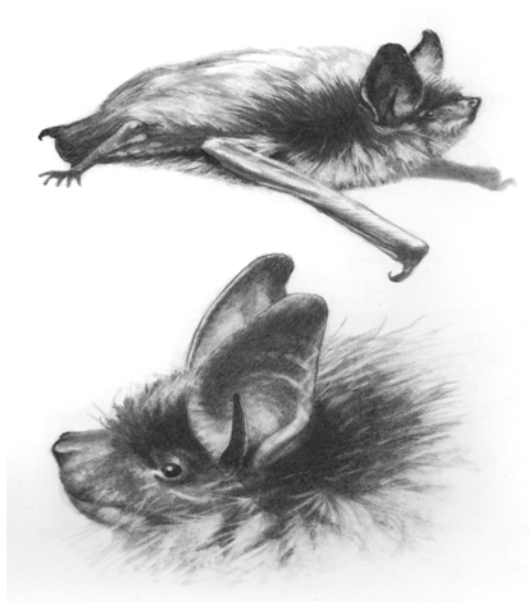
COSEWIC
Assessment and Update Status Report

on the

Keen's Long-eared Bat
Myotis keenii

in Canada



DATA DEFICIENT
2003

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE
IN CANADA

COSEPAC
COMITÉ SUR LA SITUATION
DES ESPÈCES EN PÉRIL
AU CANADA

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC
Assessment Summary

Assessment Summary – November 2003

Common name
Keen's long-eared bat

Scientific name
Myotis keenii

Status
Data Deficient

Reason for designation
The situation for this species is generally similar to that for any species of bats that occur in Canada. There are no data about population sizes, population trends, or patterns of reproduction (it is not known if females bear young annually; age at sexual maturity is unknown), and there are only scattered records documenting occurrence and patterns of distribution. Furthermore, there is a lack of information about patterns of habitat use (roosting, foraging) and about migration. Uncertainty about the taxonomic status of this species further complicates the matter. It is unknown if it is a distinct taxon. It is unknown if this is a distinct population.

Occurrence
British Columbia

Status history
Designated Special Concern in April 1988. Status re-examined in November 2003 and designated Data Deficient. Last assessment based on an update status report.

COSEWIC
Executive Summary

Keen's Long-eared Bat
Myotis keenii

Species information

Keen's long-eared bat *Myotis keenii* (Merriam, 1895) is one of 6 morphologically very similar long-eared *Myotis* bats found in North America. Taxonomically, it is placed in the *evotis* group along with the western long-eared bat (*M. evotis*), northern long-eared bat (*M. septentrionalis*) and southwestern *myotis* (*M. auriculus*), although recent mtDNA analysis has demonstrated that it may actually be in a monophyletic group with *M. evotis*, fringed bat (*M. thysanodes*) and Miller's *myotis* (*M.* milleri). *M. keenii* and *M. evotis* are morphologically so similar that they are impossible to identify in the field, making this species difficult to study in southwestern BC and western Washington where the two are sympatric. Their low mtDNA sequence divergence suggests that *M. keenii* and *M. evotis* could be conspecific.

Distribution

Globally, *M. keenii* has one of the most restricted distributions of any bat in North America, being limited to western Washington State, western British Columbia and southeastern Alaska. It is the only North American bat confined to the Pacific coast. It has been recorded at twenty-five locations in Canada.

Habitat

Ecomorphological characteristics (short, broad wings and long ears) and a high frequency, low intensity echolocation call suggest that *M. keenii* is adapted to a coastal old growth rainforest environment, although it does not appear to be limited to this habitat. It has also been captured foraging in estuaries, riparian habitats, and urban environments.

M. keenii is known to roost in rock crevices and under boulders, but has also been found roosting in trees and buildings, and under bridges. The only maternity colony described in detail is unusual in that it is associated with hydrothermal activity. At Gandl K'in Gwaayaay, Haida Gwaii, approximately 40 reproductive females take advantage of heated crevices, boulders and a small cave in which to roost and raise their young. The only other known maternity colony was suspected to be in a tree located in a low elevation, southwest-facing cliff at Knoll Hill near Tahsis, Vancouver Island.

The only known hibernacula are on northern Vancouver Island where *M. keenii* has been found in 8 caves from 3 separate areas. In the Weymer Creek drainage, 4 species of bats have been captured while 'swarming' in August at the entrances of at least 14 high elevation (550 m – 945 m) caves, and *M. keenii* has been confirmed as hibernating in three of them. Conditions where bats were hibernating were a constant 100% relative humidity and a stable temperature of 2.4 ^{o} – 4.0^{o} C.

Biology

Detailed reproductive information comes from a two-year study of the Gandl K'in Gwaayaay maternity colony on Haida Gwaii. Female *M. keenii* returned to this colony near the end of May, and parturition occurred during early July. Non-reproductive females and males did not appear to use the nursery roosts before July. Young became volant by early August but continued to use the nursery roosts into early September. Adults left the colony once young were flying.

Reproductive chronology of the bats at the Gandl K'in Gwaayaay maternity colony was variable and dependent on weather conditions. For *M. keenii*, gestation appeared to be shorter during the cool, wet year of 1999 than during the warm, dry year of 1998. This was attributed to its ability to glean prey, which allowed it to continue to forage under cool, wet conditions when insects were less likely to be flying, and to prey on non-flying invertebrates. Results of faecal analysis supported this conclusion in that *M. keenii* at Gandl K'in Gwaayaay fed primarily on spiders and Lepidoptera. There was no evidence that food was a limiting factor.

M. keenii is probably long-lived like most other bats. The oldest known *M. keenii* was 12 years and 11 months old at the time of recapture.

Population sizes and trends

No estimates of population size or trend are available for this species. The maternity colony at Gandl K'in Gwaayaay has remained viable for at least the last 40 years despite extensive scientific collections during the 1960s. Population estimates made during the 1990s indicate that it remained stable between 1991 and 2000. Elsewhere within its range, *M. keenii* is rarely encountered although this may be due in part, to the problem of identifying it in the field.

Limiting factors and threats

Habitat loss may be an important threat to *M. keenii*. Although *M. keenii* does not appear to be limited to coastal old growth forests, it does forage in these habitats. These forests continue to be logged, and patches of old growth forest are becoming scarce.

Disturbance resulting from human activities is also an important threat, as all known hibernacula remain open to recreational cavers. Hibernating bats are particularly vulnerable to disturbance and winter arousal, which are energetically demanding and could exhaust a bat's fat reserves. While forest harvesting activities near cave entrances do not appear to modify cave microclimate, fallen debris may block access and blasting activities from road construction could arouse hibernating bats.

M. keenii 's behaviour of flying close to the ground makes it vulnerable to predation by cats and possibly other mammals such as raccoons, marten, squirrels and rats. It is also vulnerable to predation by deer mice (*Peromyscus maniculatus*, *Peromyscus keeni*) during hibernation and when roosting under boulders or in crevices. Owls occasionally prey on bats but the significance of this predator on *M. keenii* is unknown.

Special significance of the species

M. keenii is of special significance because about 80% of its range occurs within Canada. It is currently the only bat species listed as an Identified Wildlife Species under the Identified Wildlife Management Strategy of the British Columbia Provincial Forest and Range Practices Code.

Existing protection or other status designations

This species is not listed by the IUCN. It was designated as a Species of Special Concern by COSEWIC in 1988 (see Balcombe 1988). The global heritage status rank is G2; national ranks are N1 for the United States and N1N3 for Canada. *M. keenii* is ranked SH for both Alaska and Washington States. British Columbia has designated the species as S1S3 and also provides protection from it being killed under the provincial Wildlife Act.

To date, only one Wildlife Habitat Area has been designated (Knoll Hill Cave) under the Forest and Range Practices Code — it protects a maternity site near Tahsis, Vancouver Island. Nearby, Weymer Cave and White Ridge Provincial Parks protect areas that support *M. keenii* hibernacula and roosting habitat. The former park has a draft management plan that identifies the need to protect the bat roosts, but also identifies recreational caving, hiking, and tourism as acceptable park activities. The latter park has no management plan. The maternity colony at Gandl K'in Gwaayaay is protected by Gwaii Haanas National Park Reserve and Haida Heritage Site. An area plan has been prepared for the island that documents the re-development of the area while taking into consideration the protection of the colony. Gwaii Haanas staff monitor bat use of the colony and the island for the presence of introduced species.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species and include the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal organizations (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biosystematic Partnership, chaired by the Canadian Museum of Nature), three nonjurisdictional members and the co-chairs of the species specialist and the Aboriginal Traditional Knowledge subcommittees. The committee meets to consider status reports on candidate species.

DEFINITIONS
(After May 2003)

Species	Any indigenous species, subspecies, variety, or geographically or genetically distinct population of wild fauna and flora.
Extinct (X)	A species that no longer exists.
Extirpated (XT)	A species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A species facing imminent extirpation or extinction.
Threatened (T)	A species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Not at Risk (NAR)**	A species that has been evaluated and found to be not at risk.
Data Deficient (DD)***	A species for which there is insufficient scientific information to support status designation.

* Formerly described as “Vulnerable” from 1990 to 1999, or “Rare” prior to 1990.

** Formerly described as “Not In Any Category”, or “No Designation Required.”

*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994.

