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Environmental Data Associated With Sites Infected With White-Nose Syndrome (WNS) Before October 2011 in North America

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U.S. Department of the Interior
U.S. Geological Survey

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By Christopher S. Swezey and Christopher P. Garrity

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U.S. Geological Survey

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C = (°F – 32) / 1.8.

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F = (1.8 × °C) + 32.

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

GIS	geographic information system
ppm	parts per million
USGS	U.S. Geological Survey
USGS NWHC	U.S. Geological Survey National Wildlife Health Center
WNS	white-nose syndrome

Environmental Data Associated With Sites Infected With White-Nose Syndrome (WNS) Before October 2011 in North America

By Christopher S. Swezey and Christopher P. Garrity

Abstract

White-nose syndrome (WNS) is an emerging infectious disease of hibernating bats caused by a fungus previously known as *Geomyces destructans* and reclassified as *Pseudogymnoascus destructans*. The disease was first documented in 2006 in New York, has since spread across much of eastern North America, and as of January 2012, had caused the death of at least 5.7 to 6.7 million bats. Previous studies have suggested that environmental conditions play a strong role in WNS mortality. However, to predict where and when the disease will spread to new sites is difficult because detailed site information and associated environmental data are notably sparse. This paper presents a chronology of where and when WNS was detected in North America before October 2011 and indicates who reported the infections. This paper also presents available data on WNS-infected site elevation, geology, sediment chemistry and biota, air temperature, and relative humidity.

By the end of September 2011, at least 241 known WNS-infected sites were in North America and the number of infected sites per winter season had increased each year since 2006. The progressive increase in the number of infected sites per winter season suggests that the number of WNS infections had not peaked as of the 2010–11 winter season. WNS-infected sites include caves and mines, but the sites are not restricted by elevation, lithology, or strata age. Available data on site sediment chemistry are sparse but present a wide range of values, suggesting that caves and mines may contain a great range of microenvironments that are still poorly understood. The distribution of WNS may be restricted by air temperature and relative humidity. Published air temperature values from WNS-infected sites range from −15 to 33 degrees Celsius (but most temperature values are less than 20 degrees Celsius), and relative humidity values range from 50 to 100 percent. The spread of WNS may be restricted by a cave or mine temperature threshold of 20 degrees Celsius (which is likely to be south of most of the continental United States) and by some yet to be determined threshold of low relative humidity. These results indicate that WNS may not spread south into Mexico or to Puerto Rico.

Introduction

Numerous bat colonies in North America (fig. 1) have experienced dramatic and unusual incidences of mortality since the year 2006. In these colonies, a white fungus has been observed on the muzzles, noses, ears, or wings of bats, and this condition has been named white-nose syndrome (WNS) (Blehert and others, 2009). The fungus is a species of terrestrial saprophyte that was initially named *Geomyces destructans* (Gargas and others, 2009) and later reclassified as *Pseudogymnoascus destructans* (Minnis and Lindner, 2013). This fungus has been demonstrated to be the causal agent for WNS (Lorch and others, 2011). WNS was first documented in February 2006 at a cave in New York (fig. 1) (Porter, 2008b,c; Armstrong, 2009; Blehert and others, 2009; Turner and others, 2011) and has since spread across much of North America (figs. 1–3, table 1). Although exact numbers are difficult to determine, the U.S. Geological Survey National Wildlife Health Center (USGS NWHC) estimated that more than 1 million bats had died from WNS as of 2007 (USGS NWHC, 2009a), and the U.S. Fish and Wildlife Service estimated that at least 5.7 to 6.7 million bats had died from WNS as of January 2012 (U.S. Fish and Wildlife Service, 2012). These precipitous declines in population are predicted to cause extinction or extirpation of several bat species in North America (Frick and others, 2010; Thogmartin and others, 2013). Bats eat nocturnal insects that are agricultural pests, and a study published in 2011 indicated that the loss of bats in North America could result in agricultural losses estimated at more than $3.7 billion per year (Boyles and others, 2011).

WNS may be understood within the conceptual framework of the "disease triangle," which is the intersection of pathogen properties, host dynamics, and environmental parameters (Reeder and Moore, 2013). The disease occurs at the intersection of these three components (fig. 4). To date (2020), most studies of WNS have focused on the pathogen properties or the host dynamics, or both, whereas the environmental parameters of infected sites have received less attention.

Despite the research focus on the pathogen and host apices of the disease triangle, a few previous studies have suggested the importance of environmental parameters for

Table 1. List of sites infected with white-nose syndrome (WNS) before October 2011 in North America.

[See text for additional details and sources of data. no., number; m, meters above sea level; ft, feet above sea level; °C, degrees Celsius; %, percent; --, no data; >, greater than]

Site no. (figs. 1–3)	Infected site name	State or province	County or district	Site elevation (m)	Site elevation (ft)	Air temperature (°C)	Relative humidity (%)	Month detected	Year detected
1	Howe Caverns	New York	Schoharie	319	1,047	9.4 to 10.6	68 to 72	February	2006
2	Barytes Cave	New York	Schoharie	244	799	--	--	March	2006
3	Garden of Dina Mine	New York	Schoharie	258	847	--	--	--	2007
4	Schoharie Caverns	New York	Schoharie	304	997	--	--	January	2007
5	Gage Caverns	New York	Schoharie	387	1,271	8.9 to 12.2	--	March	2007
6	Hailes Cave	New York	Albany	356	1,167	--	--	March	2007
7	Knox Cave	New York	Albany	401	1,315	5.8 to 10.0	93 to 100	April	2007
8	Merlin’s Cave	New York	Columbia	223	731	8.9	--	December	2007
9	Howes Quarry Mine	New York	Schoharie	259	849	--	--	--	2008
10	Mass Hole	Massachusetts	Berkshire	33	108	--	--	January	2008
11	Williams Preserve Mine	New York	Ulster	65	214	--	--	January	2008
12	Williams Hotel Mine	New York	Ulster	77	253	--	--	January	2008
13	Morris Cave	Vermont	Rutland	250	820	6.1	--	January	2008
14	Elizabeth Mine	Vermont	Orange	356	1,167	--	--	January	2008
15	Unspecified site	Vermont	Washington	--	--	--	--	January	2008
16	Glen Park Caves	New York	Jefferson	134	439	--	--	January	2008
17	Clarksville Cave	New York	Albany	232	761	4.4 to 10.6	--	February	2008
18	Mitchell's Cave	New York	Montgomery	215	705	--	--	February	2008
19	Williams Lake Mine	New York	Ulster	81	266	--	--	February	2008
20	Bat’s Den Cave	Massachusetts	Berkshire	329	1,081	4.5 to 8.3	--	February	2008
21	The Old Mine	Massachusetts	Hampden	206	675	--	--	February	2008
22	Bakers Quarry Cave	Massachusetts	Berkshire	460	1,510	--	--	February	2008
23	Red Bat Cave	Massachusetts	Berkshire	457	1,500	--	--	February	2008
24	Unspecified mine	Massachusetts	Franklin	--	--	--	--	February	2008
25	Aeolus Bat Cave	Vermont	Bennington	763	2,503	6.1	--	February	2008
26	Bensons Cave	New York	Schoharie	330	1,082	--	--	March	2008
27	Hell’s Wells	New York	Schoharie	298	977	--	--	March	2008
28	Lasell’s Hell Hole	New York	Schoharie	367	1,203	--	--	March	2008
29	Ain’t No Catchment Cave	New York	Schoharie	277	910	--	--	March	2008
30	South Bethlehem Cave	New York	Albany	66	216	--	--	March	2008

Table 1. List of sites infected with white-nose syndrome (WNS) before October 2011 in North America.—Continued

[See text for additional details and sources of data. no., number; m, meters above sea level; ft, feet above sea level; °C, degrees Celsius; %, percent; --, no data; >, greater than]

Site no. (figs. 1–3)	Infected site name	State or province	County or district	Site elevation (m)	Site elevation (ft)	Air temperature (°C)	Relative humidity (%)	Month detected	Year detected
31	Martin Mine	New York	Ulster	74	244	--	--	March	2008
32	Williams Mine #7–8	New York	Ulster	77	252	--	--	--	2008
33	Williams Mine #9–10	New York	Ulster	77	252	--	--	--	2008
34	Williams Mine #11	New York	Ulster	77	252	--	--	--	2008
35	Unnamed cave near New Milford	Connecticut	Litchfield	--	--	--	--	March	2008
36	Unspecified site	Connecticut	Hartford	--	--	--	--	March	2008
37	Williams Cave	Vermont	Bennington	564	1,850	--	--	March	2008
38	Skinner Hollow Cave	Vermont	Bennington	585	1,920	--	--	March	2008
39	Main Graphite Mine	New York	Warren	486	1,596	--	--	March	2008
40	Greeley Mine	Vermont	Windsor	272	892	--	--	March	2008
41	McFail's Cave	New York	Schoharie	375	1,231	7.3	--	April	2008
42	Nature's Way Cave	New York	Albany	261	856	--	--	April	2008
43	Shindle Mine	Pennsylvania	Mifflin	389	1,277	--	--	November	2008
44	Hasbrouck Mine	New York	Ulster	26	84	--	--	December	2008
45	Indian Oven Cave	New York	Columbia	300	984	--	>95	December	2008
46	Surprise Cave	New York	Sullivan	221	726	--	--	December	2008
47	Barton Hill Mine	New York	Essex	455	1,493	1.0 to 11.1	--	December	2008
48	Fisher Hill Mine	New York	Essex	499	1,638	--	--	December	2008
49	Williams Fire Pit Mine	New York	Clinton	30	98	--	--	--	2008
50	Hitchcock Mine	New York	Essex	1,107	3,635	--	--	--	2009
51	Cave or mine at Friends Lake	New York	Warren	--	--	--	--	January	2009
52	East Magnesia Talc Mine	Vermont	Washington	388	1,274	--	--	January	2009
53	Unspecified cave	New York	Washington	--	--	--	--	January	2009
54	Jamesville Quarry Cave	New York	Onondaga	231	759	--	--	January	2009
55	Lawrenceville Mine	New York	Ulster	50	165	--	--	--	2009
56	Ely Copper Mine	Vermont	Orange	377	1,236	--	--	--	2009
57	Bridgewater Mines	Vermont	Windsor	361	1,184	--	--	January	2009
58	Camp Brook Mine	Vermont	Windsor			--	--	--	2009
59	Dover Iron Mine	Vermont	Windham	695	2,281	--	--	--	2009

Table 1. List of sites infected with white-nose syndrome (WNS) before October 2011 in North America.—Continued

[See text for additional details and sources of data. no., number; m, meters above sea level; ft, feet above sea level; °C, degrees Celsius; %, percent; --, no data; >, greater than]

Site no. (figs. 1–3)	Infected site name	State or province	County or district	Site elevation (m)	Site elevation (ft)	Air temperature (°C)	Relative humidity (%)	Month detected	Year detected
60	Unspecified mine	New Hampshire	Merrimack	--	--	--	--	January	2009
61	Unspecified mine	New Hampshire	Grafton	--	--	--	--	January	2009
62	Fahnestock State Park Mine	New York	Putnam	305	1,000	--	--	January	2009
63	Hibernia Mine	New Jersey	Morris	262	861	0.0 to 6.0	99 to 100	January	2009
64	Mount Hope Mine	New Jersey	Morris	244	800	--	--	January	2009
65	Pahaquarry Copper Mine	New Jersey	Warren	168	552	--	--	January	2009
66	Dunmore Mine	Pennsylvania	Lackawanna	316	1,036	--	--	January	2009
67	Shickshinny Mine	Pennsylvania	Luzerne	260	853	--	--	January	2009
68	Nuangola	Pennsylvania	Luzerne	442	1,450	--	--	--	2009
69	Hamilton Cave	West Virginia	Pendleton	640	2,100	10.8 to 12.8	--	January	2009
70	Trout Cave	West Virginia	Pendleton	622	2,040	6.0 to 13.0	81 to 92	January	2009
71	Brandon Mine	Vermont	Rutland	180	590	6.5	--	February	2009
72	Roxbury Mine	Connecticut	Litchfield	125	410	--	--	February	2009
73	Alexander Caverns	Pennsylvania	Mifflin	194	636	11.1	--	February	2009
74	Cave Mountain Cave	West Virginia	Pendleton	683	2240	--	--	February	2009
75	Breathing Cave	Virginia	Bath	717	2,354	0.6 to 33.0	--	February	2009
76	Single X Cave	New York	Schoharie	293	960	--	--	March	2009
77	Eagle Cave	New York	Hamilton	740	2,428	-5.0 to 4.4	--	--	2009
78	Fort Drum	New York	Jefferson	191	626	--	--	March	2009
79	Site near Ithaca	New York	Tompkins	--	--	--	--	March	2009
80	Site near Newstead	New York	Erie	--	--	--	--	March	2009
81	Site near Lancaster	New York	Erie	--	--	--	--	March	2009
82	Site near White Plains	New York	Westchester	--	--	--	--	March	2009
83	New-Gate Prison Mine	Connecticut	Hartford	137	450	--	--	March	2009
84	Carbondale Mine #1	Pennsylvania	Lackawanna	342	1,123	--	--	March	2009
85	Carbondale Mine #2	Pennsylvania	Lackawanna	342	1,123	--	--	March	2009
86	Seawra Cave	Pennsylvania	Mifflin	229	752	13.9	--	March	2009
87	Aitkin Cave	Pennsylvania	Mifflin	220	723	--	--	March	2009
88	Site at or near Woodward	Pennsylvania	Centre	340	1,114	--	--	--	2009

