CONCLUDING REMARKS: WHAT DO WE NEED TO KNOW ABOUT BATS IN NORTHWESTERN NORTH AMERICA?

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ABSTRACT—After being virtually ignored, bats in northwestern Canada and Alaska have recently been subject to increasing attention by scientists, resource managers, and the public. We review recent advances in bat research in the region and identify key priorities for future research, including what we believe is needed to provide a more coordinated approach to filling in these knowledge gaps. Our knowledge of the diversity and distribution of bats has improved considerably as a result of dedicated survey efforts. Scientists have provided a tantalizing glimpse into the natural history and ecology of bats in far northwestern North America and some of the unexpected adaptations they exhibit in response to the challenges imposed by northern environments. Despite these recent advances, further work is required to document the distribution of bats in the region; identify key summer roosting habitats and hibernacula; assess population status and trends; evaluate the impact of anthropogenic change and develop mitigation strategies; and better understand the natural history ecology of bats in the region. Improving our knowledge of these aspects of bat biology will be useful for informing conservation planning initiatives and environmental impact assessment processes. To ensure that new information is reliable and accessible, we strongly recommend that researchers strive to meet minimum evidentiary standards; deposit data, samples and voucher specimens in appropriate repositories; coordinate monitoring efforts and data collection; and publish or otherwise report results. We hope that our concluding remarks will help guide bat research in northwestern Canada and Alaska, and that the hard-earned results obtained in future studies will impart a positive impact on bat conservation in the region.

Key words: Alaska, bats, boreal forest, Chiroptera, conservation, monitoring, northwestern Canada, Pacific Coast, research priorities

Bats in Alaska and northwestern Canada have received comparatively little attention from scientists or managers (Parker and others 1997; Jung and others 2006; Olson and Jung 2014). Reasons for the paucity of bat research in the region are varied. In general, monitoring bat population trends is problematic and much work on methodological issues remains (O'Shea and others 2003; Weller and others 2009). Moreover, studying bats in the North is logistically difficult given the vast and remote nature of the landscape (Olson and Jung 2014; Wilson and others 2014). Additionally, with the exception of Keen's Myotis (*Myotis keenii*), species of bats in the region occupy large distributional ranges in North America, are somewhat ubiquitous where they occur, and are well studied elsewhere in their range (where it is less logistically challenging). Coupled with this, local bat assemblages are quite simple, with many areas believed to be occupied by a single species, the Little Brown Myotis (*Myotis lucifugus*; Slough and Jung 2008). Thus, bat communities in the North may not have been of particular scientific interest to bat biologists. Many local people in the North have historically had little interest in bats, likely because of their very late daily emergence in the summer commensurate with the region's longer days. As Fenton (1997, 2005) remarked, public perception and interest largely drive the amount of support bat research and conservation receives, and public interest in bats in the North appears to have increased only in the past 5 to 10 years. Finally, there may have been a perception among some scientists, managers, and granting agencies that there are no management or conservation concerns for bats in the North. Taken together, these factors have likely limited bat research in the region, until recently.

Concern over the westward spread of white-nose syndrome (WNS; for example, Frick and others 2010a; Dzal and others 2011; Foley and others 2011; Knudsen and others 2013), along with the response of bats to climate change (Humphries and others 2002; Lausen and others 2014) and habitat alteration (such as forest disturbances; Crampton and Barclay 1998; Patriquin and Barclay 2003; Randall and others 2011) and increased curiosity about the life history of bats in northern environments (Talerico 2008; Randall 2009; Reimer 2013), have fueled a growing interest in bats in the North (Wilson and others 2014; Olson and Jung 2014). As a result, there have been a number of recent and pioneering studies on the diversity, distribution, and ecology of bats in the region. This special issue is further testament to the growing attention bats in northwestern North America are receiving.

Our intent here is to briefly review recent advances in bat research in northwestern Canada and Alaska, drawing primarily from papers in this special issue, and to identify what we believe are currently the most pressing questions for bat conservation and management in the region. We conclude with suggestions for how best to ensure that hard-earned field data are translated into knowledge that can impart a conservation benefit to bats. While our remarks are focused on bats in northwestern North America, they may apply equally across the northern reaches of North America and Eurasia.