Environment Canada / Environnement Canada
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Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

Update
COSEWIC Status Report

on the

Keen's Long-eared Bat
Myotis keenii

in Canada

2003

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SPECIES INFORMATION

Name and classification

Keen's long-eared bat, *Myotis keenii* (Merriam, 1895), belongs to the Order Chiroptera, Family Vespertilionidae. Findley (1972) assigned the North American long-eared *Myotis* species *M. keenii*, northern long-eared *Myotis* (*Myotis septentrionalis*), western long-eared bat (*Myotis evotis*), and the southwestern bat (*Myotis auriculus*) to the *evotis* group within the subgenus *Myotis*. The *evotis* group may also include Miller's *Myotis* (*Myotis milleri*) and the fringed bat (*Myotis thysanodes*). Although they share a number of similar morphological and behavioural traits, Manning (1993) speculated that North American long-eared *Myotis* were not a monophyletic group. Reducker et al. (1983), however, suggested that, based on chromosomal, electrophoretic, and mtDNA sequence data this group is monophyletic. The most recent mtDNA analysis by Dewey (unpublished data) indicates that only *M. evotis*, *M. keenii*, *M. thysanodes* and *M. milleri* form a monophyletic group.

Taxonomy of *M. keenii* and related species of long-eared *Myotis* is complex with a confusing nomenclatural history. This taxon was first described and named by Merriam (1895) who treated it as a subspecies of *Verspertilio subulatus*. The type locality for the type specimen (USNM 729220) is Masset, Graham Island, Queen Charlotte Islands, British Columbia. Miller (1897) subsequently classified this species as a member of the genus *Myotis* (*Myotis subulatus keenii*). In their taxonomic revision of American *Myotis*, Miller and Allen (1928) treated *M. keenii* as a distinct species, *Myotis keenii* with two allopatric subspecies: a coastal form *M. keenii keenii* and a central-eastern form *M. keenii septentrionalis*. Although a third subspecies (*M. keenii auriculus*) was recognized by Findley (1960) when he assigned long-eared *Myotis* from the southwestern United States to this species, Genoways and Jones (1969) treated the *auriculus* group as a distinct species *M. auriculus*, an arrangement recognized by most taxonomists. Based on a multivariate study of morphological traits, van Zyll de Jong (1979) concluded that *M. k. keenii* and *M. k. septentrionalis* were separate species distinguished by cranial, dental, and pelage characters. The two taxa were formally recognized as distinct species by van Zyll de Jong (1985) and Jones et al. (1986).

Taxonomists (e.g., Manning, 1993) have generally considered *M. septentrionalis* to be the closest relative among the long-eared *Myotis* species to *M. keenii*. However, from morphological and biogeographic evidence, van Zyll de Jong and Nagorsen (1994) concluded that *M. keenii* was most closely related to *M. evotis*. Using discriminant function analysis, they found that *M. keenii* from Haida Gwaii (=Queen Charlotte Islands)[1] and *M. evotis* from areas east of the Coast Mountains showed no morphological overlap, and museum specimens from coastal areas of British Columbia could be confidently assigned to either species. Specimens from western Washington, however, showed some overlap in their morphology. They suggested that the two species were parapatric, with *M. keenii* being found in coastal regions, while *M. evotis* was found primarily east of the coastal mountain ranges. They speculated that *M. keenii* may have evolved in a coastal

[1]We use the Haida name Haida Gwaii for the Queen Charlotte Islands throughout this report.

refugium. Because they had few samples from the lower Fraser River valley, southeastern Vancouver Island, and western Washington State where the ranges of the two species overlap, they were unable to assess introgression.

Results from a recent molecular study using mtDNA (cytochrome b gene) by Tanya Dewey (unpublished data) support the close association of *M. keenii* to *M. evotis* and their distant relationship with *M. septentrionalis* (Fig. 1). Sequence divergence between *M. keenii* and *M. septentrionalis* was greater than 10% consistent with differentiation at the species level (Bradley and Baker 2001). Dewey also identified 3 relatively distinct lineages within *M. keenii/ evotis* – a clade corresponding to the present range of *M. keenii*, an *evotis* clade found in southern BC, Washington and Oregon, and an *evotis* clade found primarily in Alberta through to South Dakota. The *M. evotis* and *M. keenii* clades are largely allopatric, but individuals from both clades were found at the same location in the Skeena Mountains, and all 3 clades are represented in the Skagit valley. The sequence divergences among these lineages range between 0.8% and 3.3%, which, according to Bradley and Baker (2001) are well within the range of intraspecific divergence. Dewey's results thus suggest that *M. evotis* and *M. keenii* are conspecific, with *M. keenii* representing a coastal subspecies. Until a broad systematic study is done integrating molecular (nuclear and mitochondrial DNA) and morphological data, however, we recommend that *M. keenii* be treated as a distinct taxonomic unit for conservation and management.

Other common names used for this species include: Keen's bat, Keen's *Myotis*, and Keen's long-eared *Myotis*. The French common name is Vespertilio de Keen. We know of no Aboriginal name specific to this bat species. The Haida, for example, collectively referred to bats as "GudGadu Gamhlgaal" (pronounced "Goot gaado gum hl gaal"), which translates into "the animal that hangs upside down" (B. Wilson, pers. comm.). Consultation with other Aboriginal groups indicates that there appears to be no cultural memory of bats (N. Crookes, pers. comm.; H. Morven, pers. comm).

Description

M. keenii is a small bat (Fig. 2) with dark brown dorsal fur and indistinct shoulder patches (van Zyll de Jong, 1985; Nagorsen and Brigham, 1993). The ventral fur tends to be buffy. A tiny fringe of hairs is evident on the outer edge of the tail membrane. The ears are long (usually >16 mm); the calcar (a cartilaginous spur on the heel bone) lacks a distinct keel. The skull has a relatively narrow rostrum and a steep sloping forehead region. The dental formula is: incisors 2/3, canines 1/1, premolars 3/3, and molars 3/3. Representative body measurements for adults (range in parentheses) are: wingspan 241 mm (224-262), ear length 17 mm (13-20), tragus length 9 mm (6-12), forearm length 36.2 mm (33.8-39.5), body mass 5.1 g (3.8-6.7).

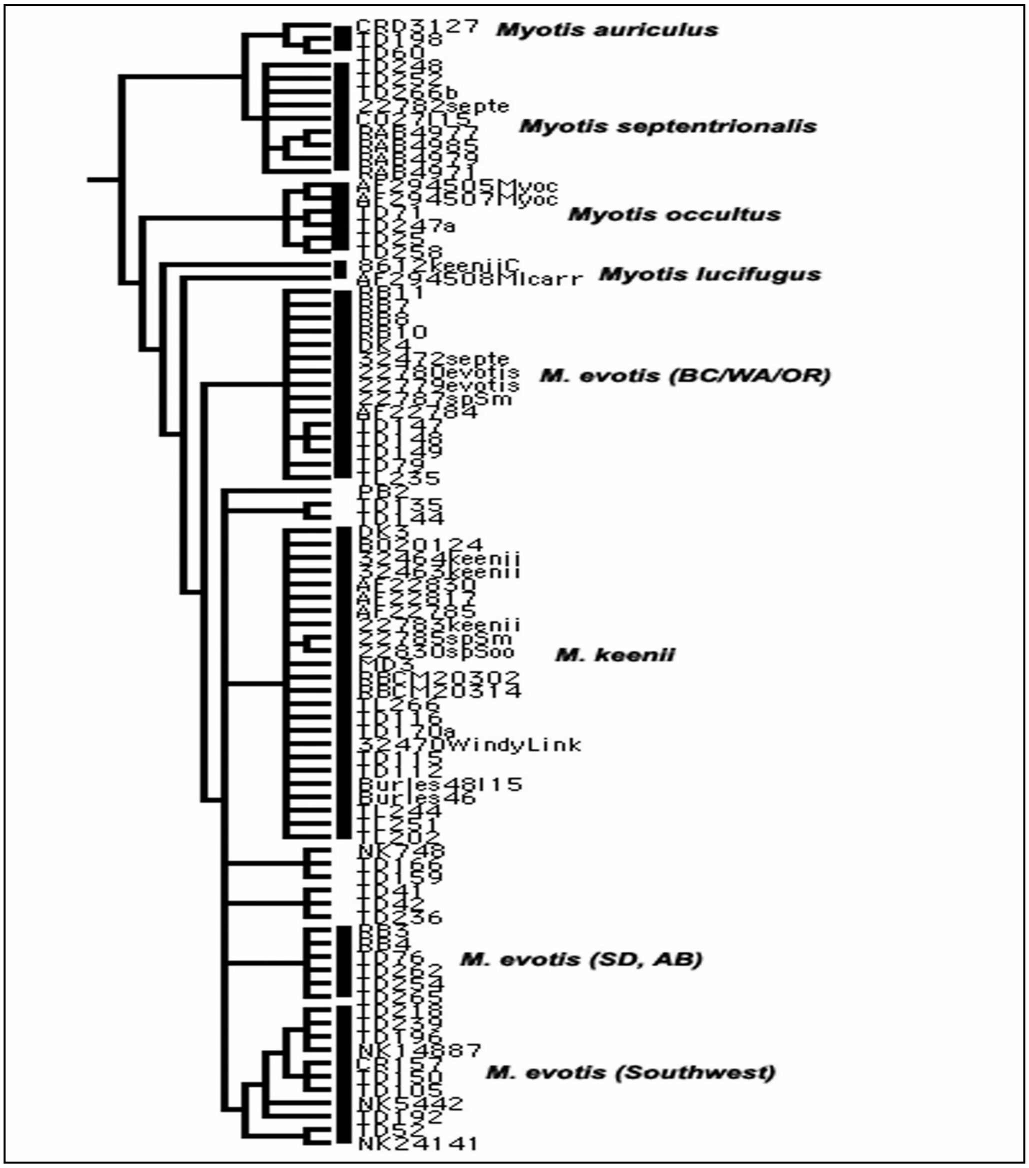

Figure 1. Phylogenetic relationships among long-eared *Myotis* species from the Pacific Northwest. Consensus tree of parsimony derived from an analysis of 765 base pairs of cytochrome b, 225 parsimony-informative characters for 187 terminal taxa. Duplicate haplotypes merged and tree pruned to display samples of interest. From T. Dewey (unpublished data).