Table 1. List of sites infected with white-nose syndrome (WNS) before October 2011 in North America.—Continued

[See text for additional details and sources of data. no., number; m, meters above sea level; ft, feet above sea level; °C, degrees Celsius; %, percent; --, no data; >, greater than]

Site no. (figs. 1–3)	Infected site name	State or province	County or district	Site elevation (m)	Site elevation (ft)	Air temperature (°C)	Relative humidity (%)	Month detected	Year detected
89	Site at or near Mount Rock	Pennsylvania	Cumberland	167	548	--	--	--	2009
90	Clover Hollow Cave	Virginia	Giles	774	2,538	--	--	March	2009
91	W Mountain Cave	New York	Franklin	821	2,693	2.8 to 5.6	--	April	2009
92	Saltpeter Cave	West Virginia	Pendleton	527	1,729	--	--	May	2009
93	Newberry-Bane Cave	Virginia	Bland	781	2,561	7.0 to 11.0	--	May	2009
94	Hancock Cave	Virginia	Smyth	789	2,590	--	--	May	2009
95	Site near Peterborough	New Hampshire	Hillsborough	--	--	--	--	June	2009
96	Endless Caverns	Virginia	Rockingham	344	1,128	13.3	--	August	2009
97	Shingle Gully Ice Caves	New York	Ulster	373	1,225	--	--	November	2009
98	Nickwackett Cave	Vermont	Rutland	613	2,011	--	--	November	2009
99	Tawney's Cave	Virginia	Giles	574	1,883	--	--	November	2009
100	Hartman Cave	Pennsylvania	Monroe	236	775	--	--	December	2009
101	Tresckow Mine	Pennsylvania	Carbon	542	1,777	--	--	December	2009
102	Durham Cave	Pennsylvania	Bucks	46	150	7.2 to 16.7	--	December	2009
103	Eiswert Cave #2	Pennsylvania	Lycoming	213	698	--	--	January	2010
104	Red Church Cave	Pennsylvania	Schuylkill	228	747	--	--	January	2010
105	Hall Cave	Pennsylvania	Huntingdon	361	1,183	--	--	January	2010
106	Plymouth Caves	Vermont	Windsor	415	1,363	8.0	--	January	2010
107	Akron Mine	New York	Erie	--	--	--	--	February	2010
108	Johnson Talc Mine	Vermont	Lamoille	264	866	--	--	February	2010
109	Canoe Creek Mine	Pennsylvania	Blair	393	1,291	--	--	February	2010
110	Four confirmed but unspecified WNS sites	Pennsylvania	Lawrence	--	--	--	--	February	2010
111	Coon Cave	Virginia	Bland	798	2,618	--	--	February	2010
112	Repass Saltpeter Cave	Virginia	Bland	845	2,772	--	--	February	2010
113	Stonley's Cave	Virginia	Tazewell	805	2,642	--	--	February	2010
114	Worley's Cave	Tennessee	Sullivan	471	1,546	--	--	February	2010
115	Grindstaff Cave	Tennessee	Carter	560	1,836	--	--	February	2010
116	Letchworth Tunnel	New York	Livingston	--	--	--	--	March	2010
117	Mount Washington	New Hampshire	Coos	--	--	--	--	March	2010

Table 1. List of sites infected with white-nose syndrome (WNS) before October 2011 in North America.—Continued

[See text for additional details and sources of data. no., number; m, meters above sea level; ft, feet above sea level; °C, degrees Celsius; %, percent; --, no data; >, greater than]

Site no. (figs. 1–3)	Infected site name	State or province	County or district	Site elevation (m)	Site elevation (ft)	Air temperature (°C)	Relative humidity (%)	Month detected	Year detected
118	Hellhole	West Virginia	Pendleton	683	2,240	2.2 to 7.8	--	March	2010
119	Sites Cave	West Virginia	Pendleton	686	2,250	--	--	March	2010
120	Short Cave	West Virginia	Pendleton	610	2,000	--	--	March	2010
121	Sinnett Cave	West Virginia	Pendleton	686	2,250	6.7 to 15.6	66 to 88	March	2010
122	Dyers Cave	West Virginia	Hardy	504	1,653	--	--	March	2010
123	Cassell Cave	West Virginia	Pocahontas	923	3,029	--	--	March	2010
124	Carpenters Pit	West Virginia	Pocahontas	867	2,843	--	--	March	2010
125	Friars Hole	West Virginia	Greenbrier and Pocahontas	711	2,334	--	--	March	2010
126	Snedegars Cave	West Virginia	Greenbrier and Pocahontas	768	2,520	8.9	--	March	2010
127	Norman Cave	West Virginia	Greenbrier	632	2,075	--	--	March	2010
128	Patton Cave	West Virginia	Monroe	738	2,421	--	--	March	2010
129	Scott Hollow Cave	West Virginia	Monroe	649	2,128	--	--	March	2010
130	Caldwell Cave	West Virginia	Mercer	721	2,366	--	--	March	2010
131	Newcastle Murder Hole	Virginia	Craig	732	2,403	--	--	March	2010
132	Shires Saltpetre Cave	Virginia	Craig	753	2,472	--	--	March	2010
133	Pig Hole Cave	Virginia	Giles	703	2,308	8.0 to 10.0	--	March	2010
134	Starnes Cave	Virginia	Giles	708	2,322	--	--	March	2010
135	Greises Cave	Maryland	Allegany	312	1,024	--	--	March	2010
136	Unspecified site near Flesherton	Ontario	Grey	--	--	--	--	March	2010
137	Unspecified site	Ontario	Peterborough	--	--	--	--	March	2010
138	Abandoned mine near Faraday	Ontario	Hastings	--	--	--	--	March	2010
139	Tyendinaga Cave	Ontario	Hastings	137	450	4.4 to 9.4	78 to 87	March	2010
140	Craigmont Mine	Ontario	Renfrew	305	1,000	2.2 to 5.6	85 to 96	March	2010
141	Renfrew Mine	Ontario	Renfrew	398	1,305	−15.0 to 8.4	>90	March	2010
142	Bonnechere Caves	Ontario	Renfrew	130	425	−5.0 to 5.0	90 to 92	March	2010
143	Abandoned mine near Kirkland Lake	Ontario	Timiskaming	--	--	--	--	March	2010

Table 1. List of sites infected with white-nose syndrome (WNS) before October 2011 in North America.—Continued

[See text for additional details and sources of data. no., number; m, meters above sea level; ft, feet above sea level; °C, degrees Celsius; %, percent; --, no data; >, greater than]

Site no. (figs. 1–3)	Infected site name	State or province	County or district	Site elevation (m)	Site elevation (ft)	Air temperature (°C)	Relative humidity (%)	Month detected	Year detected
144	White Oak Blowhole Cave	Tennessee	Blount	560	1,837	7.4 to 10.3	--	March	2010
145	Camps Gulf Cave	Tennessee	Van Buren	311	1,021	--	--	March	2010
146	Dunbar Cave	Tennessee	Montgomery	137	449	--	--	March	2010
147	Caverne Lafleche	Quebec	Outaouais	260	853	0.0 to 2.8	90	April	2010
148	Summer roost site #1	Delaware	New Castle	--	--	--	--	April	2010
149	Summer roost site #2	Delaware	New Castle	--	--	--	--	April	2010
150	Hupman's Saltpeter Cave	Virginia	Highland	742	2,436	--	--	April	2010
151	Starr Chapel Saltpeter Cave	Virginia	Bath	676	2,218	--	--	April	2010
152	Clark's Cave	Virginia	Bath	466	1,530	--	--	April	2010
153	East Fork Saltpeter Cave	Tennessee	Fentress	333	1,092	--	--	April	2010
154	Unspecified cave	Missouri	Pike	--	--	--	--	April	2010
155	Bat Cave	Missouri	Shannon	255	837	−8.3 to 9.0	--	May	2010
156	James Selman Cave	Oklahoma	Woodward	515	1,691	0.6 to 17.0	50 to 90	May	2010
157	Pocahontas State Park	Virginia	Chesterfield	--	--	--	--	June	2010
158	Bowden Cave	West Virginia	Randolph	688	2,256	5.6	--	January	2011
159	Culverson Creek Cave—Culverson Creek entrance	West Virginia	Greenbrier	631	2,069	--	--	January	2011
160	Crossroads Cave	Virginia	Bath	475	1,557	--	--	January	2011
161	Rufe Caldwell Cave	Virginia	Craig	762	2,500	--	--	January	2011
162	Mill Creek Cave	Virginia	Montgomery	550	1,806	--	--	January	2011
163	James Cave	Virginia	Pulaski	601	1,971	--	--	January	2011
164	Hamilton Cave	Virginia	Bland	661	2,170	--	--	January	2011
165	Unspecified cave—Avery	North Carolina	Avery	--	--	--	--	January	2011
166	Endless Cave	Indiana	Washington	203	665	--	--	January	2011
167	Unspecified cave #1	Indiana	Crawford	--	--	--	--	January	2011
168	Unspecified cave #2	Indiana	Crawford	--	--	--	--	January	2011
169	Unspecified site	Connecticut	New London	--	--	--	--	February	2011
170	Culverson Creek Cave—Wild Cat Cave entrance	West Virginia	Greenbrier	684	2,243	--	--	February	2011

Table 1. List of sites infected with white-nose syndrome (WNS) before October 2011 in North America.—Continued

[See text for additional details and sources of data. no., number; m, meters above sea level; ft, feet above sea level; °C, degrees Celsius; %, percent; --, no data; >, greater than]

Site no. (figs. 1–3)	Infected site name	State or province	County or district	Site elevation (m)	Site elevation (ft)	Air temperature (°C)	Relative humidity (%)	Month detected	Year detected
171	Steeles Cave	West Virginia	Monroe	577	1,894	11.7	--	February	2011
172	Honaker Cave	West Virginia	Mercer	716	2,350	--	--	February	2011
173	Honaker Cave #2	West Virginia	Mercer	716	2,350	--	--	February	2011
174	Witheros Cave	Virginia	Bath	444	1,458	2.7 to 6.3	--	February	2011
175	Higginbotham #1 and #2 Caves	Virginia	Tazewell	877	2,876	--	--	February	2011
176	Rocky Hollow Cave	Virginia	Wise	920	3,020	5.6 to 7.5	--	February	2011
177	Abandoned mine	North Carolina	Avery	--	--	--	--	February	2011
178	Abandoned mine	North Carolina	Yancey	--	--	--	--	February	2011
179	Unspecified site	Connecticut	Fairfield	--	--	--	--	March	2011
180	Abandoned mine near Val-d'Or	Quebec	Abitibi Temiscamingue	--	--	--	--	March	2011
181	Unspecified site	Ontario	Nipissing Township	--	--	--	--	March	2011
182	Unspecified site	Ontario	Mattawa	--	--	--	--	March	2011
183	Unspecified site	Ontario	Timmons	--	--	--	--	March	2011
184	Berryton Cave	New Brunswick	Albert	255	836	−0.8 to 5.6	--	March	2011
185	Unspecified site	Pennsylvania	Tioga	--	--	--	--	March	2011
186	Unspecified site	Pennsylvania	Fulton	--	--	--	--	March	2011
187	Coon Cave	Pennsylvania	Westmoreland	798	2,618	9.4	--	March	2011
188	Barton Cave	Pennsylvania	Fayette	756	2,480	--	--	March	2011
189	Eliza Cave	West Virginia	Pendleton	549	1,800	--	--	March	2011
190	Hoffman School Cave	West Virginia	Pendleton	663	2,175	6.7 to 11.7	--	March	2011
191	Minor Rexrode Cave	West Virginia	Pendleton	707	2,320	7.8	--	March	2011
192	Schoolhouse Cave	West Virginia	Pendleton	668	2,190	5.0	--	March	2011
193	Lobelia Saltpeter Cave	West Virginia	Pocahontas	798	2,617	8.9	--	March	2011
194	Marthas Cave	West Virginia	Pocahontas	685	2,246	9.4	--	March	2011
195	Beethoven's Symphony Cave	West Virginia	Hardy	--	--	--	--	March	2011
196	Carol's Crack	West Virginia	Hardy	387	1,271	--	--	March	2011
197	Kline Gap Cave	West Virginia	Grant	543	1,781	10.0	--	March	2011
198	Arbogast Cave	West Virginia	Tucker	770	2,526	--	--	March	2011

Table 1. List of sites infected with white-nose syndrome (WNS) before October 2011 in North America.—Continued

[See text for additional details and sources of data. no., number; m, meters above sea level; ft, feet above sea level; °C, degrees Celsius; %, percent; --, no data; >, greater than]