RECENT ADVANCES

Diversity and Distribution

Several targeted field inventories of bats in recent years (for example, Jung and others 2006; Lausen and others 2008; Boland and others 2009a; Grindal and others 2011; Lausen and others 2014; Reimer and others 2014), as well as a re-examination of specimens in collections (Parker and Cook 1996; Olson and others 2014) and citizen science efforts (Tessler and others 2014), have significantly advanced our knowledge of the diversity and distribution of bats in the region. For example, there have been a number of 1st records for species within the geopolitical jurisdictions in the region, including Keen's Myotis (Parker and Cook 1996), Northern Myotis (*Myotis septentrionalis*; Jung and others 2006), Yuma Myotis (*M. yumanensis*; Olson and others 2014), Long-eared Myotis (*M. evotis*; Lausen and others 2014), Long-legged Myotis (*M. volans*; West 1993; Lausen and others 2014; Slough and others 2014), Eastern Red Bat (*Lasiurus borealis*; Patriquin 2004), Hoary Bat (*L. cinereus*; Blejwas and others 2014; Slough and others 2014), and Silver-haired Bat (*Lasionycteris noctivagans*; Wilson and others 2014). An emerging theme is that local bat faunas in the North are much more diverse than previously thought.

We are also gaining a better understanding of the regional distribution of some of these species. For example, Lausen and others (2008) estimated the distribution limits of Northern Myotis based on extensive sampling in Yukon, and Blejwas and others (2014) did the same for Silver-haired Bats in Southeast Alaska. Importantly, papers in this special issue (Blejwas and others 2014; Lausen and others 2014; Slough and others 2014, Wilson and others 2014) provide evidence that Hoary Bats are well distributed in the southern part of the region. Similarly, growing evidence suggests that Eastern Red Bats may be more widely distributed throughout the eastern portion of the region than previously thought (Patriquin 2004; Grindal and others 2011; Nagorsen and Paterson 2012; Lausen and Player 2014), which may be a result of climate change (Willis and Brigham 2003) or other factors (for example, lack of previous survey effort).

Natural History and Ecology

A series of graduate theses (Talerico 2008; Randall 2009; Reimer 2013), along with papers in this special issue and others previously published, have begun to highlight the unique natural history of bats at high latitudes in northwestern North America. For example, we have learned, surprisingly, that the Little Brown Myotis exhibits considerably more flexibility in diet (Whitaker and Lawhead 1992; Talerico 2008), foraging habitat (Talerico 2008; Randall 2009), and roost site selection (West and Swain 1999; Slough 2009) than conspecifics at more southerly latitudes. For instance, a Little Brown Myotis in the North may seasonally feed on spiders gleaned from inside a cluttered forest and retire to a diurnal roost in a rock crevice, behavior that is quite a departure from that documented near the core of its range (Barclay and Fenton 1980). We have obtained a glimpse into some causes of mortality in Little Brown Myotis based on anecdotal observations (Jung and Slough 2005; Jung and others 2011); while Burles and others (2014) have provided interesting data on the winter activity of California Myotis (*M. californicus*) and the potential use of trees as hibernacula by the Little Brown Myotis on Haida Gwaii, thereby expanding the known suite of overwintering strategies in *Myotis* spp. On the other hand, observations of phenology (Slough and Jung 2008; Reimer and others 2014), activity patterns (Talerico 2008; Loeb and others 2014), and roost site selection (Randall and others 2014) in Little Brown Myotis in the North are largely consistent with those from elsewhere throughout its known range.

Taken together, these initial glimpses into the natural history and ecology of bats in the North paint a complex picture in which some aspects are similar to those observed at more southern latitudes, while others are extraordinarily different. Our initial forays into the lives of bats at high latitudes suggest that while some traits appear to be entrained and may pose limitations on survival and reproduction, others exhibit plasticity, allowing bats to adapt to the unique and changing environmental characteristics in the North.

WHAT DO WE NEED TO KNOW?

Above, we have reviewed what we believe are the most important recent scientific advances regarding bats in northwestern Canada and Alaska. While our understanding of the diversity, distribution, natural history, and ecology of bats in the region has advanced recently, further research is required to fill key knowledge gaps. Below, we outline what we view as the 5 main areas where further research is needed, including: (1) documenting diversity and distribution; (2) identifying key habitats; (3) assessing population status and trends; (4) evaluating the impacts of anthropogenic change; and (5) understanding natural history and ecology in the North.