Figure 2. Photograph of Keen's long-eared bat (*Myotis keenii*) captured at Gwaii Haanas National Park Reserve, Haida Gwaii, British Columbia. Photo by D.W. Burles.

M. keenii closely resembles *M. evotis*. Identification of live animals is problematic and a major impediment to field studies. *M. keenii* has on average a shorter forearm, metacarpal bones, and ears, but these measurements overlap among individuals of the two species (van Zyll de Jong and Nagorsen, 1994). Moreover, Burles (2001) demonstrated that ear length was a variable trait subject to significant measuring error. The identification keys in van Zyll de Jong (1985) and Nagorsen and Brigham (1993) used the distance that the ear extends beyond the nose (< 5 mm for *M. keenii*; > 5 mm for *M. evotis*) as a diagnostic trait for discriminating the species, but this trait appears to be highly variable among individuals. Burles (unpublished data) measured the extension of the ears beyond the nose in a large sample of *M. keenii* from Haida Gwaii and found that this measurement ranged from 2 to 9 mm. He concluded that it was not a valid taxonomic character. Ear colour, another trait used in the keys of van Zyll de Jong (1985) and Nagorsen and Brigham (1993), also appears to be variable. Nagorsen (2002) concluded that *M. keenii* and *M. evotis* cannot be reliably discriminated using external traits. Skull and dental measurements taken on museum specimens are more reliable, toothrow length being the best univariate discriminator (van Zyll de Jong and Nagorsen, 1994). Nevertheless, these measurements show some overlap between the two taxa, and positive identification requires multivariate analysis of cranial and dental measurements.

Nationally significant populations

No subspecies are recognized in *M. keenii* and there are no nationally significant populations.

DISTRIBUTION

Because of identification problems in areas where *M. keenii* is sympatric with *M. evotis,* occurrence records from areas other than Haida Gwaii (where *M. keenii* is the only long-eared *Myotis* species) are restricted to museum voucher specimens identified from morphometric traits described by van Zyll de Jong and Nagorsen (1994), or voucher specimens or captured animals released alive that were identified from mtDNA analysis of tissue samples (Dewey, unpublished data).

Global range

M. keenii is restricted to western Washington State, western British Columbia, and southeastern Alaska (Fig. 3). In Washington, this species inhabits the Olympic Peninsula and the Puget Sound area including Whidbey and San Juan Islands. Southern limits of its range appear to be delimited by the Columbia River. In Alaska, *M. keenii* is known from four islands (Chichagof, Prince of Wales, Revillagigedo, and Wrangell) in the Alexander Archipelago. Although there are no records, this bat probably also inhabits the adjacent coastal mainland of the Alaska panhandle.

Canadian range

In Canada, *M. keenii* is restricted to British Columbia (Fig. 3) where it occurs on the coastal mainland as far north as Telegraph Creek in the Stikine River valley, four islands in Haida Gwaii (Kunghit, <u>G</u>andl K'in Gwaayaay = Hotspring Island[2], Graham, Moresby), and Vancouver Island and associated islands (Denman Island). While its main BC range is on coastal islands and the mainland coast and coastal mountains, recent captures at Nine Mile Creek in the Skeena Mountains demonstrate that *M. keenii* ranges east of the Coast Mountains into the British Columbia interior. A survey by Firman et al. (1993) using mist nets and bat traps is the only coastal bat survey with data on species captured at each survey site. They captured long-eared *Myotis* at only 5 of 51 sites, but since they took few vouchers and no tissue samples, most of their long-eared *Myotis* captures can only be identified as *M. keenii*/*M. evotis*. In a similar survey of the Skeena Management District by Mackay et al. (2000), long-eared *Myotis* were captured or detected at 13 of 46 sites, but *M. keenii* and *M. evotis* were only confirmed (by voucher specimens) at 1 site. Locations sampled by both surveys are shown in Figure 4. The data from these two surveys suggest a spotty distribution, although the results may be biased because each site was only sampled on 1 or 2 nights.

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[2]We use the Haida name <u>G</u>andl K'in Gwaayaay for Hotspring Island throughout this report.

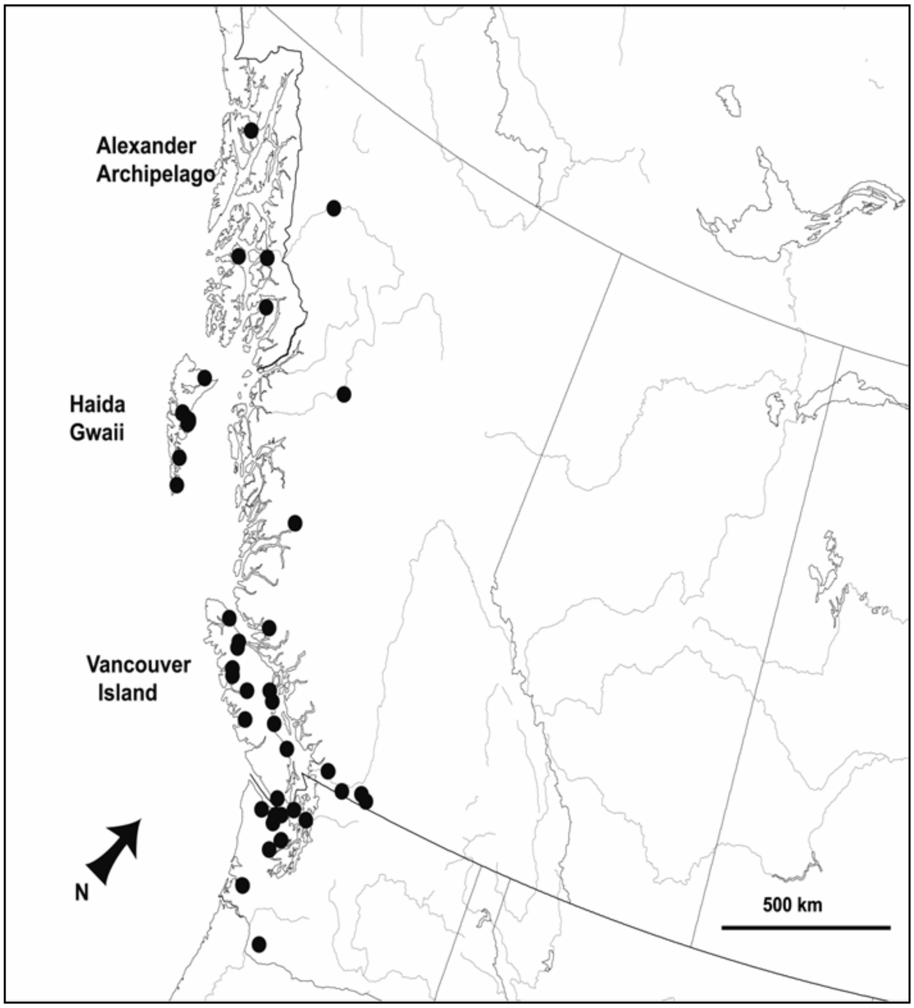

Figure 3. Distribution of Keen's long-eared bat (*Myotis keenii*) in North America. Location records are based on historical museum specimens identified from morphometric traits or recent voucher specimens or captured animals identified from mtDNA analysis of tissue samples. Magnetic north is indicated.

Because of inadequate and unsystematic inventory efforts, the distributional limits of *M. keenii*, particularly on the coastal mainland of British Columbia, are not well defined. No data exist to assess historical range changes. Some records of occurrence are historical museum specimens that were collected 50 to 120 years ago. No modern surveys have been done to verify that populations still exist at these locations. To what extent the Canadian range is fragmented is unknown. The few scattered mainland records largely reflect sampling bias and this bat may be continuously distributed throughout most of the coastal mainland. The degree of isolation among the island populations has not been studied. The most isolated island population is associated with Haida Gwaii, an archipelago that lies about 68 km from the adjacent mainland separated by the open waters of Hecate Strait. The extent to which *M. keenii* move between the Haida Gwaii and the mainland is unknown, but the *M. keenii* associated with this archipelago should probably be treated as a distinct subpopulation.