Site no. (figs. 1–3)	Infected site name	State or province	County or district	Site elevation (m)	Site elevation (ft)	Air temperature (°C)	Relative humidity (%)	Month detected	Year detected
199	Blackwater Cave	West Virginia	Tucker	579	1,898	--	--	March	2011
200	Big Spring Cave	West Virginia	Tucker	716	2,348	--	--	March	2011
201	Cave Hollow Cave	West Virginia	Tucker	693	2,273	--	--	March	2011
202	Alpena Cave	West Virginia	Randolph	817	2,680	--	--	March	2011
203	Falling Spring Cave	West Virginia	Randolph	796	2,611	--	--	March	2011
204	My Cave	West Virginia	Pocahontas	788	2,586	--	--	March	2011
205	The Boar Hole	West Virginia	Greenbrier	--	--	--	--	March	2011
206	Bone Cave	West Virginia	Greenbrier	610	2,000	--	--	March	2011
207	Buckeye Creek Cave	West Virginia	Greenbrier	600	1,970	10.7	--	March	2011
208	Higginbotham #1 Cave	West Virginia	Greenbrier	686	2,250	--	--	March	2011
209	Higginbotham #4 Cave	West Virginia	Greenbrier	668	2,191	--	--	March	2011
210	Organ Cave	West Virginia	Greenbrier	681	2,234	5.1 to 9.9	--	March	2011
211	Piercys Cave	West Virginia	Greenbrier	519	1,702	--	--	March	2011
212	The Portal	West Virginia	Greenbrier	667	2,188	--	--	March	2011
213	Brooklyn Mine	West Virginia	Fayette	614	2,013	--	--	March	2011
214	Greenville Saltpeter Cave	West Virginia	Monroe	512	1,680	--	--	March	2011
215	Laurel Creek Cave	West Virginia	Monroe	516	1,694	11.1	--	March	2011
216	Beacon Cave	West Virginia	Mercer	802	2,631	--	--	March	2011
217	Noncave site	West Virginia	Jefferson	--	--	--	--	March	2011
218	Crabtree Cave	Maryland	Garrett	551	1,807	3.0 to 11.5	60 to 100	March	2011
219	Round Top Mines	Maryland	Washington	376	1,233	--	--	March	2011
220	Ogdens Cave	Virginia	Frederick	217	711	--	--	March	2011
221	Grand Caverns	Virginia	Augusta	390	1,278	--	--	March	2011
222	Dixie Caverns	Virginia	Roanoke	350	1,147	--	--	March	2011
223	Buddy Penley Cave	Virginia	Bland	821	2,693	--	--	March	2011
224	Concrete Tank Cave	Virginia	Russell	616	2,021	--	--	March	2011
225	Cooper Creek Cave/Foster Cave	Tennessee	Montgomery	141	462	--	--	March	2011
226	Bellamy Cave	Tennessee	Montgomery	567	567	--	--	March	2011
227	Unspecified cave near Linville Caverns	North Carolina	McDowell	--	--	--	--	March	2011

Table 1. List of sites infected with white-nose syndrome (WNS) before October 2011 in North America.—Continued

[See text for additional details and sources of data. no., number; m, meters above sea level; ft, feet above sea level; °C, degrees Celsius; %, percent; --, no data; >, greater than]

Site no. (figs. 1–3)	Infected site name	State or province	County or district	Site elevation (m)	Site elevation (ft)	Air temperature (°C)	Relative humidity (%)	Month detected	Year detected
228	Abandoned limestone mine	Ohio	Lawrence	--	--	--	--	March	2011
229	Unspecified site	Ontario	Peel	--	--	--	--	April	2011
230	Unspecified site	Ontario	Halton	--	--	--	--	April	2011
231	Unspecified site	Ontario	Simcoe	--	--	--	--	April	2011
232	Frenchman's Cave	Nova Scotia	Hants	--	--	0.0 to 6.7	82 to 94	April	2011
233	Unspecified site near Pisgah Center for Wildlife Education	North Carolina	Transylvania	--	--	--	--	April	2011
234	Cool Spring Cave	Kentucky	Trigg	--	--	--	--	April	2011
235	Unspecified site near Wawa	Ontario	Algoma	--	--	--	--	May	2011
236	Unspecified site	Quebec	Jamesie	--	--	--	--	May	2011
237	Unspecified cave	Maine	Oxford	--	--	--	--	May	2011
238	Unspecified site	Maine	Oxford	--	--	--	--	May	2011
239	Battered Bar Cave	Virginia	Bath	675	2,215	--	--	May	2011
240	Blind Faith Cave	Virginia	Bath	697	2,286	--	--	May	2011
241	Bobcat Cave	Virginia	Bath	771	2,528	--	--	May	2011

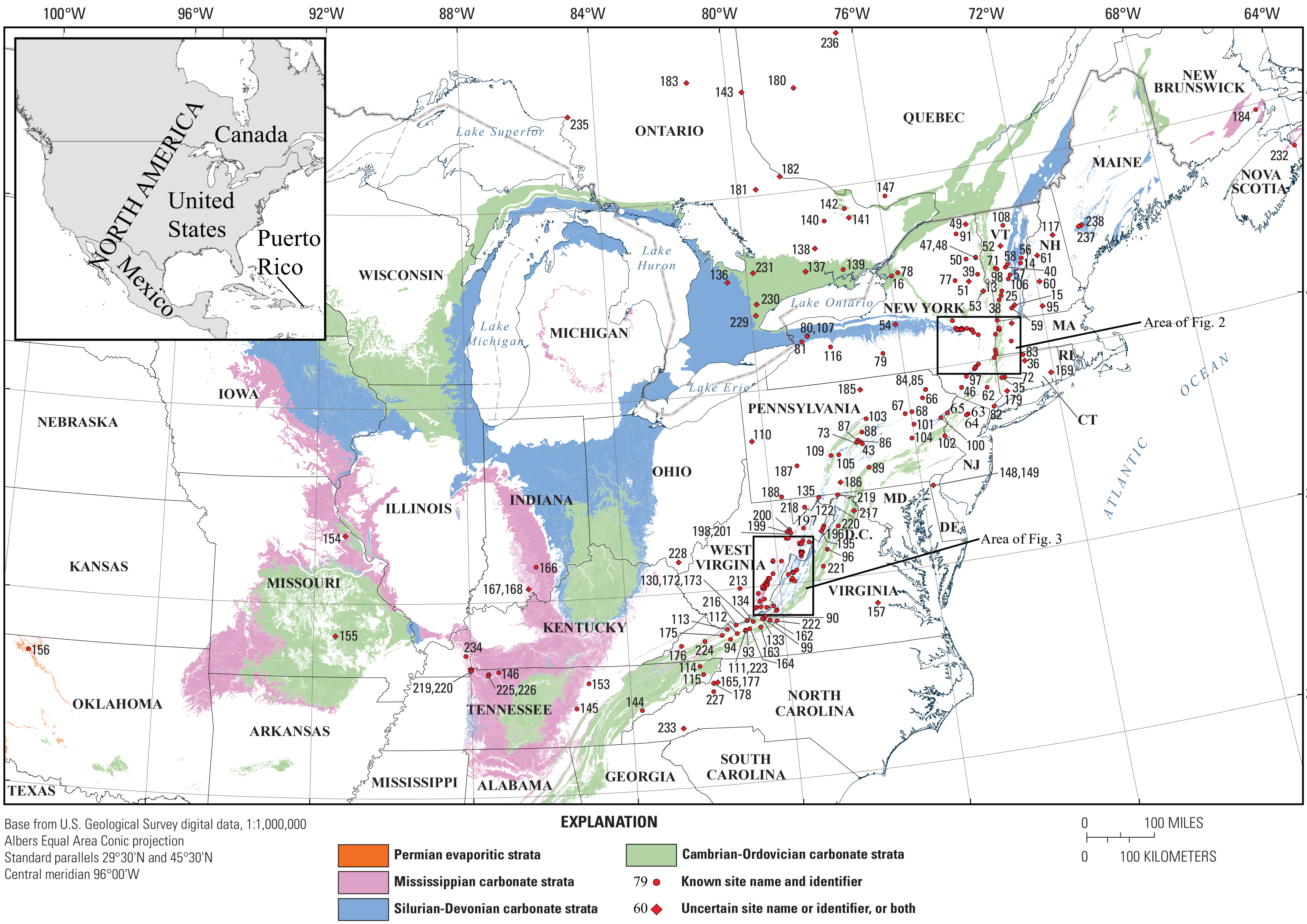

Figure 1. Map showing cave-bearing carbonate strata and the locations of sites infected with white-nose syndrome (WNS) before October 2011 in North America. Sites are numbered in the approximate order in which WNS infections were detected, and the key to site numbers is given in the first column of table 1. Geological data were derived from the U.S. Geological Survey (2012). Locations of figures 2 and 3 are denoted by rectangular boxes.

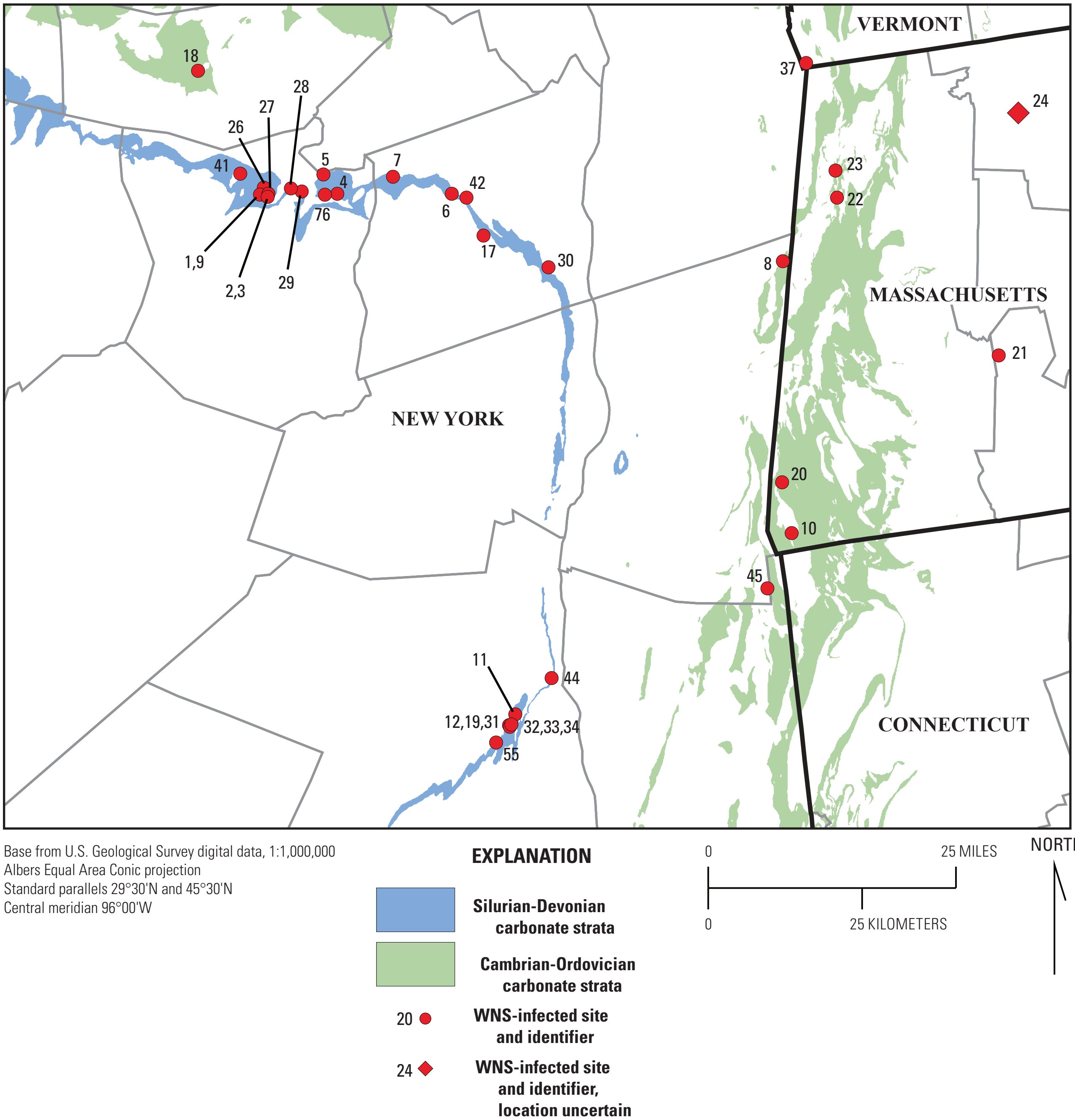

Figure 2. Map showing cave-bearing carbonate strata and the locations of sites infected with white-nose syndrome (WNS) before October 2011 in eastern New York and adjacent regions (see fig. 1 for location of fig. 2). Sites are numbered in the approximate order in which WNS infections were detected, and the key to site numbers is given in the first column of table 1. Geological data were derived from the U.S. Geological Survey (2012).

understanding WNS (for example, Flory and others, 2012; Hallam and Federico, 2012; Maher and others, 2012; Hayman and others, 2016). One study has indicated that the fungus can persist on cave and mine walls (Puechmaille and others, 2011), and other studies have indicated that *P. destructans* can persist in sediment on cave and mine floors (Blehert and others, 2011; Lindner and others, 2011). Yet another study has indicated that optimal temperatures for growth of *P. destructans* are between 5 and 10 degrees Celsius (°C) and that the fungus does not grow at temperatures greater than 20 °C (Blehert and others, 2009). A subsequent study indicated that optimal temperatures for growth of *P. destructans* are between 12.5 and 15.8 °C and that the upper temperature for growth is between 19.0 and 19.8 °C (Verant and others, 2012). A physiological

