Appendix 5.6 Karst Cave Habitats

Featured Species-associated Karst Cave Habitats: Entrance Zone, Twilight Zone, and Deep Cave Zone

Karst landscape is an area of underlying limestone (carbonate bedrock) in which erosion and dissolution by ground water/chemical weathering has produced fissures, sinkholes, underground streams, and caverns. The high soil acidity and damp conditions of temperate rain forests and muskeg are ideal for creating interconnected dissolved features in alkaline calcium carbonate bedrock. This network of caves and tunnels is a distinct habitat type located underground but connected, in varying degrees, to the overlying landscape through sinkholes (also called dolines or collapse pits), cave entrances, and subsurface hydrology.

In Alaska, karst landscape is primarily located in the Alexander Archipelago, which includes Prince of Wales, Dall, Coronation, Sumez, Heceta, Baker, Kosciusko, Kuiu, Long, Etolin, Revillagigedo, Kupreanof, and Chichigof Islands (Baichtal 1996; Experts group). The mainland near Haines, Haines State Forest in Southern Chilkat Valley (Streveler and Brakel 1993), and the Wrangell-St. Elias Mountains also contain areas of karst. Outside of Southeast Alaska, the only other karst landscapes overlain by temperate rain forest are located in Chile and Tasmania. Other karst areas in Alaska include the Lime Hills on the west side of Cook Inlet, the Jade Mountains in northwest Brooks Range (sinkholes, springs, and underground streams) and the White Mountains in the Interior. The karst cave systems in Southeast Alaska are the most extensively studied; very little is known about the extent and ecology of Alaska’s northern and western karst areas. The following habitat descriptions address karst cave conditions in Southeast, in the coastal areas of Canada, or generalized cave conditions.

Within the karst cave system are several zones of differential habitat use and characteristics. The “entrance zone” is located immediately around the cave or tunnel opening and is the most influenced by surface conditions. The “twilight zone” extends from the entrance to mid-depth and is best characterized by decreasing light levels and connectivity to the exterior. The final zone is the “deep cave” area, which is almost entirely isolated from exterior conditions. Within and between these zones are a range of characteristics that affect species distribution: light level; temperature; the range of temperature variation; air flow patterns; cavern size; the cave’s depth below land surface and elevation relative to sea level; humidity; substrate type; connectivity to surface water/flow levels; level of human disturbance; turbidity, pH, and conductivity of water; nutrient input to the system; and thickness of epikarst (Aley and Aley 1997). The one factor that influences all of these habitat characteristics is the degree of connectivity between the surface and subsurface. In a karst cave system, the speed and magnitude of transfers between surface and subsurface is controlled by sinkholes and hydrologic flows (Karst Task Force for the Resources Inventory Committee 2001; Baichtal 1993).

Nutrient input to cave systems depends on surface organics being transported through connections from the surface. These nutrient sources may take the form of debris falling into sinkholes or being washed into cave systems by sinking streams (streams descending through the cave system).

Karst cave inhabitants can be obligate, opportunistic, or accidental. Accidental inhabitants are those organisms introduced into the systems through sinkholes or flushed in by water flow. While accidental species rarely survive, they present an important influx of nutrients to the system. Opportunistic use is generally limited to terrestrial or littoral openings, but this use does represent a wide range of taxonomic groups.

Starlight Cove, Prince of Wales Island T. Heaton, University of South Dakota

Obligate cave inhabitants consist of troglobite (terrestrial cave dwellers) and stygobite (aquatic cave dwellers) invertebrates and bats. The most extensive invertebrate surveys to date were conducted in 1992 and 1995. Collections from over 300 cave and resurgence sites in Southeast yielded at least 5 troglobitic and 40 troglophilic invertebrate species (Carlson 1997a). Another extensive survey of cave invertebrates conducted in 1997 on Vancouver Island initially identified 192 taxa. Investigators in this study found “remarkable” similarities between cave fauna compositions on Vancouver Island and in Southeast (Shaw and Davis 2000).

Entrance Zone

The entrance zone is characterized by lower light levels and higher relative humidity than exterior conditions, and more dramatic temperature variations and higher nutrient availability than interior areas of caves. Davis et al. (2000) defined the entrance zone as 0–10 m from the entrance of the caves, but actual entrance zone parameters may exist in varying locations depending on cave entrance size.