Documenting Diversity and Distribution

Reliable information on the diversity and distribution of bats in the region is necessary for providing a baseline against which to assess change (Lausen and others 2014; Wilson and others 2014). For instance, Humphries and others (2002) noted that global warming could create conditions allowing Little Brown Myotis to expand its range northward. This may be reasonably expected for other species as well. Changes in distribution may also occur as a result of white-nose syndrome or other threats. Knowledge of current conditions, including sex-biased differences in distribution, will allow an evaluation of changes in the regional bat faunas over time. Baseline diversity and distribution data are also needed so that threats to bats can be assessed and addressed. For instance, evaluating the environmental impacts of proposed developments on bats requires knowledge of which bat species occur in the area.

Unfortunately, for reasons outlined above, our knowledge of the diversity and distribution of bats in northwestern Canada and Alaska lags well behind that for much of southern Canada and the contiguous United States. It is almost certain that some species occur, but remain unconfirmed, in some political jurisdictions (for example, Big Brown Bats in Yukon), and we require additional survey work to be able to delineate the range of most species (for example, Long-legged Myotis). Our knowledge has advanced significantly for many species that are readily identified based on unique morphological or echolocation call characteristics (for example, Hoary Bats), or aggregate, making them conspicuous (for example, Little Brown Myotis *sensu lato* Weller and others 2009). Similar discoveries may await inconspicuous species, which are difficult to detect and identify in the field or even after preparing voucher specimens (for example, Yuma Myotis; Olson and others 2014).

Ideally, once an adequate data set of occurrences is available, the distributions of bats in the region would be predicted using species distribution models (SDM; Guisan and Thuiller 2005; Elith and others 2006; Phillips and others 2006). It is important that these models then be validated with field inventories and used in conservation planning exercises and environmental impact assessment processes. Similar approaches to mapping bat distribution have been successfully used elsewhere (for example, Sattler and others 2007; Reblo and Jones 2010; Moratelli and others 2011; Rutishauser and others 2012).

Identifying Key Habitats

Most work identifying research priorities for bats places an emphasis on documenting and securing key habitats (for example, Fenton 1997; Keeley and others 2003; Kingston 2010), and this is also a top priority in northwestern Canada and Alaska. Habitat features important for the conservation of bats include hibernacula, maternity roosts, and migratory stopover sites. These sites are critical to bats and may be limited across the landscape (Fenton 1997).

Most maternity roosts are likely used repeatedly over the course of years, decades, or longer, and facilitate aggregation, social interactions, information transfer, and gene flow. Additionally, they provide sites where bats may be more readily monitored by biologists and citizen scientists. Maternity roosts are extraordinarily important in the life history of bats (Fenton 1997), and their selection by bats for key characteristics is well documented (for example, Crampton and Barclay 1998; Jung and others 2004; Psyllakis and Brigham 2006; Boland and others 2009b). Structures used as maternity colony roosts vary greatly in the region and may include anthropogenic structures (Whitaker and Lawhead 1992; Slough and Jung 2008; Randall and others 2014; Tessler and others 2014), live or dead trees (Boland and others 2009b; Loeb and others 2014; Randall and others 2014), rock crevices (Slough 2009; Randall and others 2014), and hot springs (West and Swain 1999; Burles and others 2008). Further work on identifying roost site selection in the region is needed. Specifically, the types and characteristics of roost site locations need to be identified, and roost fidelity and switching should be examined (for example, Johnson and others 2012; Olson and Barclay 2013). This would provide information needed for developing management guidelines to reduce the impacts of timber harvest on bats and mitigate other disturbances to bat maternity colonies.

