Much labour, time, expense and disturbance to the animals is involved in this procedure, and the resulting estimates may be unreliable. Hay (1958) found live-trapping to be unreliable as an intensive census method (*e.g.*, time-consuming, kits often not caught), and so he used kill trapping to determine the average number of beavers per colony. Novak (1987) believes that trappers rarely catch all the beavers in a lodge and thus estimates based on kill trapping are conservative. Trapping in general to determine colony size is not recommended, as it is expensive and produces inconsistent results. Kill trapping beavers for research purposes is inappropriate.

3.4.2 Ground Lodge Count for Beaver

In areas where beavers do not regularly construct food caches (*i.e.*, areas where there is seldom heavy ice cover; possibly coastal and/or southwestern B.C.) a cache count is of little use (Swenson *et al.* 1983). An alternative method under these circumstances is a lodge count; however, this approach is confounded by the fact that a colony may build more than one lodge in the summer (Hay 1958). Thus, although a summer ground lodge count will provide an indication of the number of lodges in an area, it will not necessarily reflect the number of colonies, since up to three summer lodges may be maintained by a single colony (Hay 1958). Trend and abundance data obtained from this inventory method must be used with caution, since there is no way to relate the number of summer lodges observed to the number of colonies occupying the area, or to know if the number of summer lodges/colony changes with time or among habitats. There are little comparative data in the literature on lodge counts (as opposed to cache counts).

Fall ground lodge counts have a better chance of determining the number of colonies in an area because summer lodges are abandoned in favour of a single lodge for winter quarters. Fresh mudding and freshly cut sticks on the lodge should indicate whether a lodge is occupied. Signs of recent activity are better observed from the ground, in areas where food caches are not constructed.

Protocol

For Ground Lodge Counts for Beavers, follow the same protocol as that found in section 3.3.2 Physical Sign Surveys for Beavers.

Considerations for Ground Lodge Counts for Beavers

The objective of this type of inventory should be clearly thought out prior to initiation of Ground Lodge Counts. Determination of the number of colonies per unit area or length of transect will not be possible using this technique. Fall ground counts have a better chance of enumerating lodges used for winter quarters (one per colony). Extra time and several revisits to an area may be needed to reliably determine lodge occupancy.

Data analysis

Relative abundance can be reported as:

- # of food caches (colonies) per unit area
- # of food caches (colonies) per length of transect

These numbers must be accompanied by statements as to the limitations of this method. Specifically, it should be stressed that lodges do not equate to colonies, and that the number of lodges is likely greater than the number of colonies due the potential for one colony to maintain up to three different lodges.

It is generally also useful to include a map showing search areas and/or transects as well as the locations of lodges and other beaver sign.

3.4.3 Ground Dwelling Count for Muskrat

Ground counts of dwellings are recommended to obtain relative abundance data for musktrats. Ideally, a biologist using this method should have some baseline information (*e.g.*, relative use of burrows and houses) on the muskrat population to be inventoried. This is probably not likely and so it is important to recognize the problems associated with an inventory based on a count of muskrat dwellings, and take the following factors into consideration to achieve the most accurate estimate of abundance:

i) Observers must be able to differentiate between houses and other structures (primarily push-ups), and determine whether or not a dwelling (house or burrow) is occupied (Sather 1958). Proulx and Gilbert (1984) found that aerial counts in fall would have overestimated the population if all emergent structures were recorded as active houses. Houses are easy to count from an aircraft, but one cannot reliably determine whether or not they are occupied from the air (Sather 1958; Danell 1982). Parker and Maxwell (1980) apparently were able to distinguish active versus inactive houses from the air when flying 30-40 m above the ground in a helicopter. However, Brooks and Dodge (1986) indicated that periodic ground reconnaissance appeared to be the only way to accurately assess muskrat abundance in riverine environments, and Sather (1958) felt that ground surveys were better than aerial surveys. Burrows can only be surveyed on the ground.

ii) Unless it is known or believed that the muskrats in question only live in houses, the inventory should include a count of both houses and burrows. The relative use of burrows versus houses may shift with changes in population density (Sather 1958; Messier and Virgl 1992) on a seasonal and annual basis.

iii) Changes in number and distribution of dwellings may be a reflection of changes in parameters other than population size. For example, Kroll and Meeks (1985) indicated that broad fluctuations in the number of houses per marsh unit were likely the results of changes in water level created by drawdowns and differing vegetation communities among units, that is, muskrats moved between units. In Proulx and Gilbert's (1984) study area, the number of fall houses did not signify a relative change in number of muskrats from year to year, but instead indicated how building activity varied with water level conditions and with the amount of accessible vegetation.

