Methods to Evaluate and Develop Minimum Recommended Summer Survey Effort for Indiana Bats: White Paper

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Introduction

The Indiana bat (*Myotis sodalis*) was originally listed as being in danger of extinction under the Endangered Species Preservation Act of 1966 (32 FR 4001, March 11, 1967), and is currently listed as endangered under the Endangered Species Act (ESA) of 1973, as amended. Therefore, the U.S. Fish and Wildlife Service (Service) has a statutory requirement to conserve the Indiana bat. To help target conservation actions and to determine whether actions may impact Indiana bats, it is necessary to understand the species' distribution on regional and local landscapes. Although we have successfully monitored this species in the winter when large concentrations of Indiana bats are clustered in caves and mines, locating Indiana bats in the summer when maternity colonies are scattered across the eastern half of the United States has continued to be a monitoring issue. This challenge has increased and will continue to grow as white-nose Syndrome (WNS) continues to adversely impact Indiana bat populations. As a consequence, the Service is in the process of revising its recommended summer survey guidance. As part of this revision, we must ensure that the methods and levels of survey effort are adequate to detect the species and provide confidence in negative results.

The majority of summer surveys are conducted to facilitate permitting/project review decisions. Surveys are conducted at several sites within an area to determine if Indiana bats occupy the project area. The outcome is a binary presence/absence decision for the entire area, and the status of each survey site within the area is of secondary importance. Although a survey may or may not detect bats, the Service recognizes that results may not always represent the true status of a given survey area. For example, Indiana bats may be present and go undetected (i.e., false absence) or they may be absent, but a survey produces a false presence.

In 2011, the Service developed a multi-agency team (Team) to determine whether improvements could be made to the 2007 Indiana Bat Mist-Net Protocols[5] (2007 protocols). Briefly, the 2007 protocols (and previous versions) were designed to determine presence/probable absence of Indiana bats at a given location and required 4 net nights/123 acres of suitable habitat. The Team included biologists from each of the four Service regions (Midwest, Northeast, Southeast, and Southwest) where Indiana bats are known to occur, representatives of state natural resource agencies from three of those four regions (Midwest, Northeast, and Southeast), and representatives from three additional federal agencies (U.S. Army Corps of Engineers [USACE], U.S. Forest Service [USFS] and U.S. Geological Survey [USGS]).

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[5] See Appendix 5 in U.S. Fish and Wildlife Service. 2007. Indiana Bat (Myotis sodalis) Draft Recovery Plan: First Revision, U.S. Fish and Wildlife Service, Fort Snelling, MN. 258 pp. Available online http://www.fws.gov/midwest/endangered/mammals/inba/inba_drftrecpln16ap07.html.

In 2013, the Service implemented revised Indiana Bat summer survey guidelines (2013 Summer Survey Guidance) while the Team conducted a scientific peer review to further evaluate the appropriateness of methodologies used for calculating detection and occupancy rates and subsequent minimum levels of survey effort for 2014 and beyond. The 2013 Summer Survey Guidance called for a higher level of mist netting (24 net nights/123 acres of suitable habitat) in the Service's Northeast Region than in the other regions. In the Midwest, Southeast, and Southwest regions, the Service continued to accept 4 net nights/123 acres, following the 2007 protocols level of effort for mist netting. This regional difference in minimum level of survey effort for mist netting was due to an observed lower detection probability in the Northeast Region as a result of WNS-related reductions in winter and summer Indiana bat populations, which have not yet been observed in the Midwest, Southeast or Southwest regions.

This paper provides the Service's methodologies for developing recommended minimum levels of survey effort for the 2014 (and beyond) Indiana Bat Summer Survey Guidelines. Although the focus of this paper is the level of survey effort needed to determine presence/probable absence of Indiana bats at a given site, there are additional protocols in the 2014 Summer Survey Guidance that may help characterize the local population (e.g., radio-tracking and emergence counts).

Objectives

The Team's objectives (and therefore, the objectives of the Indiana bat summer survey guidelines) were to (1) standardize range-wide survey procedures; (2) maximize the potential for detection/capture of Indiana bats at a minimum acceptable level of effort; (3) make accurate presence/absence determinations; and (4) aid in conservation efforts for the species by identifying areas where the species is present.