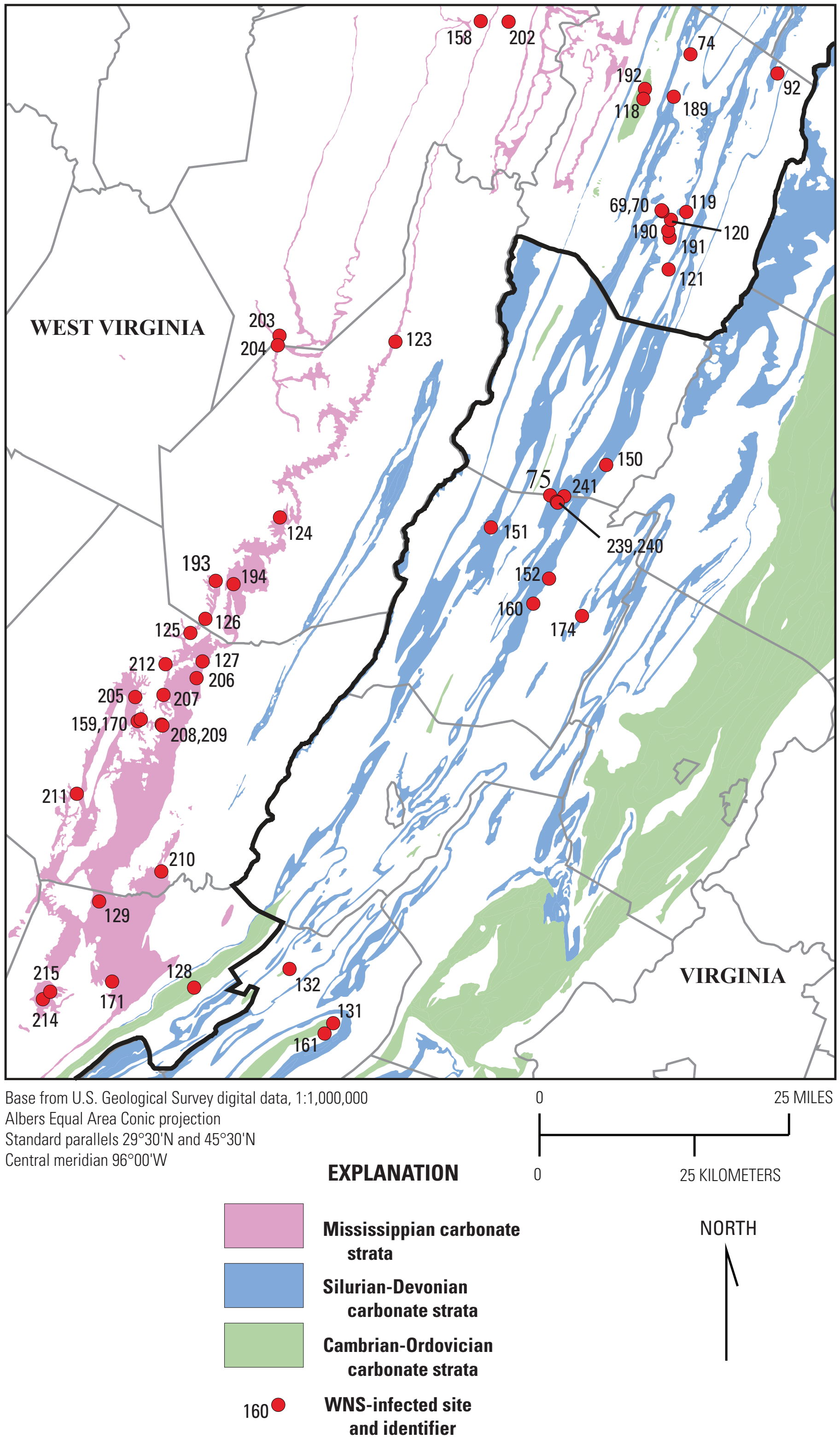

Figure 3. Map showing cave-bearing carbonate strata and the locations of sites infected with white-nose syndrome (WNS) before October 2011 in a part of eastern West Virginia and western Virginia (see fig. 1 for location of fig. 3). Sites are numbered in the approximate order in which WNS infections were detected, and the key to site numbers is given in the first column of table 1. Geological data were derived from the U.S. Geological Survey (2012).

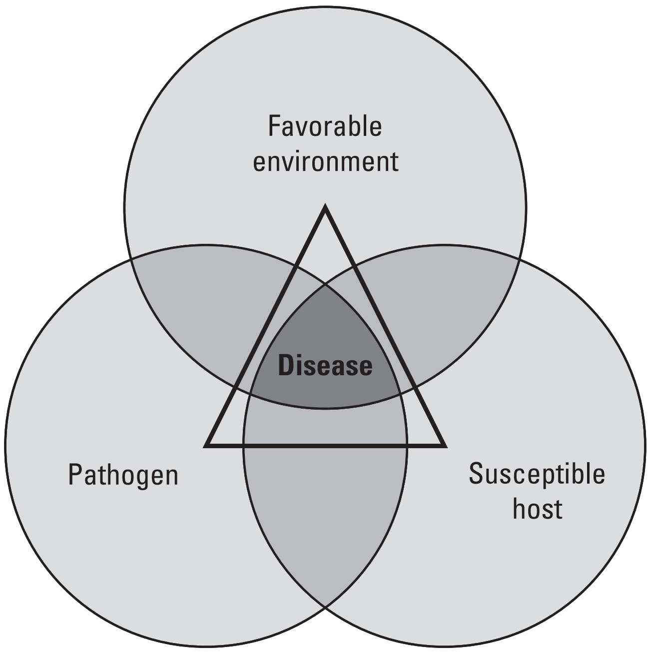

Figure 4. The "disease triangle" is a conceptual framework in which the disease occurs at the intersection of the pathogen, the susceptible host, and the environmental parameters (Van der Plank, 1964; Reeder and Moore, 2013).

model was used to conclude that bats hibernating in caves with warmer air temperatures may have better chances of surviving the effects of WNS (Hallam and Federico, 2012). Laboratory studies of *P. destructans* at a temperature of 13 °C have determined that (1) at relative humidity of 70 percent or less, mycelial growth was impeded but conidia production was not restricted; (2) with increasing relative humidity from 70.5 to 81.5 percent, mycelial growth and conidia production increased; and (3) at relative humidity values of more than 81.5 percent, mycelial growth and conidia production did not increase substantially (Marroquin and others, 2017).

To date (2020), however, few data have been published on the composition of infected cave and mine walls, the composition of sediment on the floors of infected caves and mines, or the air temperature or relative humidity of infected caves and mines. The few publications that have presented environmental data from WNS-infected sites have been hampered by (1) the lack of a publicly available list of infected sites and (2) the paucity of detailed environmental data from these sites. Despite these difficulties, Langwig and others (2012) analyzed data from 32 WNS-infected sites and postulated that the effect of WNS increases with air temperature and relative humidity. Thogmartin and others (2012) identified 59 WNS-infected sites and indicated that the spread of WNS is affected by distance from the nearest infected source population. Flory and others (2012) analyzed data from 81 WNS-infected sites and postulated that WNS mortality correlates with site elevation, air temperature, and precipitation. Swezey and Garrity (2011b) analyzed data from 41 WNS-infected sites, and Swezey and Garrity (2011a) analyzed data from 75 WNS-infected sites, and results indicate that the distribution of WNS does not correlate with site elevation, bedrock lithology, or strata age.

The purpose of this report is to provide data on the environmental apex of the disease triangle by presenting a detailed list of 241 WNS-infected sites that were identified in North America before October 2011 and a chronology of when the infected sites were detected. In addition, this report provides available data on site geology, sediment chemistry and biota, air temperature, and relative humidity. These data indicate trends in the geographic and temporal spread of the disease, and the data elucidate a range of environmental parameters at infected sites. As stated by Reeder and Moore (2013), this environmental variability is not well understood, but is likely to affect the progression of WNS as well as cave and mine suitability as hibernacula for various bat species. The data presented in this paper hopefully will be useful for modeling the spread of the disease, and the quantification of various environmental parameters should lead to a greater understanding of the dynamics of WNS.

Methods

The methods used in this paper include the compilation of site locations and infection dates from a variety of journal and online sources; the plotting of site locations on various maps in order to determine site elevation and geologic setting; and the compilation of available published information on site geology, sediment chemistry and biota, air temperature, and relative humidity. Particular emphasis is given to the environmental variables of sediment composition, site air temperature, and relative humidity. Sediment composition is considered to be important because *P. destructans* is a terrestrial saprophyte that can persist in sediment on cave and mine floors after the infected bats are dead (Blehert and others, 2011; Lindner and others, 2011). Air temperature is considered to be important because air temperature affects the growth of *P. destructans* (Blehert and others, 2009). Relative humidity is considered to be important because evidence indicates that *P. destructans* may prefer high relative humidity (Swezey and Garrity, 2011b). These three parameters (sediment composition, site air temperature, relative humidity) are presented in table 2, figure 5, and figure 6 (respectively). For the calculation of values given in table 2, x was used for individual values given as greater than x. Where data from an individual site are given as a range of values, the mean value of this range was used to calculate the environmental parameter mean value and standard deviation.

Site elevation, longitude, and latitude were calculated for most of the WNS-infected sites using geographic information system (GIS) software and available information in published literature. These data were used to construct figures 1–3, 5, and 6, but specific latitude and longitude values are not listed in table 1 for reasons of cave security.

Table 2. Composition of sediment at white-nose syndrome (WNS) infected sites.

[no., number; Ca, calcium; ppm, parts per million; Mg, magnesium; Na, sodium; P, phosphorus; K, potassium; Cl, chloride; NO_3, nitrate, SO_4, sulfate; Ref., sources of data; >, greater than; --, no data; n, number of sites; StdDev, standard deviation]

Site no. (figs. 1–3)	Infected site name	Ca (ppm)	Mg (ppm)	Na (ppm)	P (ppm)	K (ppm)	Cl ppm)	NO_3 (ppm)	SO_4 (ppm)	pH	Ref.
70	Trout Cave	>15,000	594	--	125	508	--	2,100	--	7.4	([1,2])
74	Cave Mountain Cave	--	--	--	--	--	--	300 to 2,200	--	--	([3])
118	Hellhole	>15,000	709	--	125	429	--	--	--	6.7	([1])
121	Sinnett Cave	>15,000	713	--	125	82	--	480 to 580	--	8.0	([1,4])
152	Clark's Cave	1,118 to 5,350	280 to 1,270	122 to 620	--	24 to 104	178 to 419	4,544 to 25,290	481 to 1,780	--	([5])
158	Bowden Cave	>1,200	>120	--	24	49	--	--	--	8.0	([1])
174	Witheros Cave	684 to 5,285	64 to 1,783	36 to 546	--	34 to 72	10 to 508	67 to 18,790	773 to 2,034	--	([5])
190	Hoffman School Cave	>15,000	273	--	125	155	--	--	--	6.7	([1])
191	Minor Rexrode Cave	>15,000	706	--	131	1,044	--	--	--	7.7	([1])
192	Schoolhouse Cave	9,820	684	--	83	189	--	--	--	7.9	([1])
201	Cave Hollow Cave	8,343	395	--	102	170	--	--	--	7.9	([1])
210	Organ Cave	>15,000	652	--	121	123	--	300 to 1,000	--	7.7	([1,4])
218	Crabtree Cave	--	Low to very high	--	Very high	Very high	--	--	--	7.2 to 7.8	([6])
Mean	--	10,507 (n=11)	595 (n=11)	331 (n=2)	107 (n=9)	261 (n=11)	278 (n=2)	4,813 (n=6)	1,267 (n=2)	6.8 (n=10)	--
Range	--	684 to >15,000	64 to 1,783	36 to 620	24 to 131	24 to 1,044	10 to 508	67 to 25,290	481 to 2,034	6.7 to 8.0	--
StdDev	--	5,676	237	57	35	301	28	5,464	194	0.5	--

[1]Landolt and others, 1992.

[2]Swezey and others, 2004b.

[3]Hoke, 2005.

[4]Swezey and others, 2004a.

[5]Hubbard and others, 1986.

[6]Miller and Franz, 1963.