Terrestrial openings are used by various species of bats for swarming and feeding activities. Temporal, gender, and life cycle differences in cave use relate to the elevation, temperature, variation of temperature, humidity, and size of the cave. Caves at lower elevations are used by *Myotis* spp. females and juveniles in late summer months (Davis et al. 2000).

Aquatic invertebrate accidentals washed into Vancouver Island cave habitat are mostly from the taxonomic groups Plecoptera, Ephemeroptera, and Trichoptera. Terrestrial beetles and mosquitoes also use cave entrances. The highest invertebrate diversity occurs in the entrance area, and the composition is dominated by taxa that would likely be found elsewhere in similar surface environments. Near-entrance fauna is dominated by a number of flies and associated predators, such as spiders and weevils (Shaw and Davis 2000).

California myotis (*Myotis californicus*)
M.R. Stromberg, University of California, Berkeley

Additional habitat functions of the entrance zone include denning by black and brown bears, river otters, wolves and mustelids, although there is uncertainty about the extent of this use (Streveler and Brakel 1993). Sitka black-tailed deer use the thermal buffering effects of air currents at cave entrances both summer and winter (Baichtal and Swanston 1996). This effect has been called “cave breath” and may allow some species or individuals to live at the temperature limits of their distribution (Streveler and Brakel 1993). Both songbirds and seabirds use openings for nesting and feeding depending on proximity to shore (Baichtal 1995).

Entrance Zone-associated Species:

Little brown bat, *Myotis lucifugus*
Keen's bat, *Myotis keenii*
California myotis, *Myotis californicus*
Long-legged bat, *Myotis volans*
Silver-haired bat, *Lasionycteris noctivagans*

Twilight Zone

The “twilight zone” extends from the entrance to mid-depth; it has sheltering characteristics but is not completely isolated from the surface. Most invertebrates found in caves reside in the twilight zone. Few true obligate troglobites occur here, but there is large potential for finding as yet undescribed and unidentified species. Other species may have certain portions of their life cycle that necessitate different zones of the caves. The twilight zone is the area of a cave used by roosting bats (Davis et al. 2000).

Twilight Zone-associated Species

Little brown bat, *Myotis lucifugus*
Keen's bat, *Myotis keenii*
California myotis, *Myotis californicus*
Long-legged bat, *Myotis volans*
Silver-haired bat, *Lasionycteris noctivagans*

Deep Cave Zone

The deep-cave zone is a very stable, insulated habitat, but this stability is a function of a very narrow range of habitat conditions. Deep cave invertebrates (hypogean invertebrates) are highly specialized to cave conditions, with extremely limited tolerance for light, humidity, temperature, and pH variations, but with the ability to exploit low nutrient and oxygen levels (CWCS Expert Group 2004). The interior of a deep cave generally has little organic debris, no light, temperatures slightly above freezing, high humidity (100%), a pH near neutral (a consequence of the buffering effects of the dissolved calcium carbonate), and a very limited input of new species, predators, or competitors. One possible example of a hypogean adaptation is amphipod development of reduced metabolic rates compared to their epigean counterparts in response to limited food availability or low oxygen conditions (Spicer 1998).

In deep-cave habitats, collections of invertebrates were dominated by collembola, symphyla and diplura with infrequent captures of other taxa, such as acarina (*Robustocheles occulta*), diptera or siphonaptera. In the Lower 48, for both stygobites and troglobites, only number of caves (in a system) was a significant predictor of distribution (Culver et al. 2003). For example, the more extensive a system, the more cave-adapted species it supports.

Myotis spp. use deep cave areas of high elevation caves (800 m) as hibernacula. These hibernating locations are characterized by temperatures close to freezing, with a small range of temperature variation and high humidity levels (Davis et al. 2000). However, *Myotis* spp. depend on caves of varying depths and locations at different points in the species’ lifecycle.

Deep Cave Zone-associated Species

Collembola
Arrhopalites hirtus
Arachnida
Acarina
Robustocheles occulta
Crustacea
Stygobromus quatsinensis

Hydaticus larvae
Rhynchelmis spp.
Polycelis spp.
Candona spp.
Acanthocyclops spp.
Dacylclops spp.