Caves and abandoned mines are important hibernation sites for bats in eastern North America, but little is known about overwintering strategies of bats in northwestern North America. Reimer and others (2014) describe attributes and use of one of the only known bat hibernacula in far northwestern North America. Large hibernacula containing up to several thousand *Myotis* spp. have also been documented in Alberta (Schowalter and others 1979; Olson and others 2011), Northwest Territories (Wilson and others 2014), Montana (Hendricks and others 2000; Hendricks 2012), and South Dakota (Choate and Anderson 1997), but the largest documented hibernaculum of a species of Myotis west of the Rocky Mountains was a cave in Oregon containing only 64 *M. volans* (Perkins and others 1990). Our lack of knowledge of bat hibernacula in the region is currently the most important impediment in our ability to monitor and conserve bat populations in northwestern Canada and Alaska. It is highly likely that in most areas of northwestern Canada and Alaska bats hibernate singly or in small groups, as has been documented in more southerly regions of the West (Perkins and others 1990; Nagorsen and others 1993; Hendricks 2012), which will make identifying winter roosting habitat a challenging task. In addition to caves and mines, bats in western North America have been documented hibernating in buildings (Izor 1979; Perkins and others 1990; Nagorsen and others 1993; Hendricks 2012), trees (Izor 1979; Nagorsen and others 1993), and rock crevices (Lausen and Barclay 2002, 2006; Neubaum and others 2006), and in Norway bats have been documented hibernating in rock scree (Michaelsen and others 2013). It is likely that bats in the North make use of all of these roost types for hibernation and locating hibernacula must be a priority for bat researchers in the region, especially in light of the threat posed by white-nose syndrome. Doing so will require a combination of radiotelemetry studies and enhanced outreach to and coordination with cavers, mine enthusiasts and tenure holders, and the general public.

Migration routes seasonally link summer and winter habitats, and stopover sites are crucial to the survival of migratory bats given the energetically taxing process of migration (Taylor and others 2011; McGuire and others 2012; Szentkuti and others 2013). Despite recognition of the importance of stopover sites to migratory birds, until recently they have received little attention with respect to bats. Much of the recent interest stems from the need to identify and mitigate the impacts of wind farms (for example, Baerwald and Barclay 2009, 2011; Jameson and Willis 2012; Nagorsen and others 2014a,b) and more work on the timing of migration and location of migration routes and stopover sites is needed where wind energy development projects are proposed. Migratory stopover sites likely are used annually (Rydell and others 2014), and given that they facilitate aggregation of bats, detrimental changes to these sites may result in the loss of many individuals. This may be a particular concern on the Pacific Coast, where tall mountains and vast ice fields limit suitable migration routes and low-elevation stopover sites. Identifying such sites should therefore be a high priority.

Assessing Population Status and Trends

With the potential for large declines in bat abundance due to white-nose syndrome (Frick and others 2010a; Dzal and others 2011) and other anthropogenic threats (see below), it is imperative that baselines be established and populations monitored for a change in status. Some species of bats may be useful bioindicators and knowledge of their population status and trends may be indicative of ecosystem health in general (Jones and others 2009). As such, monitoring population status is often recommended as a research priority for bats (Keeley and others 2003; Kingston 2010), but it has been widely acknowledged that assessing bat abundance is highly problematic given their secretive and nocturnal nature (O'Shea and others 2003; Weller and others 2009).

Monitoring bats in the remote and vast landscapes of northwestern Canada and Alaska will be particularly difficult and require extraordinary effort. Complicating matters is the dearth of information we have on key locations where bats can be more readily monitored (hibernacula, maternity roosts, stopover sites), and the presumably low densities of bats in large parts of the region. Although new monitoring strategies are being developed (see below), we echo the conclusion of O'Shea and others (2003) that ''(new) research is needed to develop means to replace currently used indices, particularly if bat population monitoring objectives include detecting declines before they become catastrophic''. In the interim, Weller (2007) provides a comprehensive overview of bat survey and monitoring techniques and recommendations for best practices.

Evaluating the Impacts of Anthropogenic Change

All species of bats in northwestern Canada and Alaska live in, or adjacent to, forested areas and often depend on those habitats for summer roosting and foraging habitat. Bats are an important component of the biological diversity of northern forest ecosystems, and they may serve an important role in regulating nocturnal invertebrates and in the transfer of nutrients in these nutrient-limited environments (Pierson 1998). Changes in the availability or functionality of intact forest ecosystems, in the full range of seral stages, may be an important but diffuse threat to bats (Crampton and Barclay 1998; Grindal and Brigham 1998; Pierson 1998; Jung and others 1999; Brigham 2007; Weller and others 2009), with unquantified, but likely detrimental, impacts to both bat populations and forest health.

Forest ecosystems in northwestern Canada and Alaska, however, are experiencing rapid environmental change. Climate warming (Wolken and others 2011) and landscape change from industrial development (for example, timber harvest) as well as increases in the frequency and severity of forest fires (Kasischke and Turetsky 2006) and insect outbreaks (Aukema and others 2006; Werner and others 2006) are rapidly changing the structure and functionality of northern forests. Despite the loss of forest habitat for bats being a major research focus in much of southern Canada and the contiguous United States (see Lacki and others 2007), there is a marked lack of research on the impact of anthropogenic habitat loss on bats in northwestern North America. Again, this may be because of a misinformed notion that forest-dwelling bats in the North face few threats, but the evidence is clear that vast swaths of northern temperate rainforest and interior boreal forest will continue to be increasingly affected by logging, fire, or insect outbreaks. Accordingly, there is a pressing need to assess the impacts of these disturbances on bats in the region and, where necessary and feasible, develop appropriate strategies and protocols to mitigate these impacts.