Considerations

<u>Effectiveness of 2007 Survey Protocols</u>

We reviewed available literature studying the efficacy of the traditional survey technique (mist netting) and level of effort (one net site, consisting of two nets each, for every 123 acres for a minimum of two calendar nights) for the 2007 survey protocols. MacCarthy et al. (2006) also tested the efficacy of a 1999 version of the survey protocols in southern Illinois and found that of 157 bats on video approaching within 10 m of a mist net, 36 (23.1%) avoided the net, 79 (50.0%) were caught and collected, and 42 (26.9%) were caught but escaped before the return check. No species information was provided on bats that avoided the nets. Most escapees were larger, more aggressive bats (i.e., big brown [*Eptesicus fuscus*] and red bats [*Lasiurus borealis*]) that chewed through mist net strands and freed themselves. Conversely, smaller, more timid bats such as Indiana bats, eastern pipistrelles [*Pipistrellus subflavus*], and northern long-eared bats [*M. septentrionalis*] generally remained entangled longer (MacCarthy et al. 2006). They recommended a decreased time period (10 minutes) between net checks that was incorporated in the 2007 survey protocols. However, this change does not address the fact that bats may avoid nets entirely. Robbins et al. (2008) conducted netting following the 2007 survey protocols and acoustic sampling at each net site (>25 m from mist nets) in northeastern Missouri and found low capture success (44%) for Indiana bats when using nets, and greater "capture success", i.e., recording an Indiana bat, when using acoustic detectors (however, we recognize the potential for some false positives).

We also considered that after years of surveying across the range of the species, in terms of absolute numbers, less than 13%[6] of the estimated range-wide number of Indiana bat maternity colonies had been located as of 2009. Therefore, it seems likely that previous netting efforts have at times failed to document Indiana bats when they in fact were present on the landscape and we have not adequately sampled many occupied areas. For example, most surveys are not conducted in a proactive manner in areas where data could be obtained to allow for the development of suitable or predictive habitat models. Rather, most surveys are conducted in areas associated with proposed development projects. The concentration of various development activities (e.g., natural resource extraction) may bias sampling efforts. Although the majority of known maternity colonies have been located via netting efforts to date, a growing number have also been located by aerially radio-tracking Indiana bats as they emerge from their hibernacula in spring. These efforts have, for example, discovered the majority of known maternity colonies in the Northeast Recovery Unit (NERU). Moreover, aerial tracking efforts recently documented maternity activity in Georgia, Mississippi, and Alabama – locations where little or no summer mist-netting for Indiana bats would have previously been considered necessary and most expert opinion would have dismissed the species' occurrence.

Impacts from WNS

The relative abundance of an organism affects its detection probability. Between 2007 and 2011, WNS resulted in winter population declines of Indiana bats by 70% in the NERU (Service, unpublished data, 2013). Similarly, between 2011 and 2013, Indiana bat winter counts declined by 45.8% in the Appalachian Mountain Recovery Unit (AMRU) (Service, unpublished data, 2013). We anticipate future declines across the rest of the range. Parallel declines in summer activity of Indiana bats and that of other myotids have been observed during recent summer surveys in the Northeast (Ford et al. 2011, Francl et al. 2012). Even before WNS, the efficacy of the summer survey was in question. Therefore, with WNS-induced population declines, there is strong evidence suggesting a need to revise the summer survey guidelines to reduce the likelihood of false negatives in these surveys.

Methods

Data Sources

We reviewed the literature for any estimated detection probabilities and/or occupancy rates for which we could derive detection probabilities ourselves for Indiana bats. We discovered there was limited information in the literature reporting detection probabilities of Indiana bats using acoustical methods or data whereby those probabilities could be inferred. Results (per

[6] Based on the 2011 range-wide population estimate of 552,470 bats, and assuming a 50:50 sex ratio, and an average maternity colony size of 20 to 100 adult females (Kurta 2004), the roughly 350 known maternity colonies may only represent 3 to 13% of the 2,762 to 13,812 maternity colonies assumed to exist.

detector/night) were highly variable ranging from 0.26 in southeastern Missouri (Amelon 2007) to 0.62 in west-central Indiana (Duchamp et al. 2006) (Table 1).