Keen's bat, *Myotis keenii*

Interactions with Overlying Landscape

The connectivity between karst systems and the overlying landscape also benefits the overlying forest. In Southeast Alaska, karst areas are better drained and have less acidic soil, promoting growth of larger trees than in nonkarst areas. Dissolved fissures in the bedrock allow deep root growth making large trees more windfirm. The underground portions of streams can provide buffers for water pH, water temperature, and flood discharges. For example, acidic water (pH 2.4–5.8) flowing into karst areas may exit the cave system with a pH of 7.5–9.0 (Aley et al. 1993; Baichtal and Swanston 1996). Water with dissolved minerals from contact with a karst system typically has a higher specific conductance than waters from nonkarst systems (Karst Task Force for the Resources Inventory Committee 2001). Compared with other North American karst systems, Southeast karst landscapes in particular have mid-range conductance values and high runoff values, accelerating dissolution and cave formation processes (Aley et al. 1993). These dissolved minerals represent an important source of calcium and carbon for use in biological systems.

On Your Knees Cave inside Bear Passage. Sedimentary layers and spring.
T. Heaton, University of South Dakota

Ecological Role of Karst Caves

Protection of the karst landscape is important to preserve the state's species biodiversity. The narrow range of interior conditions supports communities of species that are specifically adapted to unique environmental conditions. In addition, these environmental conditions generally occur in isolated pockets that preclude migration of individuals between habitat patches. As a result, obligate cave fauna, especially deep-cave inhabitants, have population characteristics of a species highly susceptible to rapid evolutionary change via endemism (Culver et al. 2003).

Locations of invertebrates and bats in Southeast karst caves often represent the northernmost known extent of these species' distribution. Prince of Wales Island holds records for northernmost locations of *Stygobromus* sp. and the bats *M. keenii* and *M. volans* (Baichtal 1996).

Bats are particularly vulnerable to human disturbance while hibernating. Bats do not store a lot of fat in preparation for hibernation (as bears do), and disturbance and rousing of hibernating bats can cause 10–30 days of fat to be metabolized (Brady 1982). Southeast karst caves may be extremely important to the perpetuation of bats in general in the state of Alaska. Of the 5 species of bats in the state only one, *M. lucifugus,* has a range extending northward of Southeast. *M. lucifugus* is widely distributed, with its summer range extending into the Yukon Territory. However, little is known about where the species overwinters. The Yukon Government theorizes that *M. lucifugus* migrate to the Alaskan coast to hibernate for the winter. Northern populations of *M. lucifugus* have larger females than males (southern populations do not have this sexual dimorphism). One suggested explanation for this is that juvenile bats must be larger at birth to have sufficient body resources to survive their first winter of hibernation. This may represent an adaptation unique to northern areas.

Karst caves are used as birthing dens by otters, and resting and denning sites for deer, bears, wolves and small mammals. Some bird species, including dippers, thrushes, and swallows, are known to use cave entrances for nesting and feeding.
Aquatic habitats associated with karst landscapes are more productive than nonkarst aquatic habitats (USFS 1997). Streams flowing through karst areas support larger coho salmon fry and parr than Southeast streams without karst. Higher alkalinities of karst streams are positively correlated with higher fish densities (Bryant 1997).

A consideration for preserving biodiversity in karst caves is the potential to discover previously undescribed species. A 2002 article in *Acta carsologica* identified the world's most diverse caves as having 41 to 84 species of stygobites and troglobites (Culver and Sket 2002). Meanwhile, a study of cave fauna on Prince of Wales Island preliminarily identified 77 invertebrate taxa even without many samples being identified to the species level (Carlson 1997b).