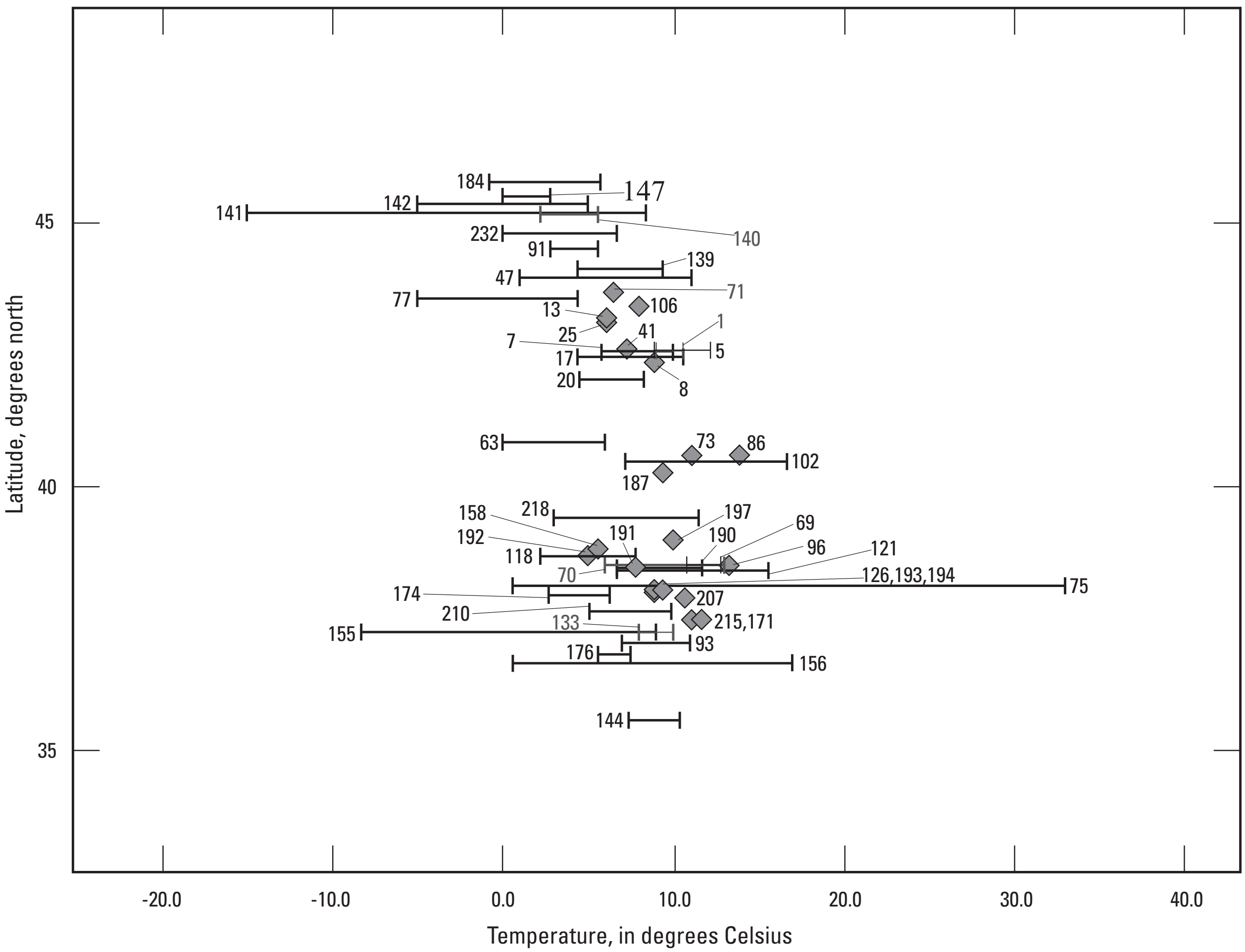

Figure 5. Air temperature versus latitude of caves and mines infected with white-nose syndrome (WNS) before October 2011. Where only one temperature measurement was recorded, this value is represented by a diamond. Where multiple temperature measurements were recorded, the range of values is represented by a horizontal line with short vertical bars at the two ends. Numbers adjacent to diamonds and horizontal bars refer to site numbers as listed in table 1. Additional details regarding temperature data are given in the text.

Results—Environmental Data from White-Nose Syndrome-Infected Sites

Results of the data compilation indicate that 241 WNS-infected sites were identified in North America before October 2011 (figs. 1–3, table 1). Because a comprehensive and publicly available database of infected sites has not been available previously, the sources of data on site location and infection date are provided in this paper so that the reader may evaluate the veracity of the information. Data on infected sites identified after September 2011 were not compiled for this paper because the available data are considered to be not comprehensive (because many infected sites detected after September 2011 were not recorded in counties that already contained another WNS-infected site).

The 241 sites that are known to have been infected with WNS before October 2011 are listed in this report in the approximate order in which the infections were detected. The sites are grouped into sections with subheadings that indicate whether the infections were detected during the winter hibernating season for bats (October through April) or during the summer nonhibernating season for bats (May through September). For each site, the site name and location are preceded by a number in parentheses that corresponds with the site numbers in figures 1–3 (and table 1). Each site name and location are followed by available data on site geology, sediment chemistry and biota, air temperature, and relative humidity. The available data are followed by the date that the WNS infection was detected and who reported the infection.

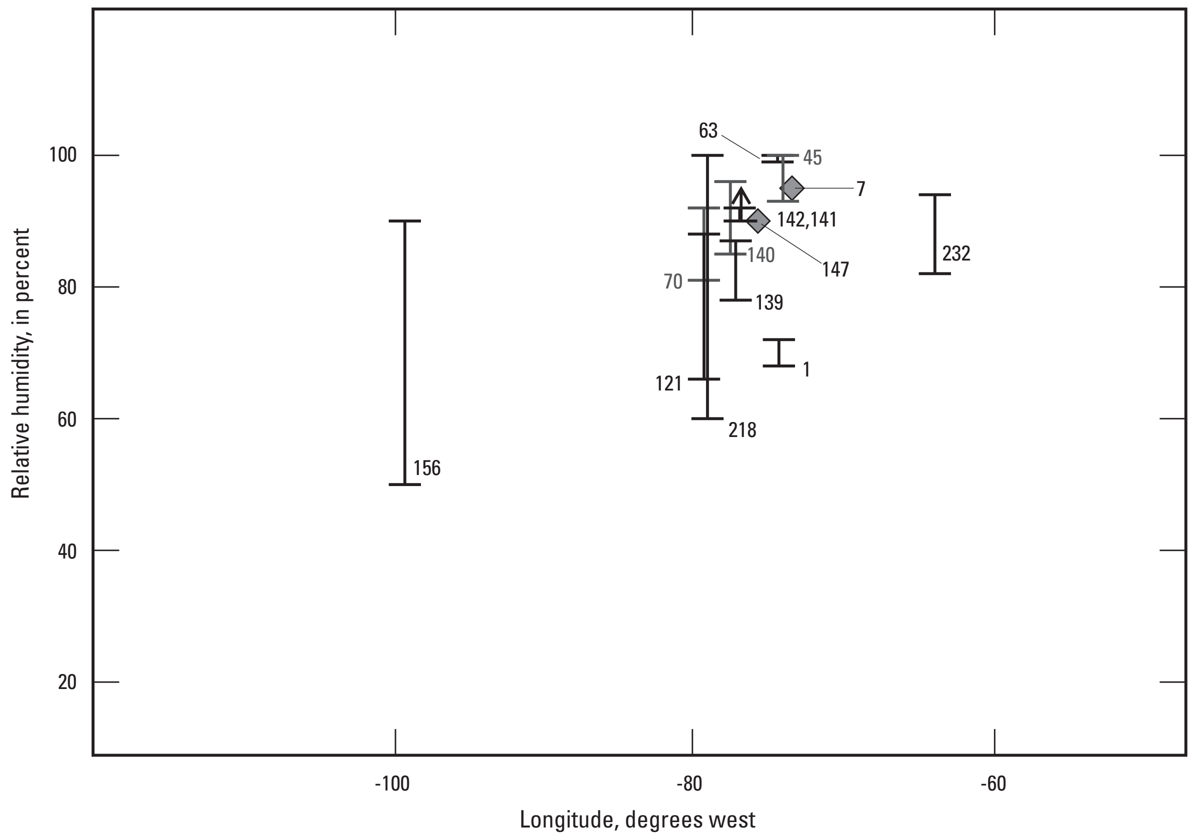

Figure 6. Relative humidity versus longitude of caves and mines infected with white-nose syndrome (WNS) before October 2011. Where only one relative humidity measurement was recorded, this value is represented by a diamond. Where multiple relative humidity measurements were recorded, the range of values is represented by a vertical line with short horizontal bars at the two ends. Where a humidity measurement was recorded as being greater than a certain value, this value is represented by a short horizontal bar and an arrow pointing upward from this bar. Numbers adjacent to diamonds and vertical lines refer to site numbers as listed in table 1. Additional details regarding relative humidity data are given in the text.

October 2005 through April 2006 (Winter Hibernating Season)

During this season, bats infected with *P. destructans* and displaying the symptoms of WNS were first documented in February 2006 in a cave that is connected to Howe Caverns (Blehert and others, 2009). A second WNS-infected site was detected in March 2006 at Barytes Cave (Hicks, 2008; Turner and others, 2011), which is a name given to some cave passages that are also connected to Howe Caverns.

(1) Howe Caverns (Commercial Caverns), Schoharie County, New York

This site is a large cave system, part of which is commercial. In some publications, the name “Howe Caverns” is restricted to only the commercial section of the cave system, and the name “Howe Cave” is given to the noncommercial sections of the cave system (Davis and others, 1966). Some cave passages that are connected to Howe Caverns are given the name Barytes Cave (Middleton, 1979), where WNS infection was detected in March 2006 (site 2). A river flows through part of Howe Caverns and dye tracing results from Baker (1970, 1973, 1976) indicated that some of this water comes from McFail’s Cave (site 41), where WNS was detected in April 2008.

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Schweiker and others, 1958; Olesen, 1961; Davis and others, 1966; Addis, 1969; Egemeier, 1969; Mylroie, 1972, 1977; Gregg, 1974; Kastning, 1975; Cullen and others, 1979).

Air Temperature.—9.4 to 10.6 °C, February 12, 1971, through May 7, 1971 (Mylroie, 1972).

Relative Humidity.—68 to 72 percent, February 12, 1971, through May 7, 1971 (Mylroie, 1972).

WNS Detected.—February 2006 (Porter, 2008b,c; Armstrong, 2009; Blehert and others, 2009; Turner and others, 2011).

(2) Barytes Cave, Schoharie County, New York

The name Barytes Cave is given to some cave passages that are connected to Howe Caverns (Middleton, 1979). Water flows into Barytes Cave from Bensons Cave (Dimbirs and Wood, 1977; Mylroie, 1977; Siemion and others, 2003; Siemion, 2005). WNS infection was detected in Bensons Cave (site 26) in March 2008.

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Schweiker and others, 1958; Davis and others, 1966; Dimbirs and Wood, 1977; Mylroie, 1977; Middleton, 1979).

WNS Detected.—March 2006 (Hicks, 2008) or 2009 (Turner and others, 2011).

May 2006 through September 2006 (Summer Nonhibernating Season)

During this season, zero infected sites were detected (two total infected sites to date [by end of September 2006]).

October 2006 through April 2007 (Winter Hibernating Season)

During this season, five infected sites were detected (seven total infected sites to date [by end of April 2007]). The range of WNS expanded beyond Schoharie County to Albany County (not shown) in New York. All of the infected sites detected through April 2007 were in limestone of the Silurian-Devonian Helderberg Group.

(3) Garden of Dina Mine (Baryte “Garden of Dina” Mine), Schoharie County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group.

WNS Detected.—2007 (Turner and others, 2011).

(4) Schoharie Caverns, Schoharie Caverns Nature Preserve, Schoharie County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Schweiker and others, 1958; Davis and others, 1966; Kastning, 1975; Dimbirs and Wood, 1977; Mylroie, 1977; Cullen and others, 1979; Schweyen, 1989).

WNS Detected.—January 2007 (Folsom, 2008; Porter, 2008b,c; supporting online material for Blehert and others, 2009; Turner and others, 2011). WNS infection at Schoharie Caverns confirmed by USGS NWHC (2008).

(5) Gage Caverns (Ball’s Cave), Barton Hill Nature Preserve, Schoharie County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Gurnee, 1957; Schweiker and others, 1958; Anderson, 1961; Baker, 1976; Mylroie, 1977; Engel, 1988).

Air Temperature.—8.9 to 12.2 °C, September 7, 1957 (Gurnee, 1957).

WNS Detected.—March 2007 (Folsom, 2008; Porter, 2008b,c; Armstrong, 2009; Turner and others, 2011).

(6) Hailes Cave, Albany County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Goldring, 1933; Thurston, 1942; Schweiker and others, 1958; Kastning, 1975; Baker, 1976; Lundy, 2001).

WNS Detected.—March 2007 (Folsom, 2008; Porter, 2008b,c; USGS NWHC, 2008; supporting online material for Blehert and others, 2009; Rajkumar and others, 2011; Turner and others, 2011).

(7) Knox Cave, Knox Cave Preserve, Albany County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Hornung, 1953; Schweiker and others, 1958; Palmer, 1963, 2000, 2001; Kastning, 1975; Rubin, 1986).

Air Temperature.—5.8 to 10.0 °C, October 20, 1962 (Kreider, 1963).

Relative Humidity.—93 to 100 percent, October 20, 1962 (Kreider, 1963).

WNS Detected.—April 2007 (Folsom, 2008; Porter, 2008b,c; Armstrong, 2009; Turner and others, 2011).

May 2007 through September 2007 (Summer Nonhibernating Season)

During this season, zero infected sites were detected (seven total infected sites to date [by end of September 2007]).

October 2007 through April 2008 (Winter Hibernating Season)

During this season, 35 infected sites were detected (42 total infected sites to date [by end of April 2008]). The range of WNS expanded beyond New York to Massachusetts, Vermont, and Connecticut (fig. 1). These new infection sites included mines as well as caves. Furthermore, these new sites included locations in strata other than the Silurian-Devonian Helderberg Group.

(8) Merlin's Cave, Merlin's Cave Preserve, Columbia County, New York

Geology.—Marble of the Cambrian-Ordovician Stockbridge Formation (Porter, 2009a).

Air Temperature.—8.9 °C, no date specified (Botto, 2007).

WNS Detected.—December 2007 (Porter, 2008b).

(9) Howes Quarry Mine, Schoharie County, New York

This site is a limestone mine under Howes Cave quarry, near Howe Caverns (site 1).

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Ebert and others, 2000).

WNS Detected.—2008 (Turner and others, 2011).