It was similarly difficult to locate literature in which detection probabilities were estimated for Indiana bats using mist-net surveys. Robbins et al. (2008) observed that in an area known to have an abundance of Indiana bats in northeastern Missouri, Indiana bats were captured at 44% of net sites (2 nets x 2 nights).

Therefore, in the spring of 2012, we requested additional information from the Northeast, Midwest, and Southeast Bat Working Groups and proposed implementation of pilot studies to assess the minimum level of effort needed to detect Indiana bats. We received data from acoustic studies conducted using stationary detector sites located within documented Indiana bat maternity colonies at: the Fort Drum Military Installation, Jefferson County, New York (Coleman et al. 2013; Coleman 2013 Dept. of Army, unpublished data); the Fort Knox Military Installation, Bullitt and Hardin counties, Kentucky (Dept. of Army, unpublished data); Wildlife Management Areas in western Kentucky (Service, unpublished date); and locations in northern Missouri (data from Rommeling et al. 2012). We also obtained data from the USFS Northern Research Station's Fernow Experimental Forest, Tucker County, West Virginia (data from Ford et al. 2005). Call identification was done through a mix of visual/manual qualitative identification and available automated software (e.g., Echoclass v. 1.1 [Fort Drum in part] and BCID [Rommeling et al. 2012]). We accept that there might be substantive differences among the techniques but we believe that would only matter if we sought to directly compare measures of relative abundance of Indiana bats between sites, not presence or absence values needed for detection probability.

For mist-netting, we reviewed data from recent surveys where Indiana bat maternity colonies had been located in Ohio and Brooke counties, West Virginia (Stantec 2012) following the 2007 survey guidance; data from reports submitted to the Service from studies along the I-69 corridor in southwest Indiana and several counties in Ohio (Service unpublished data); and data from Fort Drum Military Installation, Jefferson County, New York (Coleman et al. 2013; Dept. of Army, unpublished data). Data was categorized as "pre-WNS" or "post-WNS". Pre-WNS data were defined as data collected from sites prior to any documented occurrence of WNS in that state or prior to any documented winter or summer declines in those states. Post-WNS data were defined as data collected from sites after declines in bat communities were observed in winter and summer in those states.

We constructed Indiana bat detection histories (h) for each acoustic detector or net (site) and each occasion, where '1' indicated the detection of an Indiana bat, and '0' indicated the non-detection of an Indiana bat. For example, a detection history for site i (h_i) of 100011 would represent Indiana bat detections on the first, fifth and sixth occasions over a single season.

Estimating Detection Probabilities and Occupancy Rates

We analyzed the resulting detection histories following MacKenzie et al. (2002) using the software package PRESENCE to estimate detection probabilities p and occupancy rates Ψ (http://www.mbr-pwrc.usgs.gov/software/presence.shtml) for various geographic locations. We then calculated the mean and median detection probabilities and occupancy rates for pre-WNS and post-WNS affected areas.

Determining Level of Effort

We compared the estimated detection probabilities and occupancy rates[7] with Table 3 from MacKenzie and Royle (2005) to determine the optimal surveying strategy[8] for a removal design where all sites are surveyed until the species is first detected or the minimum number of surveys has been conducted, where cost of the first and subsequent surveys are equal. This is the standard netting design – once an Indiana bat is captured – the species is confirmed present and surveys can terminate. This is also an option for acoustic surveys.

However, we were concerned that Indiana bat detection probabilities (for netting) were much lower than presented in MacKenzie and Royle (2005). Therefore, to better determine the number of survey replicates statistically necessary to infer absence (i.e., to calculate the probability of presence given no detections), we used the following equation, as presented in Wintle et al. (2012):

$$n = \frac{\log\left(\frac{\alpha}{1-\alpha}\right) - \log(\frac{\psi}{1-\psi})}{\log(1-p)}$$

whereby n is the number of survey replicates, α is the given probability of a Type I error, ψ is the probability that a site occupied, and p is the probability of detection (probability of the species appearing in a single sampling unit). We used the mean p and ψ for sites in pre-WNS and post-WNS affected areas and explored a range of α (0.01-0.15) to determine the number of survey replicates necessary to infer absence with a high level of certainty at each study area.