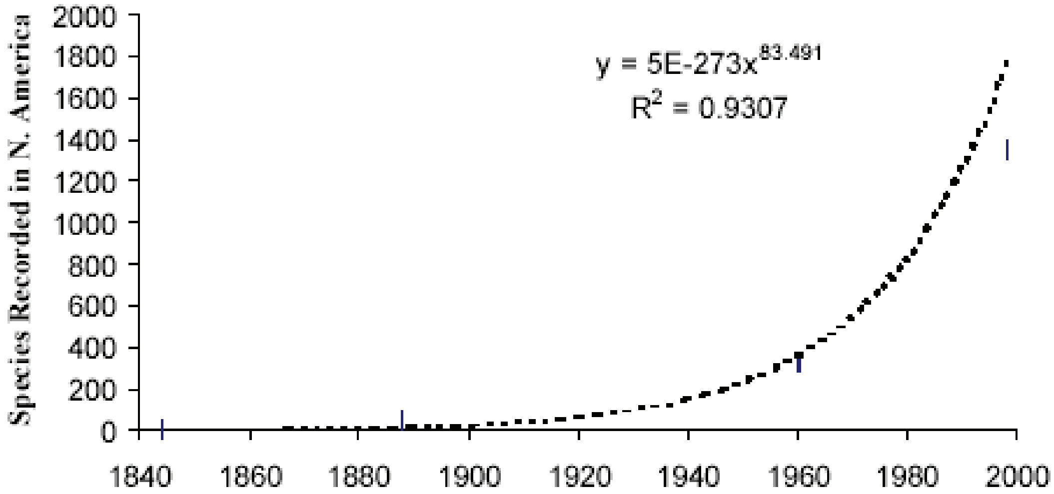

Figure 5.2. Graph showing exponential increase in the number of known obligate, cave-dwelling species in North America (DeKay, 1844; Nicholas, 1960; Packard, 1888; Peck, 1998) and a power function trend line fitted to the data.

From SUBTERRANEAN BIODIVERSITY PROJECT, Research Proposal Submitted to the Arkansas Game and Fish Commission. A.V. Brown and G.O. Graening, March 6, 2000.

Conservation Status

Alaska's karst cave habitat is generally healthy. Localized development will likely continue to result in habitat alteration. Opportunities should be sought that alleviate negative impacts and maintain connectivity, as well as suitable areas of quality habitat important to the sustainability of species.

The conservation of both karst cave habitats and associated species communities is complicated by the limited knowledge of the cave ecology in Alaska. Many unknown or poorly understood variables could impact species survival. Some of these variables include identifying links to the overlying landscape and connections to ground water and surface water systems. Hydrologic systems expand the area of impact and effects far beyond the physical limits of a cave. Habitat assessment can be complicated because karst drainage does not coincide with surface drainage patterns or even watershed or hydrologic unit boundaries (Karst Task Force for the Resources Inventory Committee 2001). Significantly, karst formation processes are impacted by both glaciers and permafrost. In Arctic regions, ground water circulation can be impeded by static ice masses (glaciers) that form in caves (Ford 1993). Little study has yet been conducted on the effects of climate change and karst cave fauna. To fully conserve karst caves and their resources, the caves and their karst landscapes must be managed as a whole.

Road development, land clearing, timber harvest, and mining activities all have the potential to alter subsurface water and nutrient flows. Timber harvest and related road construction in the vicinity of caves increase runoff and sedimentation, which may flood, scour, or fill previously stable cave environments. Debris accumulates and blocks cave entrances and exits through practices of disposing of slash and rerouting of surface flows into sinkhole ponds or dry sinkhole pits. Recreational users pose another, more direct, risk to cave habitat. A high volume of visitors can destroy terrestrial habitat in caves by compacting cave sediments (IUCN 1997). Bats are susceptible to human disturbance; caves can be gated with "bat friendly" gates to exclude human disturbance, but these can unintentionally exclude other nonhuman species that depend on, or opportunistically use, karst caves.

Karst caves have high value for paleontological research because fossils preserved in caves create records of species distribution through the last millennia and provide insight into the location and extent of glacial refugia during the last Ice Age. Species distribution may also provide insight into climate conditions when early bands of humans may have migrated through the area (Heaton 2002). There is an ongoing study funded by the National Science Foundation, National Geographic Society, Tongass National Forest, and University of South Dakota to inventory and identify paleontological deposits in caves in the Tongass National Forest.

El Capitan Cave. Female black bear skeleton radiocarbon-dated to be 10,750 years old (Late Pleistocene Epoch)
T. Heaton, University of South Dakota

The protection of a karst cave is very much dependent on the ownership of the overlying land. On state and private lands there is minimal to no protection. As of January 2005, the State of Alaska Division of Forestry did "not recognize karst topography as a significant resource to be managed on the State's limited land base in southeast. The DOF will protect karst formations that affect water quality as per the Alaska Forest Resources and Practices Act and Regulations. If significant recreational activity is found to be dependent on a karst resource, it will be taken into account during the development and implementation of the Forest Land Use Plan (FLUP) process for a proposed timber sale (Division of Forestry, Coastal Region)." In 1992 the state legislature attempted but failed to pass an Alaska State Cave Protection Act.