An additional threat to bats in the region is wind energy development (Nagorsen and others 2014). Unlike the diffuse threat of forest habitat loss, wind energy developments represent a focal threat that has an impact that is localized (*sensu* Weller and others 2009). Even so, due to bat migration these developments pose a threat to some species that is far greater than their footprint would suggest. Populations of bats that concentrate their migration along established routes are particularly at risk of decline from wind energy developments constructed along migration corridors (Baerwald and Barclay 2009, 2011). Kunz and others (2008) identified research needs for bats and wind energy developments.

Understanding Natural History and Ecology in the North

Effective conservation planning for species requires accurate information on their natural history. Yet we know little about basic demographic factors such as survival or reproductive rates of bats in the North or the factors affecting those rates. The limitations imposed by a short, cool summer breeding season may force bats to be more flexible than researchers previously thought. It is unlikely that bats would be able to live at high latitudes if they did not adapt to the environmental conditions, which likely impose a constraint on bat reproduction and survival. For example, climate may pose a severe limitation on bat reproduction and overwinter survival of adults and juveniles (Grindal and others 1992; Burles and others 2009; Frick and others 2010b). Research on factors limiting survival and reproduction is needed to better understand limitations faced by, and adaptations of bats at the northern edge of their range. Moreover, understanding the natural history and ecology of bats in the region may help in the development of actions to address threats to bats, such as white-nose syndrome, climate change, and landscape change. We encourage further research on the natural history and ecology of bats in the North. More surprising results may await discovery.

A COORDINATED APPROACH

In the preceding section, we have outlined what we believe are the most important research and monitoring needs for bats in northwestern Canada and Alaska. Given the vast landscape and limited resources and infrastructure available in the North, we argue that advancing our understanding of bats cannot occur without extensive coordination and cooperation across the region. Below, we outline what we view as the 4 main components of such a coordinated approach: (1) adherence to minimum evidentiary standards; (2) archiving of samples, specimens, and data in natural history museums; (3) coordinated collection and sharing of population monitoring data; and (4) timely dissemination of research results.

Evidentiary Standards

Documenting bat diversity and delineating species ranges in the North is an important 1st step for bat research in the region. However, identifying some species of bats remains problematic for experts and enthusiasts alike and is subject to considerable scientific scrutiny (for example, see Olson and others 2014 and references therein). What then constitutes sufficient evidence to document a species occurrence? Opinions likely vary. Unfortunately, several bat species in northwestern North America have morphological or echolocation-call characteristics that overlap significantly, making identification based on these characteristics extraordinarily difficult (for example, Betts 1998; Barclay 1999).

McKelvey and others (2008) provide a compelling review of the need to ''get it right'' when claiming that a species is recorded in an area. Rightly so, they call for the judicious application of evidentiary standards to ensure that such records are defensible. Their arguments, based on examples of anecdotal sightings of Fisher (*Martes pennanti*) in the Pacific Northwest and Wolverine (*Gulo gulo*) and Ivory-billed Woodpeckers (*Campephilus principalis*) in the Lower 48, also hold true for many other rare or elusive species, including bats. Unfortunately, the sample set of lines of evidence and their relative reliability as an evidentiary standard provided by McKelvey and others (2008) are insufficient for the majority of bats, where species are often morphologically and acoustically cryptic.

Occurrence records for bats generally come from 1 or more of 3 sources: morphological examination, recorded echolocation calls, or genetic analysis (for example, see the papers in this special issue and references therein). Several species of bats in northwestern North America are readily recognizable from their pelage and external morphology (for example, Hoary Bat, Eastern Red Bat, and Silver-haired Bat). Positive identifications of these species can be straightforward from photographs or live captures. However, most species of bats in northwestern North America are morphologically similar and difficult to distinguish from photographs or in the hand. For these species, careful examination of voucher specimens by experts may be required, and even in those cases additional evidence, such as genetic analyses, may be necessary (for example, Yuma Myotis; Olson and others 2014).