Results

For individual studies, detection probabilities ranged from 0.26 to 0.829 for acoustics (Table 1) and 0.018 to 0.316 for mist-netting (Table 2). Estimated occupancy rates ranged from 0.07 to 1 for acoustics (Table 1) and 0.038 to 0.63 for mist-netting (Table 2). Variation in values was dependent upon location as well as survey date, i.e., pre- or post-WNS. When we summarized survey data by pre-WNS and post-WNS affected areas, we found little difference between the detection probabilities reported from acoustic surveys in both periods (Tables 3, 5). However, we found higher amounts of mist-netting would be needed to detect Indiana bats after WNS impacts are observed in an area (Tables 4, 6). Further, we found that higher mist-netting survey

[7] If occupancy rates were not provided (e.g., Duchamp et al. 2006), we set to 1. Otherwise, we used estimated occupancy rates.

[8] MacKenzie and Royle (2005) state that, generally the optimal surveying strategy requires a reasonable degree of confirmation that the species is present (0.85 $<p^*<$0.95).

effort than previously estimated (i.e., 2007 protocols) is necessary to meet our objectives regardless of whether impacts from WNS have been observed in an area (Table 4, Figures 1 and 2). However, we offer an alternative presence/absence survey method with acoustics using far less effort (Table 5, Figure 3).

2014 Level of Effort

We made the following recommendations to Service management in November 2013 and received their approvals. We recommended identifying the minimum level of acoustic detector sites or net sites to achieve 90% confidence in any negative result. In other words, for every 100 projects we would likely incorrectly come to the conclusion that Indiana bats are not present when they really are 10 times. Using data from areas not yet significantly impacted by WNS, netting effort would be 9 net nights/123 acres of suitable habitat and acoustics 3 detector nights. Using data from areas impacted by WNS, netting effort would be 42 net nights and acoustics 4 detector nights.

While our original objective was to have a single range-wide survey protocol, we had concerns with making this recommendation for netting, given the extremely different results of observed detection probabilities. However, given the similar detection probabilities for acoustics, we recommended simplifying this portion of the protocols to a range-wide standard (4 detector nights/123 acres of suitable habitat). Although it will be difficult or perhaps impossible to predict each spring where impacts of WNS may be observed as the linkages between Indiana bat hibernacula and Indiana bat maternity areas are poorly understood, we decided to use Indiana Bat Recovery Units (RUs) when evaluating WNS impacts and determining an appropriate level of survey effort. We recommended this because band recaptures and telemetry have shown most Indiana bat winter/summer linkages are within a given RU. Therefore, we recommended determining levels of survey effort according to Indiana Bat RU.

For the purposes of determining level of Indiana bat survey effort we recommended the following definition for "WNS-impacted" RU. If winter counts document ≥50% of Priority 1 and 2 Indiana bat hibernacula within a RU decline by ≥30% from their most recent pre-WNS population estimates OR the total RU population declines by ≥30%, then that RU should be considered WNS-impacted[9]. Based on existing information, for 2014 summer surveys, the NERU and AMRU are considered WNS-impacted whereas the Midwest and Ozark-Central RUs are not. It should be noted that in most of the range of the Indiana bat, winter counts are conducted every other year. Accordingly, this may result in a 2-year delay in the revision of summer survey efforts.

For future years, as effects of WNS are better understood, it may make sense to revise the summer guidance by units smaller than an RU. We recommended evaluating summer netting and acoustic detection probabilities and occupancy rates and/or evaluating winter count information to assist with this decision.

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[9] Note: regardless of the cause/source of decline, if such declines are observed, the increased survey effort is needed.

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Table 1. Estimated Detection and Occupancy Rates from Acoustic Detectors. *Denotes sites with data that the authors used to calculate estimated detection and occupancy rates.