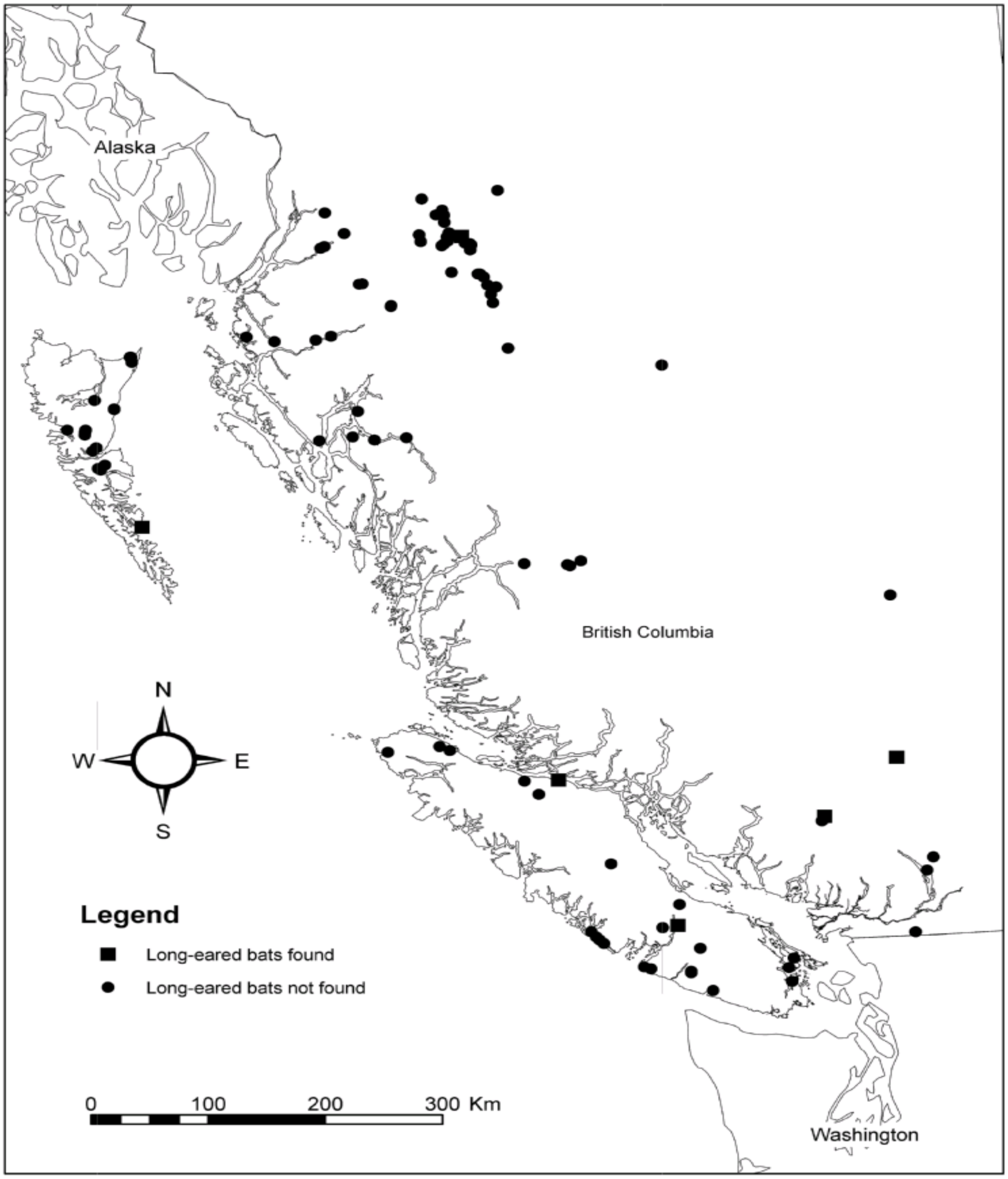

Figure 4. Fifty-three locations sampled by Firman et al. (1993) during a coast-wide survey for Keen's long-eared bat (*Myotis keenii*), and 46 sites sampled by MacKay et al. (2000) during a survey of the Skeena Management District. Squares= sites where either the western long-eared bat (*M. evotis*) or *M. keenii* were captured; circles= sites where no long-eared *Myotis* species were captured.

Because the distribution of actual populations is unknown, the area of occupancy for *M. keenii* cannot be determined. Its extent of occurrence in Canada is about 268,830 km^2 (mainland= 226,500 km^2, Haida Gwaii= 9,130 km^2, Vancouver Island=33,200 km^2). This represents about 80% of their global geographic range.

HABITAT

Habitat requirements

Summer roosts

There are few records of *M. keenii* roosting behaviour (Table 1), and only two maternity colonies are known. At Gandl K'in Gwaayaay[2], both *M. keenii* and the little brown *Myotis* (*M. lucifugus*) roost in close association with a hot springs. Three bathing pools have been developed around these springs and they have become a major tourist attraction. Most bats roosted about 50 m away from bathing pools under large boulders, in crevices, and in a small cave that were heated by hot water (Firman et al., 1993; Burles, 2000). Most *M. keenii* roosted underneath a very large boulder about 1 m above the extreme high tide line, and in a small cave that was located about 10 m away and about 3 m above extreme high tide. Some *M. keenii* also used a heated 3 – 5 cm wide crevice located in a 1 m diameter gap in the salal (*Gaultheria shallon*) located about 1 m above the main bathing pool. Use of this roost was sporadic and may have been influenced by the level of use of the bathing pool (Burles, 2001). Two radio-tagged individuals were tracked to crevices in shoreline cliffs that were only 1 cm wide, and one individual also roosted in a crevice in a 2 m diameter boulder in the thermal meadow about 30 m from the shoreline. Water temperatures of up to 50 ^{o} C and air temperatures of up 34 ^{o} C were recorded in some passages near roosts. Reproductive females used these nursery roosts from late May until about the middle of August, when they presumably left for hibernation sites. Some juveniles continued to make use of these roosts until the middle of September. The two species using the Gandl K'in Gwaayaay roosts do not appear to roost together as *M. keenii* is capable of using much narrower crevices than *M. lucifugus*. In all instances, *M. keenii* appeared to use small crevices or hollows suggesting that they may roost solitarily or in very small numbers, similar to *M. evotis* in Alberta (Chruszcz and Barclay, 2002).

Another maternity colony was found at Knoll Hill near Tahsis, Vancouver Island. A nursing *M. keenii* (identified from mtDNA taken from wing punches) captured at a cave entrance was subsequently radio tracked to a low elevation roost in a lodgepole pine (*Pinus contorta*) snag but the signal was lost shortly afterward (Mather et al., 2000). It was not possible to determine whether it had initially been roosting inside the cave, in a cliff crevice or in a nearby snag prior to capture. In other studies on Vancouver Island, Grindal (1999) and Kellner (1999) both radio-tracked reproductive female *M. keenii*/ *M. evotis* to tree roosts (N=3) located in old-growth forest.

Table 1. Known roosting data for Keen's long-eared bat (*Myotis keenii*).

Roost type	Location	Remarks	Source[1]
Natural			
Small cave, rocks hydrothermally heated	Haida Gwaii, Gandl K'in Gwaayaay, BC	Maternity colony; known for 40 years	Firman et al. (1993), Burles (2001)
Cave	Labyrinth Cave, Vancouver Island, BC	Hibernaculum. 2 *M. keenii* skeletons[2] found in cave, long-eared *myotis* observed in cave and caught swarming at entrance	Nagorsen (1995), Mather et al. (2000) RBCM 19500 (identified by D. Nagorsen), 19507 (identified by S. van Zyll de Jong)
Cave	Marmot Mausoleum Cave, Vancouver Island, BC	Hibernaculum? Skull (missing teeth) found in cave	Probably *M. keenii*; identified by D. Nagorsen; Mather et al. (2000)
Tree on cliff	Knoll Hill, Vancouver Island, BC	Maternity colony? Nursing female captured in small cave 9 August, then tracked to tree roost	Mather et al. (2000). Radio-tracked; identification verified from mtDNA taken from wing punch sample
Rock crevice, tree roost	Kamikaze Cave, Vancouver Island, BC	Male, originally caught at cave entrance 1 Sept, tracked to roost in crevice, then moved to tree	Mather et al. (2000). Radio-tracked; identification verified from mtDNA taken from wing punch sample
Manmade Structures			
Attic of cannery	Chicagof Isl., Hoonah, AK	Adult male, 11 July	Parker and Cook (1996); UAM 29831
House	Lake Cushman, WA	Adult female, 24 July	Dice (1932); UMMZ 52920
House	Kingcome Inlet, BC	Adult female, 11 September taken in *Myotis yumanensis* nursery colony	CMN 14650; field notes
House	Telegraph Creek, BC	Adult female, 7 Sept., caught in Hudson Bay store?	Heller (1914), USNM 209856
House	Campbell River, BC	In valance of house, July, sex?	RBCM 13356
Bridge	Olympic National Forest, Sol Duc River, WA	Night roost, under bridge, 2 females 15 July	Vouchers taken by Tanya Dewey, identification verified from mtDNA
Bridge	Olympic National Forest, Dosewallips River, WA	Night roost, under bridge, 1 female 20 July	Voucher taken by Tanya Dewey, identification verified from mtDNA

[1]CMN= Canadian Museum of Nature, Ottawa; RBCM= Royal British Columbia Museum, Victoria; UAM= University of Alaska Museum, Fairbanks; UMMZ= Museum of Zoology, University of Michigan, Ann Arbor; USNM= United States National Museum, Washington, DC

[2]skeletons from recent mortalities, fur still attached

Non-reproductive bats appear to roost separately from maternity colonies, at least early in the season, but may join the colony as summer progresses. At Gandl K'in Gwaayaay, only reproductive females were captured around the nursery roosts during May and June. The first males were captured in early July, and by August 40% of adults captured were either males or non-reproductive females (Burles, 2001). On Vancouver Island, a male (identified as *M. keenii* from mtDNA taken from a wing punch) captured near Tahsis on 1 September was relocated the following two days in a crevice in a SW facing limestone outcrop at about 750 ASL (Mather et al., 2000). On the 3rd day it was located in a 40 m high western hemlock (*Tsuga heterophylla*) where it roosted about 30 m up in the canopy. These researchers also tracked a non-reproductive female *M. keenii*/*M. evotis* to 3 different crevice roosts in SW facing limestone outcrops (50 – 270 m ASL). Each evening it was seen to emerge along with 3 or 4 other bats. Kellner (1999) also radio-tracked two male *M. keenii*/*M. evotis* to 3 different crevices in a granite quarry, and Kellner and Rasheed (2002) radio-tracked 3 non-reproductive female *M. keenii*/*M. evotis* to south facing cliffs (N=3) and a snag (N=1) located in old-growth forest.