Where muskrats are known to live solely in houses and where these are destroyed annually (*e.g.*, due to spring floods) Danell (1982) suggests that house counts are the most appropriate method for censusing muskrats. However, Boutin and Birkenholz (1987) felt that although the house count technique is widespread its accuracy is questionable. Changes in the number of houses or push-ups in a study area probably represent general population changes but more research is needed to determine the link between house numbers and muskrat densities (Boutin and Birkenholz 1987). Messier and Virgl (1992) assumed that for their study the number of dwellings constituted an unbiased index of muskrat abundance.

Unless there is an opportunity for an intensive study, a ground survey to count active dwellings is the recommended approach to obtain an estimate of relative abundance.

Office procedures

- Review the introductory manual *Species Inventory Fundamentals.*
- Obtain relevant maps for the Project Area (*e.g.*, nautical charts, 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Recent large scale (1:5 000, 1:10000) air photos would be ideal for recording dwelling locations.

Information can be recorded directly onto the air photos in the field using grease pencil. Parker and Maxwell (1980) plotted house distribution on air photo mosaics (1:38 500). Alternatively large scale (*e.g.*, 1:20 000 planimetric or forest cover/TRIM) maps could be used (provided they are based on NAD83).

- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for Project Area from maps.
- Select Study Areas that are likely to have suitable muskrat habitat. Do this by stratifying the Project Area by habitat or based on expected densities. Ponds dominated by pondweed, cattail and milfoil should be given the highest priority.

Sampling design

- Surveys must utilize a sampling regime which is either based on fixed-width transects or quadrats. Whichever design is chosen, it must be applied consistently among Study Areas and/or years, if relative comparisons are required. It must also be well documented.
- If data are to be extrapolated, replication of samples will be necessary.
- Design depends on the habitat to be surveyed (*e.g.*, marsh vs. stream) and the time of year of the survey:
  - Proulx and Gilbert (1984) used transects in marsh and canoe surveys along shorelines.
  - Freeman (1945) used strip transects through marshes.
  - Brooks and Dodge (1986) counted the number of houses in 250 x 250 m quadrats in wetlands and extrapolated from this to the entire wetland.
  - Danell (1982) suggests covering the area by foot (preferably when ice-covered) or by canoe.
  - Kroll and Meeks (1985) conducted late winter house counts using an ATV on ice.
- Where ice cover is complete, a systematic late winter house count can be effective, using snowmobile, snowshoes or skis. Counts during summer or fall should be strip transects through marshes (strip width will vary with visibility) or complete shoreline surveys by canoe. With stratification, surveys of selected quadrats may allow a statistical estimate of the number of dwellings in the entire marsh.

Sampling effort

- The best approach would be to conduct surveys in each season and repeat this on an annual basis. Since this may not always be feasible, the limitations of the inventory must be recognized if it is not repeated in different seasons.
- Muskrats appear to have cyclic populations both on an annual and seasonal basis - this is an essential consideration in population estimates. Surveys should be conducted in two or more consecutive years if trend data are required.
- The time required to complete a survey depends on the size of the area to be surveyed and the visibility of houses and burrows. Parker and Maxwell (1980) felt that by using an intensive and systematic search, few houses were left unrecorded.

Sampling standards

Time of year:

  - Spring counts showed variation from year to year because of high water and flooding conditions (Parker and Maxwell 1980). Clay and Clark (1985) found that in late spring the population increased as flood-displaced muskrats returned to their original habitats after seeking refuge in wooded areas or other unusual locations until waters receded. Consequently, spring counts should be done late in the season.