Site	Method	Years	WNS Status	Detection (p)	Occupancy (Ψ)	Source
Fort Knox, Kentucky	Acoustics	2012	Pre to Leading Edge	0.8292	0.5025	Silvis et al. unpub. Data*
Fort Knox, Kentucky	Acoustics	2012	Pre to Leading Edge	0.634	0.1314	Silvis et al. unpub. Data*
Fort Drum, New York	Acoustics	2012	Post	0.4375	0.4	Coleman 2013, Coleman et al. unpub. Data*
Western Kentucky WMAs	Acoustics	2012	Pre to Leading Edge	0.8265	0.683	Service, unpub. Data*
Fernow EF, West Virginia	Acoustics	2002-2004	Pre	0.3076	0.7545	Data from Ford et al. 2005*
Missouri	Acoustics	2012	Pre	0.2634	1	Data from Rommeling et al. 2012*
Missouri	Acoustics	2001-2003	Pre	0.26	0.07	Amelon 2007
Missouri	Acoustics	2002-2003	Pre	0.42	0.16	Duchamp et al. 2006, Yates and Muzika 2006
Indiana	Acoustics	2002-2003	Pre	0.62	1	Duchamp et al. 2006

Table 2. Estimated Detection and Occupancy Rates from Mist-Netting.

Site	Method	Years	WNS Status	Detection (*p*)	Occupancy (Ψ)	Source
Fort Drum, New York	Netting	2012	Post	0.019	0.038	Coleman 2013, Coleman et al. unpubl. data*
Northern West Virginia	Netting	2012	Post	0.0176	0.352	Stantec 2012
Ohio	Netting	2008-2012	Pre to Leading Edge	0.3163	0.4442	Service, unpub. Data*
Indiana	Netting	2004-2012	Pre	0.2428	0.6313	Service, unpub. Data*
Indiana	Netting	2004-2012	Pre	0.1627	0.6297	Service, unpub. Data*

*Denotes sites with data that the authors used to calculate estimated detection and occupancy rates.

Table 3. Level of Acoustic Effort (detector night) based on MacKenzie and Royle (2005).

WNS Stage	Summary	Detection (*p*)	Occupancy (Ψ)	Level of Effort (Removal)
Pre-WNS	Mean	0.5201	0.5377	5
	Median	0.52	0.59275	4
Post-WNS	Mean	0.4375	0.4	6
	Median	0.4375	0.4	6

Table 4. Level of Mist-netting Effort (net night) based on MacKenzie and Royle (2005).

WNS Stage	Summary	Detection (*p*)	Occupancy (Ψ)	Level of Effort (Removal)
Pre-WNS	Mean	0.2406	0.5684	15
	Median	0.2428	0.6297	15
Post-WNS	Mean	0.0183	0.195	>24
	Median	0.0183	0.195	>24

Table 5. Level of Acoustic Effort (detector night) to Infer Absence.

WNS Stage	Summary	Detection (*p*)	Occupancy (Ψ)	α	Level of Effort*
Pre-WNS	Mean	0.5201	0.5377	0.01	6
	Mean	0.5201	0.5377	0.05	4
	Mean	0.5201	0.5377	0.1	3
	Mean	0.5201	0.5377	0.15	2
Post-WNS	Mean	0.4375	0.4	0.01	9
	Mean	0.4375	0.4	0.05	5
	Mean	0.4375	0.4	0.1	4
	Mean	0.4375	0.4	0.15	3

*Detector nights

Table 6. Level of Mist-netting Effort (net night) to Infer Absence.

WNS Stage	Summary	Detection (*p*)	Occupancy (Ψ)	α	Level of Effort*
Pre-WNS	Mean	0.2406	0.5684	0.01	18
	Mean	0.2406	0.5684	0.05	12
	Mean	0.2406	0.5684	0.1	9
	Mean	0.2406	0.5684	0.15	7
Post-WNS	Mean	0.0183	0.195	0.01	172
	Mean	0.0183	0.195	0.05	83
	Mean	0.0183	0.195	0.1	42
	Mean	0.0183	0.195	0.15	17