Data from museum specimens and Parker and Cook (1996) demonstrate that *M. keenii* also roosts in buildings. There are at least five occurrences of this species being found in buildings (Table 1); all appeared to be solitary individuals. *M. keenii* has also been found to roost at night under bridges in Washington (T. Dewey, unpublished data).

Foraging habitat

Little information on habitat use by *M. keenii* is available because of difficulties studying such a small and secretive animal. Efforts to place radio tags or light tags on individuals have met with only limited success (MacKay et al., 2000; Mather et al., 2000; Burles, 2001). Most information on habitat use then, must be derived from ecomorphological characteristics, capture records and studies on other similar species.

Morphological characteristics, such as relatively short, broad wings and long ears, suggest that long-eared bats like *M. keenii* are slow, maneuverable fliers (Fenton and Bogdanowicz, 2002; Burles, 2001). They also have a high frequency, low intensity echolocation call, which should enable them to fly in relatively cluttered environments (Burles, 2001; Fenton, 1972). Their relatively long ears and thus sensitive hearing allow them to detect sounds generated by prey and thereby glean them from vegetation, as was predicted by Fenton (1990). Together, these characteristics allow *M. keenii* to forage within spatially complex old growth forests where most other bats find it difficult to, and to continue to forage even when adverse weather conditions, such as rain or cool temperatures, prevent insects from flying (Barclay, 1991). The ability to glean prey also enables this species to prey on spiders, one of the more common invertebrates in coastal rainforests.

Historical records support the conclusion drawn from morphological studies in that the distribution of *M. keenii* appears to be limited primarily to temperate coastal rainforests (Nagorsen and Brigham, 1993). Most recent observations also support this generalization, although a few occurrences from urban areas have been recorded. At Gandl K'in Gwaayaay, *M. keenii* were regularly observed to emerge from their shoreline roosts about 30 minutes after sunset, and to fly into adjacent old growth western hemlock – Sitka spruce (*Picea sitchensis*) forest (Burles, 2001). *M. keenii* were captured 100 – 200 m inland from these roosts at less than 3 m above ground, indicating that once they entered the forest at least some individuals foraged near ground level. Use of old growth forest may be from necessity, however, as there is virtually no open habitat on Gandl K'in Gwaayaay, with the exception of shorelines and two small thermal meadows.

Near Hazelton, where *M. keenii*, *M. evotis*, and *M. septentrionalis* were all captured at a single location, radio-tagged bats continued to forage in the area of capture over the next 11 – 14 days (MacKay et al., 2000). Although all were captured near a pond, they subsequently foraged primarily within the adjacent western red cedar (*Thuja plicata*) – western hemlock forest, rather than over open water. In southeast Alaska, one *M. keenii* was captured within 1 m of a cliff in a riparian forest dominated by large western hemlock and Sitka spruce (Parker and Cook, 1996). On Vancouver Island, *M. keenii/M. evotis* were captured in riparian or estuarine habitats associated with mature coastal western hemlock forests (Davis et al., 2000b; van den Driessche et al., 1999; van den Driessche et al., 2000), and radio tracking indicated that they foraged in estuaries (Mather et al., 2000). Both Grindal (1999) and Kellner (1999) found that riparian habitats were the most important foraging habitats for bats, including long-eared *Myotis*, on Vancouver Island.

Studies of other long-eared species generally support the inferences made above. In western Oregon, female *M. evotis* preferentially foraged in terrestrial habitats less than 100 m away from water, although they seldom foraged directly over the water (Waldien and Hayes, 2001). They often exhibited strong fidelity to a relatively small foraging area (mean size 38 ha), and these activity areas occurred in all ages of forest stands. Radio tagged bats emerged an average of 20 minutes after sunset, foraged for an average of 4.2 activity periods and then returned to their day roosts about 2 hrs before sunrise.

Hibernacula

Recent research by Davis et al. (2000b) and Mather et al. (2000) indicates that *M. keenii* hibernates in montane caves associated with karst formations on northern Vancouver Island. Bats verified as *M. keenii* from skulls or mtDNA analysis of wing tissue, have been found in association with eight caves from three separate areas: Weymer Creek near Tahsis, White Ridge near Gold River, and the Hankin Range east of Nimpkish Lake. *M. keenii* were captured in late summer at the entrances of seven caves. These captures presumably represented 'swarming', a behaviour associated with hibernation where bats make nocturnal flights through potential hibernacula (Fenton 1969; Schowalter, 1980). Additional evidence for the use of caves as hibernacula are observations of hibernating long-eared *Myotis* (*M. keenii/M. evotis*) inside two caves at Weymer Creek, and the recovery of skulls verified as *M. keenii* from deep inside two caves in this area (Table 1). Unidentified long-eared *Myotis* (*M. keenii*/*M. evotis*) were also captured at the entrances of three other caves in the Weymer area, providing additional evidence that caves are important for long-eared *Myotis*.

According to Mather et al. (2000), swarming began at the Vancouver Island caves in early August and extended until early September. The most common species caught while swarming were *M. lucifugus* and the long-legged *Myotis* (*Myotis volans*), with long-eared *Myotis* (*M. keenii* /*M. evotis*) representing about 15% of the bats captured at cave entrances. Fenton (1969) described two swarming phases: an early phase with nocturnal flights but no breeding, and a later phase that includes copulation and the build up of hibernating populations. Mather et al. (2000) did not observe any sexual activity during their study and it is unknown if mating occurs at these caves. The proportion of the bats captured swarming at the Vancouver Island caves that actually hibernate in these caves is unknown. These hibernacula supported small numbers of bats that hibernated singly or in small clusters.

Although the caves studied by Mather et al. (2000) ranged in elevation from 4 m to 945 m ASL (maximum elevation in this area =1126 m ASL), only the higher elevation ones (550 m – 945 m) were used as hibernacula, and the largest aggregations were in caves above 800 m. Bats hibernated deep in the caves (100 m inside) where the mean winter temperature remained stable between 2.4° to 4.0° C throughout the winter. The caves located at lower elevations (< 600 m) they found, were warmer and had more variable temperature profiles, conditions that result in higher body temperature (and thus increased metabolism), and more frequent arousals (Thomas et al., 1990). Hibernating in these caves would probably require greater energy reserves than most bats accumulate. High elevation caves with stable cold winter temperature regimes thus may be critical for hibernation by *M. keenii.*

No hibernacula of long-eared *Myotis* are known from the mainland coast or the British Columbian interior (Nagorsen et al., 1993). In September 2001 an attempt was made to locate hibernation sites on Haida Gwaii (Fenton et al., 2002). Radio tagged *M. lucifugus* were all found to be still using tree roosts, which led these authors to speculate that because of the moderate climate and stabilizing influence of the nearby ocean, it is possible that bats on Haida Gwaii could hibernate in tree snags along the shoreline. Subsequent research has shown that bats do occasionally become active throughout the winter (Burles, unpublished data), which lends support to the hypothesis that some bats probably hibernate in trees. Alternatively, *M. keenii* may use montane caves for hibernation on Haida Gwaii similar to Vancouver Island. Montane caves have been recently discovered in karst formations and there are unconfirmed reports from cavers of bat skulls in caves.

Trends

Although it is not known how dependent this species is on old-growth forests, it is certain that *M. keenii* forages within these stands. There is also evidence that few bats use central portions of clearcuts (Grindal, 1996), or dense second growth forests

(Parker et al., 1996), so the cutting of old growth forests does represent habitat loss for this species.

On Haida Gwaii almost 60% of the old growth available to the logging industry has been logged, most in the last 30 years, and old growth continues to be logged (Gowgaia Institute, 2002). Efforts are currently underway to modify second growth forests to make them more suitable for wildlife, including bats (T. Glasman, personal communication), although the extent of these modifications is limited.

Protection/ownership

Both of the known maternity colonies occur in protected areas. The maternity colony at Gandl K'in Gwaayaay is within Gwaii Haanas National Park Reserve and Haida Heritage Site. The Knoll Hill site, adjacent to Weymer Cave Provincial Park is designated as a Wildlife Habitat Area. Several hibernacula on Vancouver Island occur within Weymer Cave and White Ridge Provincial Parks. Most of *M. keenii*'s range, however, is on private, Aboriginal, or Crown lands that are subject to forest harvesting. With so little known of its' distribution, particularly in the central and north coast regions, we cannot estimate the proportion of the Canadian range in these different land tenures. It is noteworthy that the British Columbia Provincial Forest and Range Practices Code only regulates forest harvesting practices on provincial Crown land.

BIOLOGY

General

Like other Vespertilionids, *M. keenii* are heterothermic, and thus are well adapted to the seasonal temperature extremes and availability of food characteristic of temperate regions. They are likely capable of using torpor on a regular basis to conserve energy and survive periods of adverse weather, and of hibernating through the winter. Their reproductive chronology is also synchronized to take advantage of the short summer season. As for most *myotis* species, mating probably takes place in autumn just prior to hibernation or during the hibernation period. Mated females store and feed sperm through hibernation, and ovulation and egg fertilization occur in spring after arousal. Pregnant females return to traditional maternity roosts during April or May, depending on location. Gestation period is long (~ 40 - 60 days for *Myotis*), and typically only 1 large young (~ 25% of adult mass at birth) is raised per year (Tuttle and Stevenson, 1982; Kurta and Kunz, 1987). Length of gestation is variable in bats, and depends on how frequently the female uses torpor (Racey, 1981). Young usually become volant within about 3 weeks, but continue to be suckled for another two weeks, or until they become proficient at flying and foraging. Some juveniles are thought to mature sexually during their first summer and breed in their first autumn (Tuttle and Stevenson, 1982), although most probably don't breed until the second autumn. Contrary to the norm among small mammals, most bats typically produce 1 pup per year, although they make up for this low reproductive rate by being relatively long-lived.