Often, however, we are not confronted with a live or dead bat, or a photograph thereof, to examine. Since the advent of affordable, user-friendly bat detectors (O'Farrell and others 1999), many noteworthy records of bats have been based solely on recorded echolocation calls (for example, Blejwas and others 2014; Slough and others 2014). Although bat detectors may provide a convenient means to sample bats, the identification of species recorded should be regarded with caution (Betts 1998; Barclay 1999; Fenton 2001). Barclay (1999) correctly asserted that ''bats are not birds'', meaning that, unlike bird songs, bat echolocation calls may vary greatly among and within individuals, be highly context dependent (Broders and others 2004; Veselka and others 2013), and overlap with other species. For instance, Betts (1998) noted that the echolocation calls of Big Brown Bats and Silver-haired Bats may often be indistinguishable when recorded using bat detectors. As such, bat echolocation calls are not as reliable an indicator of species presence as are bird songs (Barclay 1999). For some species of bats in a given area, recorded echolocation calls may meet a minimum evidentiary standard of presence, providing that they are of sufficient quality and the diagnostic characteristics are unambiguous.

In our opinion, further discussion is required within the bat research community in northwestern North America to establish minimum evidentiary standards for identifying bat species in the region. We recognize that those standards may vary among species. In the interim, researchers should be conservative when using echolocation calls alone to identify species, and strive to collect genetic samples and, when necessary, voucher specimens to corroborate their field identifications.

Archiving Samples, Specimens, and Data

As mentioned above, some bat species are difficult to confidently identify in the field. External morphological measurements often overlap between species or vary geographically within species. The same is true for many qualitative external characters (for example, pelage color), which suffer the additional disadvantage of being subjective (see Olson and others 2014). In such cases, and where reliable species identification is important, it may be necessary to collect and deposit voucher specimens in accredited natural history museums (for example, the University of Alaska Museum of the North) where they can be prepared and archived in perpetuity. Voucher specimens meet the highest evidentiary standards in that they maximally satisfy the fundamental scientific criterion of repeatability. Unlike anecdotal accounts, voucher specimens can be re-examined. Bat researchers should consider the judicious collection of voucher specimens. Additionally, it is common to find dead, and often desiccated, bats. These are potentially valuable voucher specimens whose skulls and skeletons can be extracted and cleaned, whose age and sex are often discernible, and from whom genomic DNA can often be obtained (Faure and others 2009). At a minimum, field biologists should coordinate with an accredited natural history museum so that inadvertent mortalities or carcasses discovered by chance or through wind turbine mortalities can be archived.

The advent of affordable and efficient DNA sequencing has revolutionized biology and conservation. Increasingly, field biologists who live-capture bats collect wing biopsies (Simmons and Voss 2009) or other sources of DNA (Pun and others 2009) for subsequent genetic analyses prior to release, and we encourage them to do so. Field biologists should consider archiving these genetic samples in a repository where they can be properly preserved and made available to other researchers. Unfortunately, irreplaceable samples that are stored in unsecured or unreliable freezers and are not curated by experts in cryopreservation often become permanently degraded or lost.

While a proven solution exists for archiving specimens and samples, the same cannot be said for bat acoustic data or other nontraditional occurrence records. However, some natural history museums are expanding their holdings to include intangible occurrence records (or ''observations''), including photo, video, and audio files. For instance, Blejwas and others (2014) deposited their digital audio files of Hoary Bats (UAMObs: Mamm:187–UAMObs:Mamm:191), which represent the 1st records of this species in Alaska, on Arctos. Arctos (http://arctosdb.org) is a collaborative online collection management system used by a growing number of natural history museums in the US and Canada. Similarly, Tessler and others (2014) deposited photos of bats taken by citizen scientists from north and west of any previously published bat occurrence records in Alaska on Arctos (UAMObs:Mamm:150–UAMObs:Mamm:180). In both cases, these data will be archived and curated in accordance with rigorous standards developed for the long-term preservation of digital data (see http://arctosdb.org).