*Net nights

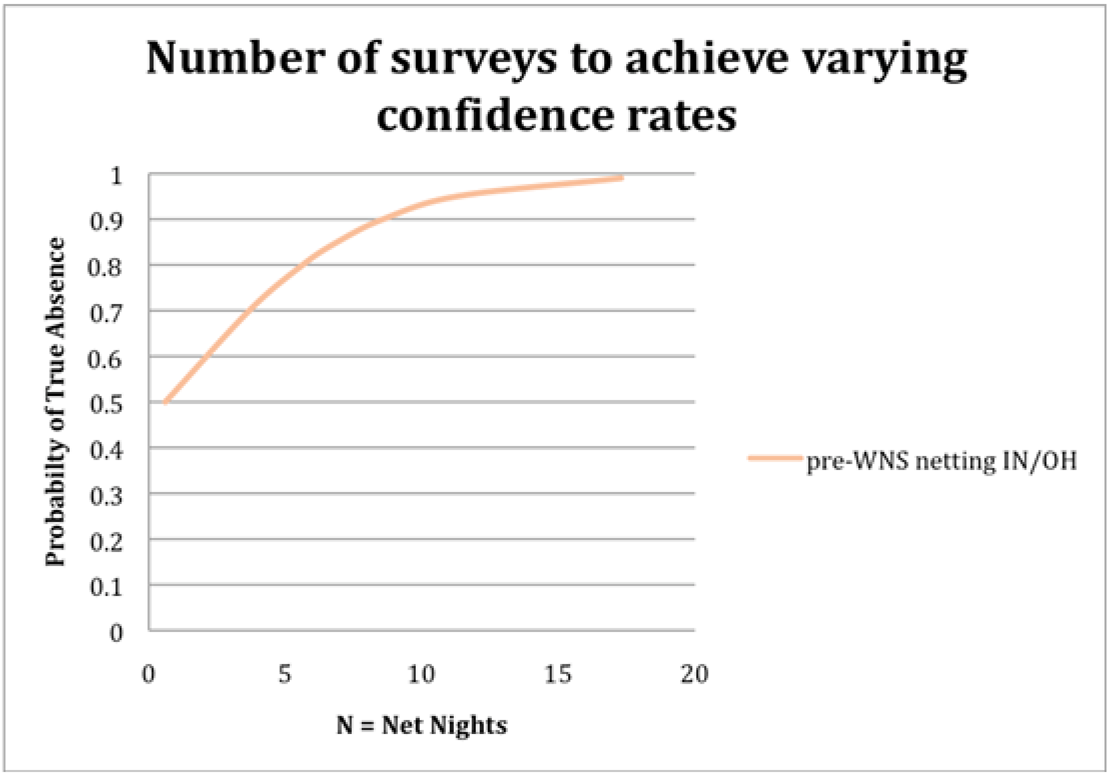

Figure 1. Number of mist-netting surveys to achieve confidence in negative results (based on data from IN and OH prior to documented impacts from WNS).