Reproduction

The Gandl K'in Gwaayaay study is the only one that reports detailed information on reproduction for this species. It was uncertain when females emerged from hibernation but few bats were present at the maternity roosts prior to the end of May in each of 2 years (Burles, 2001). Use of the roosts by females was consistently high throughout June and most were found to be pregnant. Parturition occurred during early July, and young were volant by early August. Use of the roosts declined during August as adults left for hibernation sites, although some juveniles continued to use the roosts into September. At least 80% of females captured during this study were reproductively active (either pregnant or lactating).

Reproductive chronology at Gandl K'in Gwaayaay varied between 1998 and 1999 (Fig. 5) and was linked to weather conditions. Contrary to what might have been expected, however, gestation period was long and parturition late during the unusually warm, dry summer of 1998. The prolonged gestation was thought to be the result of energetic stress due to the lower availability of prey (Burles, 2001). The warm, dry conditions resulted in fewer insects being present, and those that were present may have spent more time flying, which would have made them less available to a gleaning bat such as *M. keenii*.

```
              May          June          July          August        September
Year       15    31     15     30     15     31     15     31     15     31
1998
                <-------?------<------------Gestation-------->
                                                 <-------Lactation------->
                                                                   <------Fledging ?----->
1999            <---?--<---Gestation-->
                                        <--------Lactation------>
                                                             <-----------Fledging------------->
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Figure 5. Reproductive chronology for Keen's long-eared bat (*Myotis keenii*) at Gandl K'in Gwaayaay, Haida Gwaii during 1998 and 1999. Adapted from Burles (2001).

In 1999, reproductive chronology was more compressed, in spite of it being a cooler, wetter year. Parturition occurred during a short period of time between 5 and 12 July, and young were fledging by early August. The cooler, wetter conditions resulted in a greater abundance of Diptera and Trichoptera (Burles, 2001), and probably caused insects to spend less time flying and more time resting on vegetation, which would have made them more available to be gleaned.

The only records on longevity for this species come from the study at Gandl K'in Gwaayaay. Three individuals that were banded in 1991 by Firman et al. (1993) have subsequently been recaptured (Burles, 2001; Burles, unpublished data). A female recaptured in late May 2003 was banded as an adult, meaning that she was born in or before 1990, which made her at least 12 years and 11 months old at the time of recapture. Two others captured in 1998 were at least 8 and 7 years old at the time of recapture. These records are likely underestimates given that longevity records for most other *Myotis* species range from 13 to 22 years (Tuttle and Stephenson, 1982), and the record for *M. lucifugus* is 35 years (Davis and Hitchcock, 1994).

Survival

There is little information on survival rates for *M. keenii*, except for the longevity records mentioned above. Firman et al. (1993) banded a total of 27 individuals in 1991 but only 2 of 56 captured in 1998-99 were recaptures. This low recapture rate might suggest that survival is low, but recapture rates for bats tend to be misleading, as they quickly learn to avoid mist nets.

Data on the causes and rates of mortality are scanty. Skeletons of *M. keenii*, with fur attached, have been recovered from caves where bats hibernate on Vancouver Island, suggesting over winter mortality from depleted fat reserves or disease does occur. Over winter mortality is common in temperate region bats, particularly for juveniles. *M. keenii* is vulnerable to terrestrial predators; a number of museum specimens are cat kills (Nagorsen, unpublished data; Burles, unpublished data). The deer mouse (*Peromyscus maniculatus*) is a predator of hibernating bats in mine adits and caves in Ontario (Fenton, 1970) and mouse droppings and/or skulls (deer mouse or Keen's mouse, *Peromyscus keeni*) were found in 11 caves in the Weymer Creek area (Mather et al., 2000). As a crevice roosting bat, *M. keenii* could be particularly vulnerable to this type of predation.

Owls prey on bats, but the extent of owl predation in a coastal forest environment is unknown. There is only one resident owl on Haida Gwaii, the northern saw-whet owl (*Aegolius acadicus*). As many as 8 owl species occur in other parts of *M. keenii* ‘s range (Campbell et al., 1990).

Physiology

There is little specific information available on the physiology of this species. Temperate bats, however, are influenced by prey activities. Most insects become inactive when temperatures drop below about 10 ^{o} C, so bat activity often ceases below this threshold. *M. keenii* may be an exception, however, because of its ability to glean, and thus forage even when insects are not flying. High temperatures, on the other hand, may have a negative impact on *M. keenii*, as insects become more active and thus less available to be gleaned. Bats at higher latitudes where summer days are long are also more limited as to when they can forage because of their extreme vulnerability to predation under daylight conditions (Speakman, 1991).

The conditions under which bats hibernate are very specific. Hibernation sites with constant cool temperatures and a high humidity are considered to be essential for over winter survival. The greatest energetic costs of hibernating bats is their arousal, either because of extreme temperature fluctuations or because they have been disturbed. A high humidity is also required because most bats do arouse periodically to void themselves of metabolic wastes, and once this is done they need to replenish the water in their body. According to Davis et al. (2000b) and Mather et al. (2000), temperatures in the Vancouver Island hibernacula remained constant between 2.4 ^{o} and 4 ^{o} C year around, with a constant relative humidity of 100%.

Movements/dispersal

Only two known *M. keenii* have been successfully radio tagged and followed for a total of 5 days (Mather et al., 2000). A nursing female captured in a small cave moved about 600 m to roost in a tree roost on a cliff the next day. The transmitter subsequently failed and she was not relocated. A male captured at the entrance of a cave was tracked to a rock crevice about 300 m away where it roosted for the next 2 days. This individual then moved about 300 m to a tree roost where the transmitter apparently fell off.

The relatively short nightly movements seen on Vancouver Island are consistent with what has been found for other long-eared bats. Four long-eared *Myotis* (*Myotis spp*.) radio tracked near Smithers for 11 – 14 days each all returned to forage in the area that they were captured every night (MacKay et al., 2000). Similarly, Waldien and Hayes (2001) found that *M. evotis* in Washington State also foraged in relatively small areas.

No data are available on migratory movements between summer roosts and winter hibernacula, and virtually nothing is known of their dispersal patterns except that on Gandl K'in Gwaayaay, three females banded in 1991 were still using the same roosts when they were recaptured (Burles, 2001; Burles, unpublished data).

Nutrition and interspecific interactions

Diet for *M. keenii* occupying the maternity roosts at Gandl K'in Gwaayaay was assessed by Burles (2001) using faecal analysis. Lepidoptera were present in 78% of the 27 faecal pellets collected during 1998 and 1999, and made up 36% of the total number of individual prey items identified (Table 2). Spiders (Arachnida: Araneae) were also present in 78% of all pellets analyzed, and was the predominant prey item identified in 1999. Diptera (22%) and Neuroptera (15%) occurred less frequently, while Hemiptera, Hymenoptera and Psocoptera were each found once (4%). Coleoptera and Trichoptera were not found in faeces, but they were also rare in light trap samples (Burles, 2001). The only other direct evidence of *M. keenii* diet comes from a single male collected in southeast Alaska (Parker and Cook, 1996). Its stomach contained 40% Trichoptera, 40% Araneae and 20% Diptera.

Other long-eared *Myotis* are morphologically similar to *M. keenii*, so examination of their diet may provide further insight into that of *M. keenii*. It must be noted, however, that bat diet is influenced by prey abundance and availability, which will vary with region. On Vancouver Island, Kellner (1999) found that *M. evotis/keenii* fed primarily on Lepidoptera and Diptera, with Neuroptera, Trichoptera and Arachnida making up only a small part of their diet. In Oregon, *Lepidoptera and Diptera dominated M. evotis diet*, but Coleoptera also made up a significant portion of their prey (Whitaker et al., 1977; Whitaker et al., 1981). Spiders were an important part of their diet in western Oregon but occurred only incidentally in eastern Oregon. In Arizona *M. evotis* fed primarily on Lepidoptera, Coleoptera and Diptera, and spiders did not appear in their diet at all (Warner, 1985). The higher incidence of Coleoptera in their diet in both eastern Oregon and Arizona may be a reflection of their greater availability in these areas. The consumption of spiders by *M. evotis* appears to be limited to wetter coastal regions similar to that occupied by *M. keenii*, which may also be a result of their greater availability in these regions.

In eastern North America, *M. septentrionalis* fed mostly on Lepidoptera and Coleoptera, and to a lesser extent Diptera and Neuroptera (Griffiths and Gates, 1985). These authors found green plant material in some faeces, which they took as evidence that these bats were gleaning insects from vegetation.

At <u>G</u>andl K'in Gwaayaay, there was no evidence of competition for food between *M. keenii* and *M. lucifugus*, perhaps because of their different foraging behaviour (Burles, 2001). *M. keenii*'s greater maneuverability presumably allowed it to forage within the forest, and its ability to glean allowed it to forage on different prey (i.e., spiders), while *M. lucifugus*'s faster flight probably limited it to aerial hawking for insects in more open areas. Lepidoptera made up a large proportion of the diet of both species, however, and while their different foraging strategies likely minimized interference competition for this prey, exploitation competition may have been occurring. In the southern portion of its range where *M. keenii* is sympatric with *M. evotis*, another gleaner, competition for food could be a significant factor.