El Capitan Cave fish fossils; otoliths, vertebrae, spines and jaws dated to the early Holocene
T. Heaton, University of South Dakota

There is a higher level of protection for caves on federally owned lands due to the Federal Cave Resources Protection Act of

1988. This act applies to listed “significant caves” on federal lands. The significance is determined by criteria established by the Secretary of the Interior or his/her delegates. In Alaska, a large amount of the karst landscape is located on federal lands: Portions of the White Mountains are under BLM management; many of the caves in the Alexander Archipelago are in the Tongass National Forest; karst landscape is located in Wrangell–St. Elias National Park and Glacier Bay National Park; and the Lime Hills and the Jade Mountains are both located on a mixture of federally owned and Native-owned or -selected lands.

The 1997 Tongass Forest Plan Cave Standards and Guidelines (USFS 1997) implemented a karst resources management strategy that included developing an inventory of caves and hydrologic systems and protecting and maintaining significant caves and cave resources to the extent feasible. These guidelines fulfill responsibilities under the Federal Cave Resources Protection Act. The Forest Service in the Ketchikan area has developed a cooperative effort with the Alaska Cavers Association to inventory and document caves. The Thorne Bay Ranger District has developed trails and viewing platforms and tours for 2 of the larger caves in Southeast. Even within the Tongass National Forest, different land designations (monuments, wilderness areas, etc.) may affect the degree of cave protection (Streveler and Brakel 1993).

There are no species-specific legal protections for obligate cave inhabitants on nonfederal lands. *M. keenii* is on the “Red List” of potentially endangered species in Canada. Many troglobite invertebrates in the Lower 48 states are listed as endangered species due to their high degree of endemism and limited distributions.

One of the most important aspects of conserving karst caves is the preservation of aquatic systems. Currens (2001) documented changes in ground water flow after applying best management practices for protection of a karst aquifer similar to riparian best management practices instituted to protect ground water quality. Sinkholes should be recognized as a direct link to underground streams and vegetated buffer zones required around the sinkhole, as well as surface use restrictions in the immediate drainage area. Rapid transmission of ground water with little filtering through external vegetation and karst makes underground aquatic systems susceptible to pollution inputs (IUCN 1997).

Conservation actions that focus on cooperative working relationships between land managers and speleologists regarding karst cave habitats are an important tool for managing and protecting these areas. Identifying areas important to maintaining species diversity should continue.

Recommended conservation actions for karst caves include the inventory of caves in northern and western Alaska to acquire basic knowledge, such as extent, location, and any ecological use. Efforts toward achieving protected species status for rare, endemic cave fauna, such as the identification and description of Southeast invertebrate species and their associated habitat, should be supported. Research regarding the effectiveness of best management practices in karst areas to protect hydrology and prevent introduction of debris and contaminants is critical to sustaining healthy karst cave habitats. In addition, investigation of the use of instream flow reservations for ground water and subsurface ownership to protect cave resources should be considered. Final recommendations include support for identification of caves, and the establishment of guidelines for recreational use through working relationship with Alaska Caver's Association.

Literature Cited

Aley, T., C. Aley, W.R. Elliott, and P.W. Huntoon. 1993. Karst and cave resource significance assessment Ketchikan Area Tongass National Forest, Alaska. Ozark Underground Laboratory, Protem, MO.

Aley, T. and C. Aley. 1997. Groundwater recharge area delineation, hydrobiological assessment, and vulnerability mapping of four Ozark cavefish (AMBLYOPSIS ROSAE) populations in Missouri. A Report to the Missouri Department of Conservation. 115 pp. + app.

Baichtal, J.F. 1993. Evolution of Karst Management on the Ketchikan Area of the Tongass National Forest: Development of an Ecologically Sound Approach, In: Proc. Natl. Cave Mgmt. Symp., 1993. Ama. Cave Conserv. Assoc. In Press., 14 pp.

Baichtal, J.F**.** 1995. Evolution of Karst Management on the Ketchikan area of the Tongass National Forest: Development of an ecologically sound approach. Proceedings of the 1993 National Cave Management Symposium, Carlsbad, New Mexico. p. 190-202.

Baichtal, J.F. and D.N. Swanston. 1996. Karst landscapes and associated resources: a resource assessment. General Technical Report PNW-GTR-383. USFS Pacific Northwest Research Station, Portland OR.

Brady, J.T. 1982. The status of the Indiana bat (*Myotis sodalis*). In: R.C. Wilson and J.J. Lewis, editors. National Cave Management Symposia Proceedings, Carlsbad, NM, 1978, and Mammoth Cave, KY, 1980. Pygmy Dwarf Press, Oregon City, OR. p. 127–132

Bryant, M.D., D.N. Swanston, R.C. Wissmar and B.E. Wright. 1998. Coho salmon populations in the unique landscape of North Prince of Wales Island, Southeast Alaska. American Fisheries Society. 127:425–433.