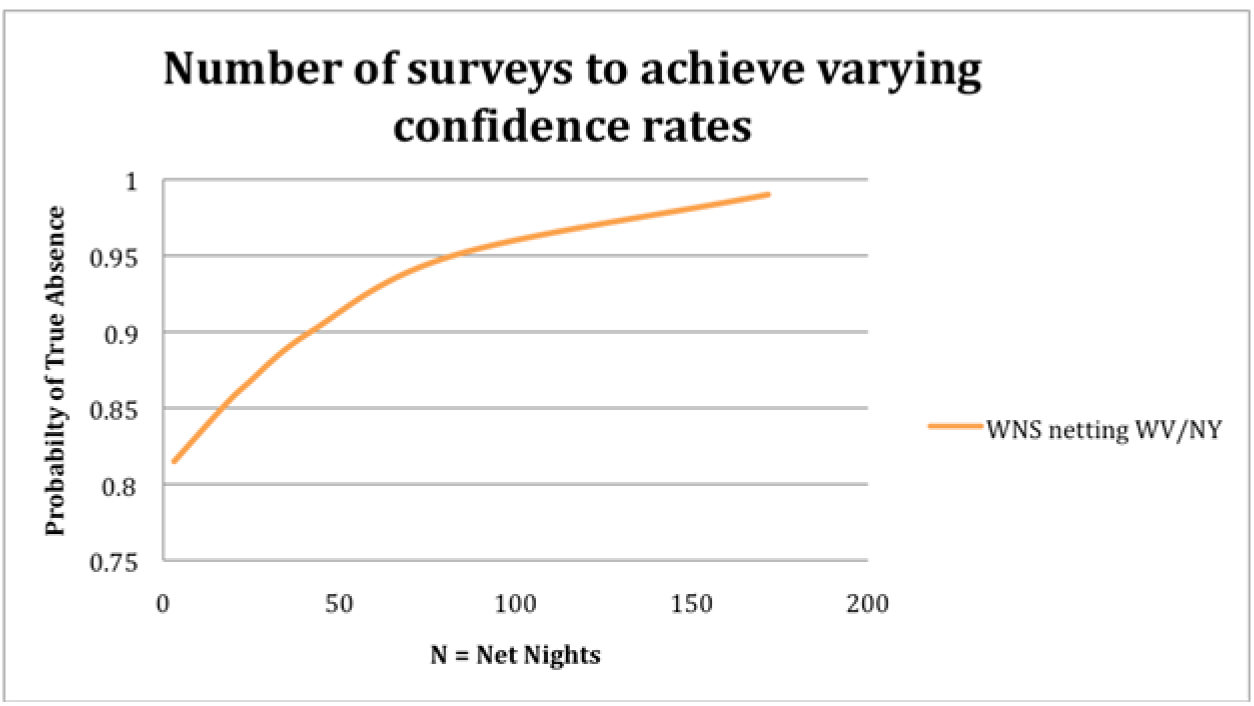

Figure 2. Number of mist-netting surveys to achieve confidence in negative results (based on data from NY and WV after documented impacts from WNS).

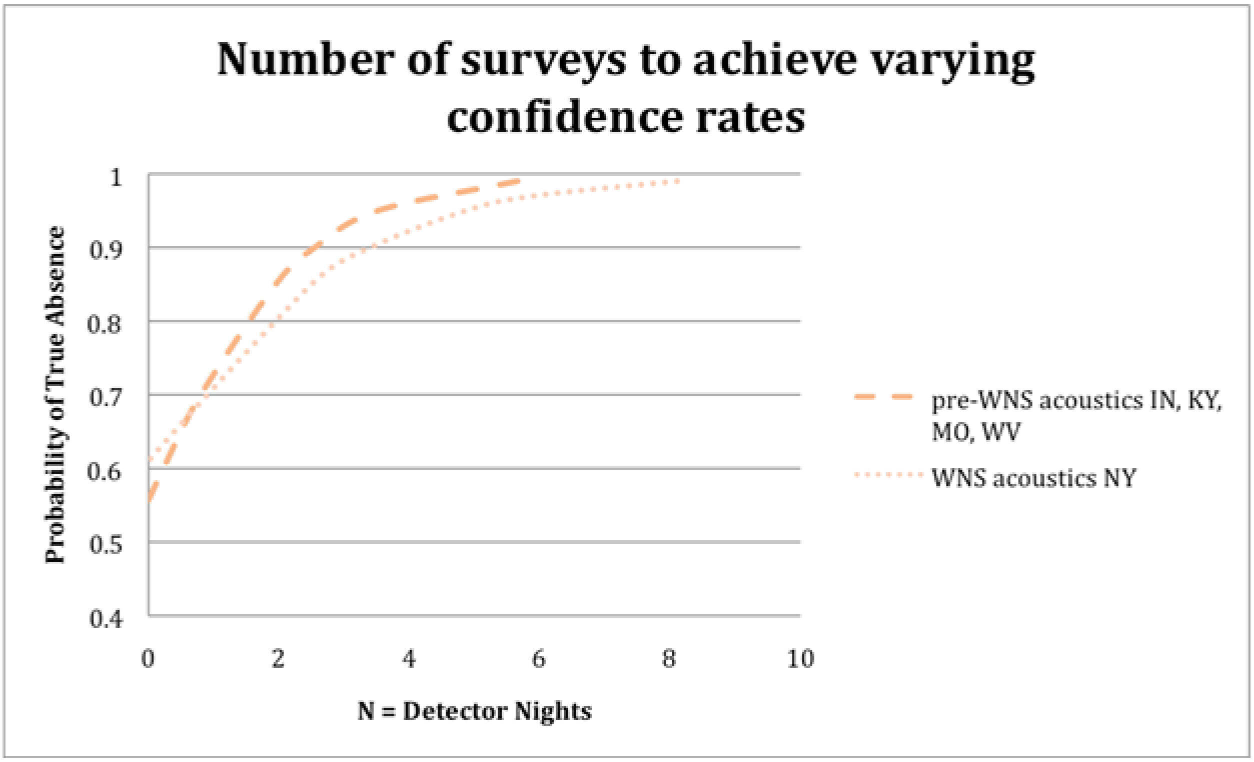

Figure 3. Number of acoustic surveys to achieve confidence in negative results.