Information about interactions with other species is limited. At <u>G</u>andl K'in Gwaayaay, *M. lucifugus* roosted in close proximity to *M. keenii*, although not in the same roosts. The crevices used by the latter were generally narrower than those used by the former. In southeast Alaska, however, a *M. keenii* was collected from a maternity colony of *M. lucifugus* (Parker and Cook, 1996), suggesting that they may occasionally roost together. Similarly, in Kingcome Inlet a *M. keenii* was captured in a nursery colony of Yuma bats (*M. yumanensis*), in the attic of a house. In the Weymer Creek hibernacula, *M. keenii* was found in the same caves as other *Myotis* species, although they apparently did not roost together.

Table 2. Summary of the prey items consumed by Keen's long-eared bat (*Myotis keenii*) at Gandl K'in Gwaayaay, Haida Gwaii. (N = 12 pellets in 1998 and N = 15 pellets in 1999). From Burles (2001).

	1998		1999		Both years combined	
Invertebrate order	**Number of pellets in which order occurred**	**Number of individuals identified**	**Number of pellets in which order occurred**	**Number of individuals identified**	**% frequency of occurrence in pellets**	**% of total number of individuals identified**
Psocoptera	0	0	1	1	2	2
Hemiptera	1	1	0	0	2	2
Neuroptera	3	3	1	1	7	7
Diptera	3	3	3	3	10	10
Lepidoptera	10	10	11	11	78	36
Hymenoptera	0	0	1	1	2	2
Araneae	8	8	13	17	78	42

Behaviour/adaptability

The ability of long-eared bats to glean prey from vegetation has been clearly demonstrated under laboratory conditions (Faure and Barclay, 1992; Faure et al., 1993), and the prevalence of spiders in the diet of *M. keenii* is evidence that gleaning is an important foraging strategy for them in the field (Burles, 2001). Bats that glean typically have sensitive hearing, which allows them to locate prey by passively listening for prey-generated sounds. This strategy is thus energetically efficient because there is no need to vocalize, an activity that is energetically expensive (Norberg and Rayner, 1987). It is also more efficient because insects with ears are less likely to detect them, and insects at rest have greater difficulty avoiding predators. Gleaning bats also have an advantage because they can continue to forage even after low temperatures prevent insects from flying.

On Haida Gwaii, the ability to glean likely broadened the prey base of *M. keenii*, allowing them to continue to forage during a cool, rainy summer when prey were less abundant and insects were less likely to be flying (Burles, 2001). A similar situation was found in the mountain regions of Alberta, where the ability to glean allowed *M. evotis* to forage even during cold mountain nights when insects ceased to fly (Barclay, 1991). In both locations, the ability to glean appears to be a key factor that allowed these long-eared bats to survive and successfully breed when other bats could not. The ability to forage by gleaning then, may provide long-eared bats with an advantage in regions where cool and/or wet conditions limit insect activity or abundance (Burles, 2001).

This species' ability to tolerate human disturbance is unknown. However, the persistence of the maternity colony at Gandl K'in Gwaayaay for more than 40 years despite human activity on the island is noteworthy. Moreover, this colony was affected by the collection of 26 *M. keenii* (mostly adult females) in the early 1960s for the Cowan Vertebrate Museum at University of British Columbia and the Canadian Museum of Nature.

POPULATION SIZES AND TRENDS

No estimates exist for the total Canadian population and nothing is known about their overall population trend. The paucity of records, however, indicates that this species is not commonly encountered, and may only occur in low densities. This is supported by the results of a 1991 survey specifically designed to determine the distribution and abundance of *M. keenii* in British Columbia (Firman et al., 1993). Despite mist netting and trapping bats for 76 nights at 53 locations, the authors only captured 38 long-eared bats at five different locations (Fig. 4). All *M. keenii* (29 individuals) were captured at Gandl K'in Gwaayaay. Two of the remaining 9 were identified as *M. evotis*, while identification of the other 7 could not be determined to the species level.

The only other indication for population trends for this species comes from recent studies of the Gandl K'in Gwaayaay maternity colony. In the initial survey of this colony, Firman et al. (1993) estimated that about 140 bats were present in early August 1991, of which they estimated that one half were *M. keenii*. In subsequent studies, using emergence counts conducted in June and a ratio of the relative numbers of each species captured, Burles (2001) calculated that the ratio was more likely 1/3 *M. keenii*/2/3 *M. lucifugus*, and estimated that 39 - 41 adult female *M. keenii* and 71 - 86 *M. lucifugus* used the roosts during 1998, 1999 and 2000 (Table 3). Burles (2001) found that the total number of bats using the roosts increased during late July as a result of young beginning to fledge and non-reproductive bats frequenting the roosts. By early August 1999, for example, the total number counted had risen to at least 149, which is similar to the number estimated by Firman et al. (1993). These results suggest that the number of female *M. keenii* using the Gandl K'in Gwaayaay roosts remained quite stable during the period 1998 – 2000, and probably did not vary much between 1991 and 2000.

Table 3. Estimates of the number of adult female Keen's long-eared bats (*Myotis keenii*) and little brown bats (*Myotis lucifugus*) at the Gandl K'in Gwaayaay maternity colony. Adapted from Burles (2001) and Burles (unpublished data).

	Number of adult females		Number of
Year	*Myotis* keenii	*Myotis* lucifugus	emergence counts
1998	39	71	10
1999	41	70	9
2000	40	86	1
2002	17	79	2

Emergence counts conducted during 2002 indicated that fewer bats were using the roosts at Gandl K'in Gwaayaay, and, based on the relative numbers of the two species seen emerging (Table 3), this decline appeared to be due to fewer *M. keenii* being present (Burles, unpublished data). As Burles (2001) pointed out, however, emergence counts at this particular colony can be quite variable because not all females use the maternity roosts every day, and not all females emerge to forage every evening. Multiple emergence counts are thus required in order to sample on an evening when most, if not all, bats are present and emerge. It remains to be seen then, whether the 2002 counts are an accurate reflection of the number of *M. keenii* using the maternity roosts.

LIMITING FACTORS AND THREATS

Habitat loss

There are inadequate habitat data to demonstrate that *M. keenii* is limited to old growth coastal forests but this bat has been primarily captured in these habitats and forages under the canopy of old growth forests. A number of studies have demonstrated that, while some bat species may forage along the edges created by cut blocks (Grindal, 1996), few bats forage in the clear cuts themselves or in the dense second growth forest that follows (Thomas, 1988; Parker et al., 1996; Humes et al., 1999; Ericksen and West, 2003). Tree roosting bats also rely heavily on old growth forests to provide suitable roost trees (Kellner, 1999; Grindal, 1998, 1999). It remains unknown what sort of a barrier an open cut block might create for forest dwelling bats but current logging practices may be seriously fragmenting habitat. Habitat loss is thus a concern as coastal old growth forest continues to be lost to harvesting. On Haida Gwaii, for example, almost 60% of the old growth available to the logging industry has been eliminated (Gowgaia Institute, 2002), and the remaining old growth continues to be logged.

Disturbance

On Vancouver Island, caves associated with karst landscapes are used for swarming and as hibernacula, and *M. keenii* has been verified at eight different caves. With the hibernation period extending from October to mid-May, and the swarming period from August to September (Mather et al., 2000), these caves are used by *M. keenii* for nearly 10 months. Hibernating bats are particularly vulnerable to disturbance, and even brief visits by humans without physical disturbance are enough to cause them to arouse (Thomas, 1995). Arousals are energetically costly — each winter arousal burns the same amount of fat as would be used in 68 days of torpor (Thomas et al., 1990). Swarming bats could also be affected by disturbance near the cave entrance.

Recreational caving and forest harvesting activities are potential disturbances at these caves. Cavers using these caves during the hibernation period will disturb hibernating bats, and as caving increases in popularity, this disturbance could become a significant factor in the over winter survival of bats. Although forest harvesting activities around cave entrances do not appear to alter cave microclimate (Davis et al., 2000a), logging debris may accumulate in the entrance and block access. The effects of blasting and other activities associated with logging road construction are unknown, but seismic effects and other noise could disturb hibernating bats.

The only known maternity colony at Gandl K'in Gwaayaay is located within 50 m, and some case < 10 m, of bathing pools that are frequently used by visitors. Roost sites have been identified, however, and measures have been put in place to minimize disturbance from visitor activities.

Predation

M. keenii's behaviour of flying and roosting close to the ground makes it vulnerable to predation by cats. It is difficult to quantify this predation but at least three individuals have been killed in this way in Sandspit alone (Burles, unpublished data), and a number of museum specimens from other parts of its range are also from cat kills.

As a bat that frequently roosts in cliffs or caves, *M. keenii* may be vulnerable to predators such as rodents or raccoons that could enter or reach into their roosts. The presence of mice (*Peromyscus* spp.), a known predator of hibernating bats, in the

Weymer caves is noteworthy but their impact on hibernating bats in these caves has not been studied. Keen's Mouse is present on Gandl K'in Gwaayaay in close proximity to the roosts but their impact on the maternity colony is also unknown.

On Haida Gwaii, where the islands' native fauna is depauperate, introduced mammals have become serious predators. Raccoon predation on seabirds has been documented (Hartman, 1993; Golumbia, 2000), and like cats, may be capable of capturing *M. keenii* as they forage. Rats (*Rattus rattus*, *Rattus norvegicus*) and red squirrels (*Tamiasciurus hudsonicus*) have also been documented as predators of seabirds and songbirds (Harfenist, 1994; Martin et al., 1994; Martin et al., 2001), and if either were ever introduced to Gandl K'in Gwaayaay, could have a devastating impact on the colony there.