Carlson, K.R. 1997a. The distribution of troglobitic and troglophilic invertebrates in Southeast Alaska. Proceedings of the 1997 Karst Cave Management Symposium, 13^{th} National Cave Management Symposium, Oct. 7–10, Bellingham, WA. p 28–33.

Literature Cited (continued)

Carlson, K.R. 1997b. Invertebrate habitat complexity in Southeast Alaskan karst ecosystems. Proceedings of the 1997 Karst Cave Management Symposium, 13th National Cave Management Symposium, Oct. 7–10, Bellingham, WA. p 34–43.

Christman, M.C. and D.C. Culver. 2001. The relationship between cave biodiversity and available habitat. Journal of Biogeography 28:367–380.

Culver, D.C., M.C. Christman, W.R. Elliott, H.H. Hobbs, and J.R. Reddell. 2003. The North American obligate cave fauna: regional patterns. Biodiversity and Conservation 12:441–468.

Culver, D.C. and B. Sket. 2002. Biological monitoring in caves. Acta Carsologica 31(1):55–64.

Currens, J.C. 2001. Changes in ground-water quality in a conduit flow dominated karst aquifer following BMP implementation. In: Beck and Herring, editors. Geotechnical and Environmental Applications of Karst Geology and Hydrology. p. 209–216.

CWCS Karst Cave Expert Group. 2004. Personal Communication.

Davis, M.J., A.D. Vanderberg, T.A. Chatwin, and M.H. Mather. 2000. Bat usage of the Weymer Creek cave systems on Northern Vancouver Island. In: Darling, L.M., editor. Proceedings of a Conference on the Biology and Management of Species and Habitats at Risk. Kamloops, BC. Feb. 15–19, 1999. vol. 1, p. 305–312.

Division of Forestry. Coastal region southern southeast area five-year schedule of timber sales (FYSTS) 2005–2009. p. 9.

Ford, D.C. 1993. Karst in cold environments. In: H.M. French and O. Slaymaker, editors. Canada's cold environments. McGill-Queen's University Press, Montreal. p. 199–222.

Heaton, T. 2002. Ice age paleontology of Southeast Alaska. http://www.usd.edu/esci/alaska/ Downloaded 5/04/2005.

IUCN. 1997. Guidelines for cave and karst protection/World Commission on Protected Areas (WCPA); synthesized and edited by J. Watson, E. Hamilton-Smith, D. Gillieson, and K. Kiernan for the WCPA Working Group on Cave and Karst Protection.

Literature Cited (continued)

Karst Task Force for the Resources Inventory Committee. 2001. Karst inventory standards and vulnerability assessment procedures for British Columbia. Version 1.0. Government Publications Centre, Province of British Columbia. http://srmwww.gov.bc.ca/risc/pubs/earthsci/karst/

Peck, S.B. 1988. A review of the cave fauna of Canada, and the composition and ecology of the invertebrate fauna of caves and mines in Ontario. Canadian Journal of Zoology 66:1197–1213.

Shaw, D.P. and M. Davis. 2000. Invertebrates from caves on Vancouver Island. In: Darling, L., editor. Proceedings of a conference on the biology and management of species and habitats at risk, Kamloops, BC, Feb15–19, 1999. BC Ministry of Environment, Lands and Parks, Victoria, BC, and University College of the Cariboo, Kamloops, BC. p.121–124.

Spicer, J.I. 1998. Is the reduced metabolism of hypogean amphipods solely a result of food limitation? Hydrobiologia 377:201–204.

Streveler, G. and J. Brakel. 1993. Cave lands of Southeast Alaska, an imperiled resource; a report to the Southeast Alaska Conservation Council. Appendix IV. Published by Icy Straits Environmental Services, Gustavus, AK.

USFS. 1997. Final EIS Tongass National Forest land management plan revision, Alaska.

Whitman, J., revised by Parker, D. 1996. ADF&G, Wildlife Notebook Series-Bats. http://www.adfg.state.ak.us/pubs/notebook/smgame/bats.php.

Yukon Government, Department of Environment. 2001. Little Brown Bat. http://www.environmentyukon.gov.yk.ca/bat.html.