- The problem with summer surveys is that houses may be harder to see when marsh vegetation is fully developed (Boutin and Birkenholz 1987). Proulx and Gilbert (1984) suggest house counts in summer are an alternative to fall surveys in areas where muskrats seldom use burrows in the summer.
- In areas where muskrats generally use burrows in summer, house counts in fall or winter are more reliable (Proulx and Gilbert 1984). Timing of house counts is crucial as house-building continues until freeze-up. Counts should be done as late in the season as possible (Boutin and Birkenholz 1987). For example, Parker and Maxwell (1980) conducted fall surveys after first ice, but before extensive snow cover. However, the problem with waiting for ice formation is that, although houses may be more reliably counted, burrows can not be counted under once ice has formed.
- Messier and Virgl (1992) conducted systematic surveys for dwellings during the ice-free months and marked the dwellings with stakes. They did not do winter surveys. Overwinter occupancy was assessed based on the last survey in fall and first survey in spring.

Personnel

- Require one or more people with expertise in detecting, identifying and interpreting animal sign, and, in particular, with the ability to recognize muskrat sign from that of other aquatic or semi-aquatic animals.
- It is necessary to be able to distinguish recent muskrat sign (indicative of present occupation) from old muskrat sign (indicative of past occupation) and to be able to assign a relative age to that sign (*e.g.*, within the year versus historic).
- It is essential that personnel be able to determine whether or not houses and burrows are currently occupied by muskrats.

Equipment

- Waterproof marking pens
- Waterproof copies of maps or airphotos
- Waterproof field notebooks and data forms
- Personal field gear, including chest or hip waders.
- Canoe or kayak with appropriate safety gear if conditions suitable; snowshoes, skis, ATV or snowmobile if winter study

Field procedures

- Walk transects along marshes, use canoe trasencts along shorelines. Transects should be a fixed width, to ensure the area is covered. Transect width will depend on visibility. All dwellings >30 cm above the water with fresh muskrat sign should be recorded (Proulx and Gilbert 1984). The area surveyed should be documented on aerial photos or maps to ensure complete coverage.
- In wetlands count the number of houses in a block quadrat or quadrats and extrapolate this to the entire wetland; sampling within an area stratified based on expected muskrat distribution can refine the estimate for the wetland. Cover the area by foot (preferably when ice-covered) or by canoe. House counts can also be conducted in late winter using an ATV or snow machine on ice.

- UTM coordinates of dwellings are required for the survey data forms, and should be recorded using a handheld GPS. Alternatively, if lodge locations are accurately mapped on aerial photos or forest cover/TRIM maps produced by a GIS, UTM coordinates of lodges can be obtained through post-survey processing. Whichever method is used, UTM coordinates must be referenced to NAD83.

Data analysis

Relative abundance can be reported as:

- # of dwellings per unit area
- # of dwellings per length of transect

These numbers must be accompanied by statements as to the limitations of this method. Specifically, it should be stressed that the type of dwelling (*e.g.*, house vs. burrow) may influence its detectibility, and thus, the types of dwellings in an area may potentially influence how many are counted. The seasonal presence or absence of certain dwelling-types may also influence counts.

If count numbers are to be extrapolated to a larger area, this should be based on replicated counts which similar environmental characteristics to the larger area.

It is generally also useful to include a map showing search areas and/or transects as well as the locations of lodges and other beaver sign.

Estimating the Number of Individuals (optional)

Unless a muskrat population is being managed very intensively, dwelling counts alone will likely be adequate. If an estimate of the number of individuals is considered essential then the recommended method is to use values for mean number of occupants per dwelling as reported for other studies in similar habitats, in conjunction with ground counts of dwellings. This method relies heavily on assumptions and will not permit tracking of year-to-year changes in abundance resulting from varying numbers of occupants per dwelling.

A reliable count of individual muskrats is difficult to obtain without very intensive work. An estimate of the number of individuals can be determined by multiplying the number of occupied houses and burrows in an area by the mean number of occupants. This approach should not be misinterpreted as anything but a coarse estimate of abundance. The following are two basic methods for determining mean number of muskrats per dwelling.

i) The simplest approach is to use values for mean number of occupants that have been reported in the literature. However, it is important to remember that this value varies from year to year (Boutin and Birkenholz 1987), and may vary between seasons. The mean number of muskrats per house that has been used as a conversion factor to estimate population size varies from 2.5 to 6 (Freeman 1945; Westworth 1974; Parker and Maxwell 1980; Proulx and Gilbert 1984; Boutin and Birkenholz 1987). Sather (1958) assumed each active dwelling to have the number of muskrats corresponding to the average litter size. He used 6.9 as average number of young per litter (as obtained from placental scar counts).

ii) Live or dead trapping of all occupants in houses and burrows. Much labour, time and disturbance to the animals is involved in this procedure. Danell (1982) suggests trapping all muskrats which are living within a chosen number of adjacent houses. The muskrats can be eartagged using a handling cone, and trapping can be continued until only tagged individuals are caught. Mark-recapture population estimates could be the next stage of a live-trapping program, however, Boutin and Birkenholz (1987) suggest that, although accurate, mark-recapture is expensive and labour-intensive which makes it unrealistic for most management situations. Trapping programs in general are not recommended for inventory purposes unless they are part of larger studies examining population and habitat characteristics. Kill trapping of muskrats for research is inappropriate.