(10) Mass Hole, Berkshire County, Massachusetts

Geology.—Marble of the Cambrian-Ordovician Stockbridge Formation (Berkshire Diggers and the Rockeaters, 2008; Goodman, 2009; Hackley, 2009).

WNS Detected.—January 2008 (Berkshire Diggers and the Rockeaters, 2008; Porter, 2009c.

(11) Williams Preserve Mine (Walter Williams Preserve), Ulster County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group.

WNS Detected.—January 2008 (Porter, 2008b; USGS NWHC, 2008; Turner and others, 2011).

(12) Williams Hotel Mine, Ulster County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group.

WNS Detected.—January 2008 (Porter, 2008b,c; USGS NWHC, 2008; supporting online material for Blehert and others, 2009; Rajkumar and others, 2011; Turner and others, 2011).

(13) Morris Cave, Rutland County, Vermont

Geology.—Ordovician Shelburne Marble of the Stockbridge Group (Thayer, 1967; Schweyen, 1987; Higham, 1992) or Cambrian Clarendon Springs Dolomite (Quick, 1994).

Air Temperature.—6.1 °C, no date specified (Thayer, 1967).

WNS Detected.—January 2008 (Porter, 2008b,c). WNS infection in Rutland County (not shown) confirmed by USGS NWHC (2009b).

(14) Elizabeth Mine, Orange County, Vermont

Geology.—Schist, quartzite, and amphibolite of the Lower Devonian Gile Mountain Formation (Howard, 1959a,b, 1969; Annis and others, 1983; Slack and others, 1993, 2001; Balistrieri and others, 2007).

WNS Detected.—January 2008 (USGS NWHC, 2008, 2009b).

(15) Unspecified Site, Washington County, Vermont

WNS Detected.—January 2008 (USGS NWHC, 2009b).

(16) Glen Park Caves, Jefferson County, New York

Geology.—Ordovician Black River Limestone and the overlying Ordovician Trenton Limestone (Fisher, 1958; Carroll, 1970, 1972b; Nekvasil-Coraor, 1979; Engel, 1987, 2009).

WNS Detected.—January 2008 (Porter, 2008b,c; Turner and others, 2011).

(17) Clarksville Cave (Ward-Gregory Cave), Clarksville Cave Preserve, Albany County, New York

Geology.—Devonian Onondaga Limestone (Gregg, 1974; Kastning, 1975; Cullen and others, 1979; Rubin, 1986, 1991; Engel, 1999, 2009).

Air Temperature.—4.4 to 10.6 °C, April 2003 through July 2004 (Porter, 2004).

WNS Detected.—February 2008 (Porter, 2008b,c; Armstrong, 2009; Youngbaer, 2009a; Turner and others, 2011).

(18) Mitchell's Cave, Montgomery County, New York

Geology.—Cambrian Little Falls Dolomite (Curl and Peters, 1954; Jurgens, 1960; Porter, 1972).

WNS Detected.—February 2008 (Porter, 2008b; Armstrong, 2009).

(19) Williams Lake Mine, Ulster County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group.

WNS Detected.—February 2008 (Porter, 2008b; Turner and others, 2011). WNS infection in Ulster County (not shown) confirmed by USGS NWHC (2009b).

(20) Bat's Den Cave, Berkshire County, Massachusetts

Geology.—Marble of the Cambrian-Ordovician Stockbridge Formation (Hauer, 1969; Plante, 1991, 1992).

Air Temperature.—4.5 to 8.3 °C, January 22, 2006 (Veilleux, 2007).

WNS Detected.—February 2008 (Porter, 2008b; supporting online material for Blehert and others, 2009).

(21) The Old Mine (Upper Chester Mine), Hampden County, Massachusetts

Geology.—Ordovician Chester Amphibolite Member of the Rowe Schist (Hartline, 1965; Lincks, 1978; Hatch and others, 1970).

WNS Detected.—February 2008 (Porter, 2008b,c; supporting online material for Blehert and others, 2009). WNS infection in Hampden County (not shown) confirmed by USGS NWHC (2009b).

(22) Bakers Quarry Cave, Berkshire County, Massachusetts

Geology.—Ordovician Shelburne Marble of the Stockbridge Group (Barr, 1958, 1960; Hauer, 1969; Plante, 1992).

WNS Detected.—February 2008 (Porter, 2008b).

(23) Red Bat Cave, Berkshire County, Massachusetts

Geology.—Marble of the Cambrian-Ordovician Stockbridge Group (Davis and Palmer, 1959; Hauer, 1969).

WNS Detected.—February 2008 (Porter, 2008b).

(24) Unspecified Mine, Franklin County, Massachusetts

Two large mines near Rowe and a mine near Zoar are known to be bat hibernacula in Franklin County (not shown).

WNS Detected.—February 2008 (MassWildlife News, 2008).

(25) Aeolus Bat Cave, Bennington County, Vermont

Geology.—Ordovician Shelburne Marble of the Stockbridge Group (Scott, 1959; Carroll, 1969; Quick, 1994; Porter, 2009b).

Air Temperature.—6.1 °C, no date specified (Kennedy, 2002).

WNS Detected.—February 2008 (Porter, 2008b,c; USGS NWHC, 2008; supporting online material for Blehert and others, 2009; Bat Conservation and Management, 2010).

(26) Bensons Cave, Schoharie County, New York

Water from Bensons Cave flows south and east to Barytes Cave (Mylroie, 1977), where WNS infection was detected in March 2006 (site 2).

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Schweiker and others, 1958; Davis and others, 1966; Egemeier, 1969; Kastning, 1975; Dimbirs and Wood, 1977; Mylroie, 1977).

WNS Detected.—March 2008 (Porter, 2008b; Armstrong, 2009).

(27) Hell's Wells, Schoharie County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Schweiker and others, 1958; Davis and others, 1966; Mylroie, 1977).

WNS Detected.—March 2008 (Hicks, 2008; Armstrong, 2009).

(28) Lasell's Hell Hole, Schoharie County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Schweiker and others, 1958; Davis and others, 1966; Eckler, 1966; Gregg, 1974; Kastning, 1975; Baker, 1976; Hopkins, 1996b).

WNS Detected.—March 2008 (Porter, 2008b).

(29) Ain't No Catchment Cave (ANC Cave), Schoharie County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Hopkins, 1996b; Rubinstein, 1998; Armstrong and others, 2005).

WNS Detected.—March 2008 (Porter, 2008b; Armstrong, 2009).

(30) South Bethlehem Cave, Albany County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Schweiker and others, 1958; Kastning, 1968, 1975; Cullen and others, 1979).

WNS Detected.—March 2008 (Porter, 2008b; Turner and others, 2011).

(31) Martin Mine, Ulster County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group.

WNS Detected.—March 2008 (supporting online material for Blehert and others, 2009; Turner and others, 2011). WNS infection in Ulster County confirmed by USGS NWHC (2009b).

(32) Williams Mine #7–8, Ulster County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group.

WNS Detected.—2008 (Turner and others, 2011). WNS infection in Ulster County confirmed by USGS NWHC (2009b).

(33) Williams Mine #9–10, Ulster County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group.

WNS Detected.—2008 (Turner and others, 2011). WNS infection in Ulster County confirmed by USGS NWHC (2009b).

(34) Williams Mine #11, Ulster County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group.

WNS Detected.—2008 (Turner and others, 2011). WNS infection in Ulster County confirmed by USGS NWHC (2009b).

(35) Unnamed Cave near New Milford, Litchfield County, Connecticut

Geology.—All known caves in Litchfield County (not shown) are in marble of the Cambrian-Ordovician Stockbridge Formation (Huntington, 1963).

WNS Detected.—March 2008 (Connecticut Department of Environmental Protection, 2008; Kocer, 2009; supporting online material for Blehert and others, 2009).

(36) Unspecified Site, Hartford County, Connecticut

This site is not New-Gate Prison Mine (site 83), which also is in Hartford County (not shown).

WNS Detected.—March 2008 (Kocer, 2009). WNS infection in Hartford County confirmed by USGS NWHC (2009b).

(37) Williams Cave, Bennington County, Vermont

Geology.—Schist of the Precambrian to Cambrian Nassau Formation (Porter, 1968; Potter, 1972; Keough, 2000; Ratcliffe and others, 2011).

WNS Detected.—March 2008 (Porter, 2008b).

(38) Skinner Hollow Cave, Bennington County, Vermont

Geology.—Marble of the Ordovician Bascom Formation of the Beekmantown Group (Perry, 1942; Scott, 1959; Carroll, 1988; Quick, 1994, 2001).

WNS Detected.—March 2008 (Porter, 2008b; Armstrong, 2009).

(39) Main Graphite Mine, Warren County, New York

Geology.—Precambrian graphite-rich schist (Kemp and Newland, 1899; Craytor, 1969).

WNS Detected.—March 2008 (Porter, 2008b; Blehert and others, 2009; Rajkumar and others, 2011; Turner and others, 2011).

(40) Greeley Mine, Windsor County, Vermont

Geology.—Precambrian-Ordovician serpentinite (Gillson, 1927; Trombulak and others, 2001; Walsh and Falta, 2001).

WNS Detected.—March 2008 (Porter, 2009e; U.S. Fish and Wildlife Service, 2009). WNS infection in Windsor County (not shown) confirmed by USGS NWHC (2009b).

(41) McFail's Cave, McFail's Cave Nature Preserve, Schoharie County, New York

Dye tracing results indicated that water in McFail's Cave flows to Howe Caverns (Baker, 1970, 1973, 1976), where WNS infection was detected in Howe Caverns in February 2006 (site 1).

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Olesen, 1961; Egemeier, 1969; Kastning, 1975; Baker, 1976; Mylroie, 1977; Palmer, 2002).

Air Temperature.—7.3 °C, no date specified (van Beynen and others, 2004).

WNS Detected.—April 2008 (Porter, 2008b; Armstrong, 2009).

(42) Nature's Way Cave (Zinzow's Cave), Albany County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Hopkins, 1996a,b; Haberland and others, 2000; Martuscello, 2000).

WNS Detected.—April 2008 (Porter, 2008b; Armstrong, 2009).

May 2008 through September 2008 (Summer Nonhibernating Season)

During this season, zero infected sites were detected (42 total infected sites to date [by end of September 2008]).

October 2008 through April 2009 (Winter Hibernating Season)

During this season, 49 infected sites were detected (91 total infected sites to date [by end of April 2009]). The range of WNS expanded to Pennsylvania, New Hampshire, New Jersey, West Virginia, and Virginia (fig. 1). Before 1870, the cave sediments (soils) at some of these sites were mined for nitrate to make gunpowder. Although air temperature data are sparse, the warmest recorded air temperature of any WNS-infected site identified before October 2011 is Breathing Cave in Virginia (USGS NWHC, 2008; Dasher, 2009a; Lambert, 2009; Virginia Department of Game and Inland Fisheries, 2009a,b; Blue Ridge Grotto, 2011; Turner and others, 2011). This warmest air temperature (33.0 °C; Cournoyer, 1954) seems to be anomalous, and the presence of people in the cave may have affected this temperature value.

(43) Shindle Mine, Mifflin County, Pennsylvania

Geology.—Silurian Tuscarora Sandstone.

WNS Detected.—November 2008 (USGS NWHC, 2009b; Pennsylvania Game Commission, 2009a; Schalk, 2009; Bat Conservation and Management, 2010; Portnoy, 2010; Turner and others, 2011).

(44) Hasbrouck Mine, Ulster County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Chu, 2006).

WNS Detected.—December 2008 (Porter, 2008b) or 2009 (Turner and others, 2011). WNS infection in Ulster County confirmed by USGS NWHC (2009b).

(45) Indian Oven Cave, Columbia County, New York

Geology.—Dolomite of the Cambrian-Ordovician Stockbridge Formation (Fisher, 1954; Seigel, 1957; van Beynen and Febbroriello, 2006).

Relative Humidity.—Greater than 95 percent, no date specified (van Beynen and Febbroriello, 2006).

WNS Detected.—December 2008 (Porter, 2008b).

(46) Surprise Cave (Mystery Cave), Sullivan County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Peck, 1967; Febbroriello, 1984; Engel, 2009).

WNS Detected.—December 2008 (Porter, 2008b).

(47) Barton Hill Mine, Essex County, New York

Geology.—Magnetite ore in Precambrian metavolcanic rock (Kemp, 1898; Newland, 1919).

Air Temperature.—1.0 to 11.1 °C, September 1, 2001, through July 1, 2012 (Kennedy, 2002).

WNS Detected.—December 2008 (Porter, 2008a,b; Bat Conservation and Management, 2010; Turner and others, 2011). WNS infection in Essex County (not shown) confirmed by USGS NWHC (2009b).

(48) Fisher Hill Mine, Essex County, New York

Geology.—Magnetite ore in Precambrian metavolcanic rock (Kemp, 1898; Newland, 1919).

WNS Detected.—December 2008 (Porter, 2008b). WNS infection in Essex County confirmed by USGS NWHC (2009b).

(49) Williams Fire Pit Mine, Clinton County, New York

Geology.—Cambrian sandstone.

WNS Detected.—2008 (Turner and others, 2011). WNS infection in Clinton County (not shown) confirmed by USGS NWHC (2009b). This site is probably the infected site identified by Rajkumar and others (2011) as being near the town of Dannemora, New York (not shown).