Monitoring Frameworks and Databases

Monitoring bats in this vast and remote region requires harnessing all the available 'person power'. Citizen science programs in the North and elsewhere have recently been successful in mobilizing members of the public to collect incidental information on bats and their habitats, and to conduct more systematic monitoring such as maternity roost counts and acoustic surveys. Volunteers can contribute to disease surveillance, help identify sites for more focused research and monitoring, and provide new insights into the distribution and biology of bats (for example, Tessler and others 2014; Wilson and others 2014). Example programs that may be used as models include the British Columbia Community Bat Program (http://www.bcbats.ca/), Alaska's Bat Monitoring Program (http://www.adfg.alaska.gov/index.cfm?adfg=citizenscience.bats), Vermont's 'Got Bats' campaign (http://www.vtfishandwildlife.com/wildlife_bats_gotbats.cfm), and United Kingdom's National Bat Monitoring Programme (http://www.bats.org.uk/pages/nbmp.html).

Monitoring the status and trends of bat populations is notoriously difficult, and the difficulties are likely even greater in the North compared to more populated areas. However, improved monitoring strategies are being developed that should help. Biologists, population modellers, statisticians, and other experts from multiple agencies have collaboratively drafted a plan for a North American Bat Monitoring Program (NABat; Loeb and others 2013). The NABat plan proposes a large-scale coordinated monitoring program for bats across the USA, Canada, and Mexico. It is designed to provide statistically robust information on the status of bat populations (distribution and indices of abundance) and, in the long term, on population trends. Standardized techniques and protocols are provided for counting bats at hibernacula and maternity colonies, and for conducting acoustic surveys at stationary points and along mobile transects. These techniques and protocols can also be used for local or regional monitoring outside of the NABat framework. A centralized database to house and manage data (Bat Population Database; US Geological Survey, https://www.fort.usgs.gov/science-tasks/2217) compiles historic data on bats in North America, and supports new monitoring data collected through NABat. NABat aims to provide regular analysis and reporting.

Implementing any bat monitoring program in the North is challenging because there are relatively few people, limited road access, relatively little knowledge of where bats aggregate, and presumably relatively low bat densities. Pilot projects are needed to test whether the approaches proposed in the NABat plan (particularly the acoustic survey methods) are feasible and will provide useful data in the North. We encourage researchers, government agencies, and citizen scientists to test those approaches and, if necessary, suggest improvements for monitoring bats in this region. Participating in such coordinated monitoring efforts where possible will allow data from northwestern North America to be included when bat populations are assessed.

Information on where bats and their key habitats occur is dispersed in many different sources with varying levels of accessibility, such as literature, databases, and unpublished reports. Submitting spatial information to a data warehouse such as NatureServe (http://www.natureserve.org/) and acoustics information to databases such as Data Basin BatAMP (http://databasin.org/groups/59d81a3951fd4915909efacbe2317efb) adds value to that information by making it more available to other researchers, wildlife managers, environmental assessment analysts, and the public. It also facilitates the coordinated analysis of information from various sources, allowing questions to be answered at a scale larger than a single jurisdiction or study area (for example, species distributions, status assessment, and conservation planning). Data from NatureServe are also often used in environmental impact assessment processes. While we recognize issues of data sensitivity and ownership, we also encourage the sharing of spatial data as a way to improve our understanding of bats in northwestern North America and their conservation.

Reporting Results

This special issue, and key works that have preceded it (for example, Parker and others 1997; Slough and Jung 2008; Boland and others 2009a; Grindal and others 2011), amply demonstrate that bats in the region are beginning to gain greater attention from scientists and managers. However, the region is large and, accordingly, the work is distributed among varied scientists from different institutions, agencies, and organizations. As such, it is important to ensure that new findings are disseminated to others working in the field in a timely manner. It is likely that several interesting findings concerning bats in the region remain in the gray literature, unavailable to others with similar interests. Similarly, valuable data are likely stored in files awaiting analyses. Enhanced information exchange would therefore be helpful (O'Shea and others 2003).

Various bat working groups covering the region (Northern Bat Working Group; Western Bat Working Group; Western Canadian Bat Network) have annual newsletters, listservs, or online discussion boards that can help make connections among bat researchers and facilitate the rapid dissemination of information about recent or overlooked publications and noteworthy findings. Of course, traditional outlets such as peer-reviewed scientific journals provide an important venue and archive of new research results. Awareness of the results of various research efforts enables scientists to map the distribution of species and research efforts, develop new hypotheses, and, ultimately increase our knowledge about bats in the region.

This special issue helps bring to light recent advances in the study of bats in the region, and we commend the authors of its constituent papers for making their work accessible. We encourage others working on bats in northwestern Canada or Alaska to also do so.

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