3.5 Absolute Abundance

Recommended method(s): No cost-effective, reliable methods are recommended at this time.

Glossary

ABSOLUTE ABUNDANCE: The total number of organisms in an area. Usually reported as absolute density: the number of organisms per unit area or volume.

ACCURACY: A measure of how close a measurement is to the true value.

BIODIVERSITY: Jargon for biological diversity: the variety of life forms, the ecological roles they perform, and the genetic diversity they contain (Wilcox 1984 cited in Murphy 1988).

BLUE LIST: Includes any indigenous species or subspecies (taxa) considered to be Vulnerable in British Columbia. Vulnerable taxa are of special concern because of characteristics that make them particularly sensitive to human activities or natural events. Blue-listed taxa are at risk, but are not extirpated, endangered or threatened.

CACHE (beaver): A store of winter food, composed of sunken pile of deciduous branches, usually located in deep water near a beaver lodge. This is created by beavers piling branches in the deep water until the whole mass sinks. The presence of a cache in autumn generally indicates an active colony (Banfield 1974).

COLONY: A group of beavers which occupy the same aquatic habitat and share a common winter cache. A colony is normally composed of an adult pair, kits, and yearlings of the previous year. This may consist of 10-12 individuals in the fall; however, a colony may also be as small as one individual (Banfield 1974).

CREPUSCULAR: Active at twilight

DIURNAL: Active during the daytime

MONITOR: To follow a population (usually numbers of individuals) through time.

NOCTURNAL: Active at night

POPULATION: A group of organisms of the same species occupying a particular space at a particular time.

PRECISION: A measurement of how close repeated measures are to one another.

PRESENCE/NOT DETECTED (POSSIBLE): A survey intensity that verifies that a species is present in an area or states that it was not detected (thus not likely to be in the area, but still a possibility).

PROJECT AREA: An area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resource and/or species inventory. Sampling generally takes place within smaller Study Areas within this Project Area.

PUSH-UP (muskrat): A dome of vegetation covering a plunge hole in the ice on the surface of a pond or lake, in which a muskrat feeds in winter. A muskrat begins to maintain plunge holes as soon as the first freeze comes in the fall, by chewing through the ice and pulling up the submerged vegetation which acts as insulation. A muskrat will continue to do this all winter long, although towards spring, push-ups are often seen to freeze over due to poor insulation or abandonment (Banfield 1974).

RANDOM SAMPLE: A sample that has been selected by a random process, generally by reference to a table of random numbers.

RED LIST: Includes any indigenous species or subspecies (taxa) considered to be Extirpated, Endangered, or Threatened in British Columbia. Extirpated taxa no longer exist in the wild in British Columbia, but do occur elsewhere. Endangered taxa are facing imminent extirpation or extinction. Threatened taxa are likely to become endangered if limiting factors are not reversed. Red-listed taxa include those that have been, or are being, evaluated for these designations.

RELATIVE ABUNDANCE: The number of organisms at one location or time relative to the number of organisms at another location or time. Generally reported as an index of abundance.

STRATIFICATION: The separation of a sample population into non-overlapping groups based on a habitat or population characteristic that can be divided into multiple levels. Groups are homogeneous within, but distinct from, other strata.

STUDY AREA: A discrete area within a project boundary in which sampling actually takes place. Study Areas should be delineated to logically group samples together, generally based on habitat or population stratification and/or logistical concerns.

SURVEY: The application of one RIC method to one taxanomic group for one season.

SURVIVORSHIP: The probability of a new-born individual surviving to a specified age.

SYSTEMATIC SAMPLE: a sample obtained by randomly selecting a point to start, and then repeating sampling at a set distance or time thereafter.

YELLOW-LIST: Includes any native species which is not red- or blue-listed.

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