(50) Hitchcock Mine (Bennett Hill Hitchcock Mine), Essex County, New York

Geology.—Precambrian gneiss.

WNS Detected.—2009 (Turner and others, 2011). WNS infection in Essex County confirmed by USGS NWHC (2009b).

(51) Cave or Mine at Friends Lake, Warren County, New York

Geology.—Precambrian metasedimentary rock.

WNS Detected.—January 2009 (Froschauer and Coleman, 2011).

(52) East Magnesia Talc Mine, Washington County, Vermont

Geology.—Ordovician serpentinite.

WNS Detected.—January 2009 (Turner and others, 2011). WNS infection in Washington County (not shown) confirmed by USGS NWHC (2009b).

(53) Unspecified Cave, Washington County, New York

Geology.—Marble or dolomite of the Cambrian-Ordovician Stockbridge Formation.

WNS Detected.—January 2009. WNS infection in Washington County (New York) confirmed by USGS NWHC (2009b).

(54) Jamesville Quarry Cave (Beckwith's Cavern), Onondaga County, New York

Geology.—Gypsum of the Silurian Salina Group (Newland and Leighton, 1910) or limestone of the Silurian-Devonian Helderberg Group (Bottjer, 1975).

WNS Detected.—January 2009 (Turner and others, 2011). This site is probably the infected site identified by Rajkumar and others (2011) as being near the town of Dewitt, New York.

(55) Lawrenceville Mine, Ulster County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group.

WNS Detected.—2009 (Turner and others, 2011). WNS infection in Ulster County confirmed by USGS NWHC (2009b).

(56) Ely Copper Mine, Orange County, Vermont

Geology.—Schist, quartzite, and amphibolite of the Lower Devonian Gile Mountain Formation (Hermance and others, 1949; Offield and others, 1993; Slack and others, 1993, 2001).

WNS Detected.—2009 (Turner and others, 2011).

(57) Bridgewater Mines, Windsor County, Vermont

Geology.—Schist of the Precambrian Pinney Hollow Formation (Hitchcock and others, 1861; Perry 1929; Ratcliffe, 1994; Walsh and Aleinikoff, 1999).

WNS Detected.—January 2009 (Porter, 2009c,f; Rajkumar and others, 2011). WNS infection in Windsor County confirmed by USGS NWHC (2009b).

(58) Camp Brook Mine, Windsor County, Vermont

Geology.—Ordovician metasedimentary rock.

WNS Detected.—2009 (Turner and others, 2011). WNS infection in Windsor County confirmed by USGS NWHC (2009b).

(59) Dover Iron Mine, Windham County, Vermont

Geology.—Cambrian amphibolite.

WNS Detected.—2009 (Turner and others, 2011). WNS infection in Windham County (not shown) confirmed by USGS NWHC (2009b).

(60) Unspecified Mine, Merrimack County, New Hampshire

WNS Detected.—January 2009 (New Hampshire Fish and Game Department, 2009).

(61) Unspecified Mine, Grafton County, New Hampshire

WNS Detected.—January 2009 (New Hampshire Fish and Game Department, 2009, 2010; The Eagle-Tribune, 2010). WNS infection in Grafton County (not shown) confirmed by USGS NWHC (2009b).

(62) Fahnestock State Park Mine, Putnam County, New York

Geology.—Precambrian amphibolite.

WNS Detected.—January 2009 (Koontz, 2009). WNS infection in Putnam County (not shown) confirmed by USGS NWHC (2009b).

(63) Hibernia Mine, Morris County, New Jersey

Geology.—Precambrian granite (Bayley, 1910; Sims, 1953; McManus and Esher, 1971).

Air Temperature.—0.0 to 6.0 °C, February 13, 1970, through March 27, 1970 (McManus and Esher, 1971; McManus, 1974).

Relative Humidity.—99 to 100 percent, February 13–18, 1970 (McManus, 1974).

WNS Detected.—January 2009 (USGS NWHC, 2008).

(64) Mount Hope Mine, Morris County, New Jersey

Geology.—Precambrian gneiss enclosed within granite (Bayley, 1910; Sims, 1953; James and Dennen, 1962; Ross, 1982).

WNS Detected.—January 2009 (USGS NWHC, 2008).

(65) Pahaquarry Copper Mine, Delaware Water Gap National Recreation Area, Warren County, New Jersey

Geology.—Sandstone of the Silurian Bloomsburg Red Beds (Weed, 1911; Woodward, 1944; Burns Chavez and Clemensen, 1995; Monteverde, 2001).

WNS Detected.—January 2009 (USGS NWHC, 2008).

(66) Dunmore Mine, Lackawanna County, Pennsylvania

Geology.—Coal beds of the Pennsylvanian Llewellyn Formation (Baughman and Gadinski, 1997).

WNS Detected.—January 2009 (USGS NWHC, 2008; Bat Conservation and Management, 2010).

(67) Shickshinny Mine, Luzerne County, Pennsylvania

Geology.—Coal beds of the Pennsylvania Llewellyn Formation.

WNS Detected.—January 2009 (Pennsylvania Department of Conservation and Natural Resources, 2009; Pennsylvania Game Commission, 2009b; Schalk, 2009).

(68) Nuangola (New Angola), Luzerne County, Pennsylvania

This site is an abandoned tunnel that was constructed for the Wilkes-Barre and Hazelton Railroad.

Geology.—Devonian Duncannon Member of the Catskill Formation.

WNS Detected.—2008 or 2009 (Turner and others, 2011).

(69) Hamilton Cave, John Guilday Caves Nature Preserve, Pendleton County, West Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Davies, 1965; Palmer, 1975; Dyas, 1977; Medville, 2000a; Dasher, 2001a; Swezey, 2014; Swezey and Brent, 2020).

Air Temperature.—11.7 °C, April 10, 1977 (Dyroff, 1977); 12.8 °C in early winter to 10.8 °C in late winter, year(s) not specified (Hoke, 2009a,b).

WNS Detected.—January 2009 (Dasher, 2009b, 2010e; Hoke, 2009a,b; Stihler, 2009; USGS NWHC, 2009b; West Virginia Division of Natural Resources, 2009, 2010a; Turner and others, 2011).

(70) Trout Cave, John Guilday Caves Nature Preserve, Pendleton County, West Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Davies, 1965; Haas, 1961; Palmer, 1975; Medville, 2000c; Dasher, 2001a; Swezey, 2003, 2014; Swezey and Brent, 2020).

Cave Sediment.—Chemical analyses are presented in table 2. During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Faust, 1964; Davies, 1965; Garton and Garton, 1970, 2001; Powers, 1981; Dasher, 2001b; Taylor, 2001).

Air Temperature.—11.7 °C, no date specified (Davies, 1965); 8.9 °C, April 10, 1977 (Dyroff, 1977); 6.7 to 9.5 °C, February 10–11, 2001 (Hoke, 2001); 6.0 to 13.0 °C, October 26, 2003 (Swezey and others 2004a).

Relative Humidity.—81 to 92 percent, October 16, 2003 (Swezey and others 2004a).

WNS Detected.—January 2009 (Dasher, 2009b; USGS NWHC, 2009b; West Virginia Division of Natural Resources, 2009, 2010a; Porter, 2010; Turner and others, 2011).

(71) Brandon Mine, Rutland County, Vermont

Geology.—Cambrian Winooski Dolomite (Clark, 1990).

Air Temperature.—6.5 °C, March through June 2002 (Kennedy, 2002).

WNS Detected.—February 2009 (McDevitt, 2009; Porter, 2011; Turner and others, 2011). WNS infection in Rutland County confirmed by USGS NWHC (2009b).

(72) Roxbury Mine, Litchfield County, Connecticut

Geology.—Ordovician? Mine Hill Granite Gneiss (Gates, 1959; Echols, 1961; Rogers, 1985; Jacobs, 2006).

WNS Detected.—February 2009 (Kocer, 2009; Porter, 2009c). WNS infection near the town of Roxbury in Litchfield County confirmed by Connecticut Department of Environmental Protection (2009) and USGS NWHC (2008).

(73) Alexander Caverns, Mifflin County, Pennsylvania

Geology.—Ordovician Trenton Limestone (Stone, 1932; Dayton and others, 1981; Ibberson, 1988).

Air Temperature.—11.1 °C, no date specified (Stone, 1932).

WNS Detected.—February 2009 (Schalk, 2009) or 2008 (Turner and others, 2011).

(74) Cave Mountain Cave, Pendleton County, West Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Davies, 1965; Dyas, 1976a,b; Dasher, 2001a; Swezey and Dulong, 2010; Swezey, 2014).

Cave Sediment.—Chemical analyses are presented in table 2. Before and during the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Davies, 1965; Garton and Garton, 1970, 2001; Dasher, 2001b; Taylor, 2001). On the Main Level of the cave, a laminated mudstone consists of quartz, illite, kaolinite, feldspar, and chlorite (Swezey and Dulong, 2010). In the rear part of the Main Level, Haas (1960) reported that unconsolidated sand on the cave floor contains lenses of rust-red clay that consists of a mixture of very fine-grained quartz and meta-halloysite, which is a hydrated alumina silicate [$Al_2Si_2O_5(OH)_4 \cdot nH2O$] (Brindley and others, 1946; Kaze and others, 2020).

WNS Detected.—February 2009 (Dasher, 2009b, 2010e; Stihler, 2009; West Virginia Division of Natural Resources, 2009, 2010a; Turner and others, 2011).

(75) Breathing Cave (Burnsville Saltpetre Cave), Bath County, Virginia

Geology.—Breathing Cave is confined to an approximately 23-meter thick unit of shaly limestone between two 4-meter thick beds of sandstone, which have been named informally the upper Breathing sandstone and the lower Breathing sandstone (Deike, 1960a,b). These sandstone beds were initially thought to be tongues of the Silurian Clifton Forge Sandstone, and the intervening shaly limestone was thought to be part of the Silurian-Devonian Keyser Limestone (Deike, 1960a,b; Douglas, 1964; Holsinger, 1975; White and Hess, 1982; Clemmer, 2005). More recent studies, however, have suggested that the sandstone beds and silty limestone are within the Silurian Tonoloway Limestone (Haynes, 2014).

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Faust, 1949, 1964; Clemmer, 2005).

Air Temperature.—26.0 to 33.0 °C, January 9, 1943 (Cournoyer, 1954); 0.6 to 10.6 °C, December 10, 1955 (Cournoyer, 1956). The temperatures of 26.0 to 33.0 °C seem to be anomalous, and the presence of people in the cave may have affected these temperature values.

WNS Detected.—February 2009 (Dasher, 2009a; Lambert, 2009; Virginia Department of Game and Inland Fisheries, 2009a,b; Blue Ridge Grotto, 2011; Turner and others, 2011). WNS infection in Bath County (not shown) confirmed by USGS NWHC (2008).

(76) Single X Cave, Schoharie County, New York

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Middleton, 1977; Mylroie, 1977, 1980).

WNS Detected.—March 2009 (Armstrong, 2009).

(77) Eagle Cave, Hamilton County, New York

Geology.—Precambrian gneiss (Carroll, 1972a, 2009a).

Air Temperature.—Negative (−) 5.0 °C, March 26, 1983 (Bartholomew, 1991); −0.8 °C, April 9, 1983 (Bartholomew, 1991); −0.3 °C, April 23, 1983 (Bartholomew, 1991); −2.8 to 4.4 °C, January 5, 1985 (Bartholomew, 1991).

WNS Detected.—2009 (Turner and others, 2011).

(78) Fort Drum, Jefferson County, New York

Infected bats were detected in a human house and a nearby bat house (Dobony and others, 2011).

WNS Detected.—March 2009 (Dobony and others, 2011).

(79) Site near Ithaca, Tompkins County, New York

WNS Detected.—March 2009 (Rajkumar and others, 2011).

(80) Site near Newstead, Erie County, New York

WNS Detected.—March 2009 (Rajkumar and others, 2011).

(81) Site near Lancaster, Erie County, New York

WNS Detected.—March 2009 (Rajkumar and others, 2011).

(82) Site near White Plains, Westchester County, New York

WNS Detected.—March 2009 (Rajkumar and others, 2011).

(83) New-Gate Prison Mine, Hartford County, Connecticut

This site is not the unspecified site in Hartford County (site 36).

Geology.—Redbeds and sandstone of the Jurassic Portland Formation of the Newark Supergroup (Huntington, 1963; Penn and Gray, 1987).

WNS Detected.—March 2009 (Kocer, 2009; Porter, 2009c). WNS infection in Hartford County confirmed by USGS NWHC (2009b).

(84) Carbondale Mine #1, Lackawanna County, Pennsylvania

Geology.—Coal beds in the Pennsylvanian Llewellyn Formation.

WNS Detected.—March 2009 (Pennsylvania Game Commission, 2009a,b; Schalk, 2009).

(85) Carbondale Mine #2, Lackawanna County, Pennsylvania

Geology.—Coal beds in the Pennsylvanian Llewellyn Formation.

WNS Detected.—March 2009 (Pennsylvania Game Commission, 2009a,b; Schalk, 2009).

(86) Seawra Cave, Mifflin County, Pennsylvania

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Stone, 1932, 1953; Dayton and others, 1981).

Air Temperature.—13.9 °C, no date specified (Stone, 1932).

WNS Detected.—March 2009 (Schalk, 2009; Pennsylvania Game Commission, 2009b; Bat Conservation and Management, 2010).