In assessing the status of *M. keenii*, the following unanswered questions must be kept in mind:

1. What is its taxonomic relationship with *M. evotis*?
2. Is it truly rare or is it simply difficult to capture in mist nets or harp traps?
3. Where does the majority of the population hibernate?
4. What habitat or habitats are vital for foraging and summer roosting?
5. Is it strongly dependent on old growth forests?
6. What are the immediate threats to hibernacula and foraging habitats?

SPECIAL SIGNIFICANCE OF THE SPECIES

M. keenii has one of the most restricted distributions of any North American bat, and most of its geographic range (about 80%) is within Canada. It is the only North American bat with a distributional area confined to the Pacific coast region. According to van Zyll de Jong and Nagorsen (1994) this distributional pattern suggests that *M. keenii* may have evolved in a coastal refugium.

A putative old growth coastal forest bat, *M. keenii* is the only bat species currently listed as an 'Identified Wildlife Species' under the Identified Wildlife Management Strategy of the British Columbia Provincial Forest and Range Practices Code[3].

EXISTING PROTECTION OR OTHER STATUS

This species is not listed by the IUCN. It was designated a Species of Special Concern by COSEWIC in 1988 (see Balcombe 1988). The global heritage status rank is G2; national ranks are N1 for the United States and N1N3 for Canada. *M. keenii* is ranked SH for both Alaska and Washington States. British Columbia has designated the species as S1S3.

[3] Replaces the old BC Forest Practices Code. Guidelines for this species under the new BC Provincial Forest and Range Practices Code are currently in draft stage.

In British Columbia, *M. keenii* is protected from being killed under the provincial Wildlife Act and is the only bat species listed as an Identified Wildlife Species under the BC Provincial Forest and Range Practices Code. Species listed under the Code are considered to be at risk and require special management by establishing Wildlife Habitat Areas (WHA). The Code specifies that WHA's with a 100 m radius and a 200 m buffer will be established to protect known hibernacula, maternity colonies, and roosting sites of *M. keenii*. Various management prescriptions are recommended relating to forestry road access and silvicultural practices. To date only one WHA has been designated for *M. keenii* - the Knoll Hill Cave WHA (25.2 ha) designed to protect a maternity site (see Table 1) near Tahsis. Nearby, Weymer Cave Provincial Park protects an area that supports *M. keenii* hibernacula. Interestingly, the Tahsis Economic Development Society has proposed the construction of a canopy walkway in the Knoll Hill WHA to promote eco-tourism, and one of the features they wish to promote is the occurrence of *M. keenii*. An environmental assessment was commissioned by the Tahsis Economic Development Society, and the proposal is now before a provincial committee.

Because its area of occupancy is unknown, the proportion of *M. keenii* 's range that falls within protected areas is unknown. Of the 25 occurrences in Canada, 5 fall within protected areas. Two of seven occurrences on Haida Gwaii are within Gwaii Haanas National Park Reserve and Haida Heritage Site (147,000 ha). The most significant is the maternity colony at Gandl K'in Gwaayaay. An area plan has been prepared for the island that documents the re-development of the area while taking into consideration the protection of the colony (Stronge, 2001). It directs that no alteration of the surface flow of the hot springs should occur, as this might alter the thermal regime of the roosts. Visitors are allowed to use the hot pools located within 100 m of the roosts during the day, but must leave the island before bats begin to emerge. Haida Gwaii Watchmen are stationed on the island to ensure that no direct disturbance of the roosts occurs and that visitors leave before sunset. Gwaii Haanas staff regularly monitor Gandl K'in Gwaayaay for the presence of introduced species, and emergence counts are periodically carried out to determine the number of bats present.

Three of 15 occurrences on Vancouver Island are in protected areas. Inventories in Weymer Cave Provincial Park (316 ha) near Tahsis demonstrated that the outstanding karst features associated with this park include a number of caves that are used for swarming and hibernation by *M. keenii*, as well as a number of other species of *Myotis* (Mather et al., 2000). At least three caves (Slot Canyon, Labyrinth) were used by *M. keenii*, and it is likely that it roosts in trees in the park as well. A draft management plan (Clover Point Cartographics, 1998) identifies the need to protect the bat roosts in the park, but also identifies recreational caving, hiking, and tourism as acceptable park activities. Specific guidelines on how these conflicting activities, especially recreational caving, will be balanced are not part of the plan.

M. keenii has also been found at Windy Link Cave in White Ridge Provincial Park (1,343 ha). There has been no comprehensive inventory of bat use of the karst features in this park, but the Park is used extensively by recreational cavers. No management plan currently exists for this park.

SUMMARY OF STATUS REPORT

Keen’s long-eared bat (*Myotis keenii*) is morphologically similar and closely related to the western long-eared bat (*Myotis evotis*). The two taxa cannot be identified in the field and their low divergence in mtDNA suggests they could be conspecific. *M. keenii* is confined to western Washington, British Columbia, and southeastern Alaska. About 80% of its distributional area is in Canada. It forages in estuaries, riparian habitats, and urban areas. Summer day roosts are located in trees, rock crevices, buildings and under boulders. Known night roosts are under bridges. The only know hibernacula are in caves associated with karst formations on Vancouver Island in montane areas (550-945 m). Ecomorphological traits and a diet study done on Haida Gwaii suggest that the diet consists of flying insects particularly moths and non-flying invertebrates such as spiders. Females produce a single young with parturition in July; young are volant by early August. There are no estimates of population size or trends across the range. This bat is rarely captured but it is not clear if this can be attributed to rarity or capture avoidance. Limiting factors include loss of tree roosts from forest harvesting, disturbance of hibernacula by cavers or forest harvesting activity, and predators such as owls or small rodents in caves. The portion of *M. keenii*’s range that is in protected areas or on Crown land protected by British Columbia Forest and Range Practices Code is unknown. Unresolved questions about this species’ taxonomy, rarity, dependence on old growth forest, hibernation and foraging habitat, and threats hinder an assessment of this bat’s conservation status.

TECHNICAL SUMMARY

Myotis keenii
Keen's long-eared bat — Vespertilio de Keen
British Columbia

Extent and Area information	
• *extent of occurrence (EO)(km²)*	268,830
• *specify trend (decline, stable, increasing, unknown)*	Stable
• *are there extreme fluctuations in EO (> 1 order of magnitude)?*	No
• *area of occupancy (AO) (km²)*	Unknown
• *specify trend (decline, stable, increasing, unknown)*	-
• *are there extreme fluctuations in AO (> 1 order magnitude)?*	-
• *number of extant locations*	25*
• *specify trend in # locations (decline, stable, increasing, unknown)*	Unknown
• *are there extreme fluctuations in # locations (>1 order of magnitude)?*	No
• *habitat trend: specify declining, stable, increasing or unknown trend in area, extent or quality of habitat*	Declining if forest dependent
Population information	
• *generation time (average age of parents in the population) (indicate years, months, days, etc.)*	2 years
• *number of mature individuals (capable of reproduction) in the Canadian population (or, specify a range of plausible values)*	Unknown
• *total population trend: specify declining, stable, increasing or unknown trend in number of mature individuals*	Unknown
• *if decline, % decline over the last/next 10 years or 3 generations, whichever is greater (or specify if for shorter time period)*	-
• *are there extreme fluctuations in number of mature individuals (> 1 order of magnitude)?*	-
• *is the total population severely fragmented (most individuals found within small and relatively isolated (geographically or otherwise) populations between which there is little exchange, i.e., ≤ 1 successful migrant / year)?*	No
• *list each population and the number of mature individuals in each*	-
• *specify trend in number of populations (decline, stable, increasing, unknown)*	-
• *are there extreme fluctuations in number of populations (>1 order of magnitude)?*	-
Threats (actual or imminent threats to populations or habitats)	
- disturbance of hibernacula in caves by forest harvesting activity and recreational caving - removal of tree roosts from forest harvesting - disturbance of maternity colonies	
Rescue Effect (immigration from an outside source)	Low
• *does species exist elsewhere (in Canada or outside)?*	Yes
• *status of the outside population(s)?*	SH
• *is immigration known or possible?*	Yes
• *would immigrants be adapted to survive here?*	Yes
• *is there sufficient habitat for immigrants here?*	Yes
Quantitative Analysis	Insufficient data

*25 element occurrences in Canada; 10 historical (before 1990), 15 recent (after 1990). Unknown if 10 historical occurrences are extant. An element occurrence for small bats is defined by the Heritage Ranking System as sites occupied historically or at present that are separated by 10 km or more.

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Doug Burles holds a B.Sc. from the University of Calgary and an M.Sc. in biology from the University of Victoria. He has worked for Parks Canada Agency at various locations in western Canada for over 30 years, and is currently Environmental Assessment Scientist for Gwaii Haanas National Park Reserve and Haida Heritage Site. During his career he has conducted studies and inventories on large mammals and raptors in Manitoba, Saskatchewan, Yukon and British Columbia. His thesis research was carried out on the *M. keenii* maternity colony at Gandl K'in Gwaayaay, and he continues to study this colony. He has authored or co-authored more than 35 published and unpublished reports. Doug is currently a member of the Queen Charlotte Islands Ermine Recovery Team.

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COLLECTIONS EXAMINED

Canadian Museum of Nature, Ottawa
Burke Museum, University of Washington, Seattle
James Slater Museum, University of Puget Sound, Tacoma
Museum of Zoology, University of Michigan, Ann Arbor
Royal British Columbia Museum, Victoria
Royal Ontario Museum, Toronto
University of Alaska Museum, Fairbanks
University of British Columbia, Vancouver
United States Nation