(87) Aitkin Cave, Mifflin County, Pennsylvania

Geology.—Ordovician Trenton Limestone (Stone, 1932, 1953; Dayton and others, 1981).

WNS Detected.—March 2009 (Schalk, 2009; Pennsylvania Game Commission, 2009b; Bat Conservation and Management, 2010).

(88) Site at or near Woodward (Probably a Cave), Centre County, Pennsylvania

Geology.—Ordovician limestone.

WNS Detected.—2009 (Turner and others, 2011).

(89) Site at or near Mount Rock (Probably a Cave), Cumberland County, Pennsylvania

Geology.—Cambrian-Ordovician limestone.

WNS Detected.—2009 (Turner and others, 2011).

(90) Clover Hollow Cave, Giles County, Virginia

Geology.—Ordovician Witten Limestone and possibly underlying limestone units (Douglas, 1964; Sluzarski, 1972; Saunders, 1974; Holsinger, 1975; Saunders and others, 1981; Orndorff, 1995).

WNS Detected.—March 2009 (Dasher, 2009b; Virginia Department of Game and Inland Fisheries, 2009a,b; Youngbaer, 2009b). WNS infection in Giles County (not shown) confirmed by USGS NWHC (2009b).

(91) W Mountain Cave, Franklin County, New York

Initial reports placed this cave erroneously in Clinton County (Carroll, 1972c, 1974), but subsequent reports indicated that the cave is in Franklin County (Cole, 1974; Carroll, 1997, 2009b; Porter, 2009d).

Geology.—Precambrian granitic gneiss (Cole, 1974; Carroll, 1997, 2009b; Porter, 2009d).

Air Temperature.—2.8 to 5.6 °C, April 28, 1984 (Carroll, 2009b).

WNS Detected.—April 2009 (Porter, 2009c,d). WNS infection in Clinton County confirmed by USGS NWHC (2009b).

May 2009 through September 2009 (Summer Nonhibernating Season)

During this season, 5 infected sites were detected (96 total infected sites to date [by end of September 2009]). One of these infected sites, Endless Caverns (Dasher, 2009b; Virginia Department of Game and Inland Fisheries, 2009b), is the first commercial cave to be infected since WNS was detected at Howe Caverns in New York.

(92) Saltpeter Cave, Pendleton County, West Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Davies, 1965; Dasher, 2001a).

Cave Sediment.—Reports indicate that before 1862, sediment in the cave was mined for nitrate to make gunpowder; however, no evidence has been determined to verify these reports (Davies, 1965; Dasher, 2009b).

WNS Detected.—May 2009 (Dasher, 2009b; Porter, 2010).

(93) Newberry-Bane Cave, Bland County, Virginia

Geology.—Limestone of the Ordovician Wassum Formation and the overlying Witten Limestone (Douglas, 1964; Holsinger, 1975; Wright, 1982, 1995; Zokaites, 1995a; Schwartz and others, 2009).

Air Temperature.—8.5 to 11.0 °C, November 22, 1999 (Brack and others, 2005); 7.0 to 9.3 °C, February 3–5, 2000 (Brack and others, 2005).

WNS Detected.—May 2009 (Dasher, 2009a,b; Virginia Department of Game and Inland Fisheries, 2009b; Youngbaer, 2010; Blue Ridge Grotto, 2011; Turner and others, 2011).

(94) Hancock Cave, Smyth County, Virginia

Geology.—Ordovician Witten Limestone.

WNS Detected.—May 2009 (Dasher, 2009b; Virginia Department of Game and Inland Fisheries, 2009b).

(95) Site near Peterborough, Hillsborough County, New Hampshire

WNS Detected.—June 2009 (New Hampshire Fish and Game Department, 2009).

(96) Endless Caverns (Commercial Caverns), Rockingham County, Virginia

Geology.—The commercial part of these caverns is in the Ordovician New Market Limestone (Douglas, 1964; Holsinger, 1975; Hubbard, 1995a; Jones, 1999, 2009). Beyond the commercial part, the main passages have developed along the contact between the New Market Limestone and the overlying Ordovician Lincolnshire Limestone. In a few areas, the caverns extend above the Lincolnshire Limestone and into limestone of the overlying Edinburg Formation.

Air Temperature.—13.3 °C, no date specified (Reeds, 1925).

WNS Detected.—August 2009 (Dasher, 2009b; Virginia Department of Game and Inland Fisheries, 2009b).

October 2009 through April 2010 (Winter Hibernating Season)

During this season, 58 infected sites were detected (154 total infected sites to date [by end of April 2010]). The range of WNS expanded from the United States to Canada (Ontario and Quebec; fig. 1). In the United States, the range of WNS expanded to Tennessee, Maryland, Delaware, and Missouri (fig. 1). During March 2010, WNS infection was documented for the first time in a limestone of Mississippian age (Cassell Cave in Pocahontas County [not shown], West Virginia; Dasher, 2010b; Stihler, 2010a,b). Also during March 2010, the first documentation of WNS west of the Appalachian Mountains (not shown) occurred at Dunbar Cave (Dasher, 2010b; Lamb and Wyckoff, 2010a,b; USGS NWHC, 2010b; Samoray, 2011), a commercial cave in Montgomery County (not shown) of western Tennessee. At that time, the nearest known WNS-infected site was Worley's Cave (Morrill Cave, Morrell Cave) in Sullivan County (not shown) of eastern Tennessee (Dasher, 2010a; Lamb and Wyckoff, 2010a,b; U.S. Fish and Wildlife Service, 2010; USGS NWHC, 2010a; Samoray, 2011), approximately 290 kilometers from Dunbar Cave.

(97) Shingle Gully Ice Caves (Ellenville Ice Caves), Ulster County, New York

Geology.—Sandstone and conglomerate of the Silurian Shawangunk Formation (Kirkpatrick, 2006).

WNS Detected.—November 2009 (Northeastern Cave Conservancy, 2009).

(98) Nickwackett Cave, Rutland County, Vermont

Geology.—Cambrian Forestdale Marble Member of the Mendon Formation (Brace, 1953; Quick, 1994; Ratcliffe, 1997).

WNS Detected.—November 2009 (Porter, 2011).

(99) Tawney's Cave (Tony's Cave), Giles County, Virginia

Geology.—Ordovician Elway Limestone (Holsinger, 1975; Saunders and others, 1981).

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Hill, 1982; Hubbard, 1988; Washington and Vermeulen, 1995).

WNS Detected.—November 2009 (Dasher, 2010a; Front Royal Grotto, 2010c; Virginia Cave Board, 2010; Blue Ridge Grotto, 2011). WNS infection in Giles County confirmed by USGS NWHC (2009b).

(100) Hartman Cave, Monroe County, Pennsylvania

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Leidy, 1880, 1889; Barnsley, 1932b; Stone, 1953).

WNS Detected.—December 2009 (Bat Conservation and Management, 2010; Portnoy, 2010).

(101) Tresckow Mine, Carbon County, Pennsylvania

Geology.—Coal beds in the Pennsylvanian Pottsville Formation.

WNS Detected.—December 2009 (Bat Conservation and Management, 2010; Portnoy, 2010). WNS infection in Carbon County (not shown) confirmed by USGS NWHC (2010e).

(102) Durham Cave (Durham Mine), Bucks County, Pennsylvania

This cave is in an abandoned limestone quarry (Durham Mine), and much of the cave has been destroyed by quarrying (Barnsley, 1932a; Kranzel and others, 1983).

Geology.—Limestone of the Cambrian Leithsville Formation (Stone, 1953; Kranzel and others, 1983).

Air Temperature.—7.2 to 16.7 °C, no date specified (Kranzel and others, 1983).

WNS Detected.—December 2009 (Portnoy, 2010; Turner and others, 2011). WNS infection in Bucks County (not shown) confirmed by USGS NWHC (2010e).

(103) Eiswert Cave #2, Lycoming County, Pennsylvania

Geology.—Ordovician Trenton Limestone (Stone, 1953).

WNS Detected.—January 2010 (cave name estimated by senior author). WNS infection in Lycoming County (not shown) confirmed by USGS NWHC (2010e).

(104) Red Church Cave, Schuylkill County, Pennsylvania

The site is a cave that was intersected by a mine (Smeltzer, 1985).

Geology.—Silurian Bossardville Limestone (Smeltzer, 1985).

WNS Detected.—January 2010 (Portnoy, 2010).

(105) Hall Cave, Hall Cave Preserve, Huntingdon County, Pennsylvania

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Stone, 1932, 1953; Cullinan and Speece, 1978).

WNS Detected.—January 2010 (Dasher, 2010c; Mid-Atlantic Karst Conservancy, 2010; Metzgar, 2012). WNS infection in Huntingdon County (not shown) confirmed by USGS NWHC (2010d,e).

(106) Plymouth Caves, Windsor County, Vermont

Plymouth Caves consist of two caves, the larger of which is named South Cave and the smaller of which is named West Cave (Johnson, 1988; Quick, 1994).

Geology.—Dolomite of the Precambrian-Cambrian Tyson Formation (Scott, 1959; Johnson, 1988; Quick, 1994; Pingree, 1995; Ratcliffe and others, 2011)

Air Temperature.—8.0 °C, November 12, 1937 (Folk, 1940).

WNS Detected.—January 2010 (Porter, 2009f, 2010, 2011; McDevitt, 2010). WNS infection in Windsor County confirmed by USGS NWHC (2009b).

(107) Akron Mine, Erie County, New York

Geology.—Gypsum of the Silurian Salina Group (Newland and Leighton, 1910; Newland, 1919).

WNS Detected.—February 2010 (Rajkumar and others, 2011).

(108) Johnson Talc Mine, Lamoille County, Vermont

Geology.—Talc-serpentinite body within the Precambrian-Cambrian Hazens Notch Formation, which consists predominantly of schist (Chidester and others, 1951; Meade, 1993; Thompson and Thompson, 2003).

WNS Detected.—February 2010 (Porter, 2010). WNS infection in Lamoille County (not shown) confirmed by USGS NWHC (2010d).

(109) Canoe Creek Mine (Canoe Creek Cave), Blair County, Pennsylvania

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Davis, 1966, 1967).

WNS Detected.—February 2010 (Bat Conservation International, 2010). WNS infection in Blair County (not shown) confirmed by USGS NWHC (2010d,e).

(110) Four Confirmed but Unspecified White-Nose Syndrome (WNS) Sites, Lawrence County, Pennsylvania

WNS Detected.—February 2010 (Gill, 2011).

(111) Coon Cave, Bland County, Virginia

Geology.—Ordovician Witten Limestone.

WNS Detected.—February 2010 (Youngbaer, 2010; Blue Ridge Grotto, 2011; Front Royal Grotto, 2011f; Springston, 2011).

(112) Repass Saltpeter Cave, Bland County, Virginia

Geology.—Limestone or dolomite, or both, of the Ordovician Beekmantown Group (Douglas, 1964).

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Faust, 1960, 1964; Douglas, 1964).

WNS Detected.—February 2010 (Blue Ridge Grotto, 2011).

(113) Stonley's Cave (Divides Cave), Tazewell County, Virginia

Geology.—Dolomite of the Cambrian-Ordovician Knox Group.

WNS Detected.—February 2010 (Blue Ridge Grotto, 2011; Front Royal Grotto, 2010b, 2011f).

(114) Worley's Cave (Morrill Cave, Morrell Cave), Sullivan County, Tennessee

Geology.—Dolomite of the Cambrian-Ordovician Knox Group (Barr, 1961).

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Hill and others, 1981; Plemons, 1995; Matthews, 2008).

WNS Detected.—February 2010 (Dasher, 2010a; Lamb and Wyckoff, 2010a,b; U.S. Fish and Wildlife Service, 2010; Samoray, 2011). WNS infection in Blair County confirmed by USGS NWHC (2010a).

(115) Grindstaff Cave, Carter County, Tennessee

Geology.—Cambrian Shady Dolomite (Barr, 1961).

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Barr, 1961; Plemons, 1995).

WNS Detected.—February 2010 (Dasher, 2010b; Lamb and Wyckoff, 2010a,b; Samoray, 2011).

(116) Letchworth Tunnel, Letchworth State Park. Livingston County, New York

Geology.—Devonian sandstone or shale, or both.

WNS Detected.—March 2010 (Rajkumar and others, 2011).

(117) Mount Washington, White Mountain National Forest, Coos County, New Hampshire

Infected bats were seen flying around Mount Washington, but cave location is unknown.

WNS Detected.—March 2010 (New Hampshire Fish and Game Department, 2010; Porter, 2010). WNS infection in White Mountain National Forest confirmed by USGS NWHC (2010e).

(118) Hellhole (Cave), Pendleton County, West Virginia

As of April 2013, the full extent of Hellhole had not been explored or mapped. In September 2010, a connection between Hellhole and Shoveleater Cave was discovered and, therefore, Hellhole has at least two entrances—the "historical" Hellhole entrance and the Shoveleater entrance (Harman, 2012).

Geology.—Ordovician limestone (Davies, 1965; Dasher, 2001a; Zinz and Sasowsky, 2005; Brace, 2009). According to Zinz and Sasowsky (2005), most of Hellhole has developed in the Ordovician New Market Limestone, the overlying Lincolnshire Limestone, and limestone of the overlying Big Valley Formation. According to Lambert (2012), Shoveleater

Cave has developed in the Ordovician New Market Limestone, the overlying Lincolnshire Limestone, the overlying Ward Cove Limestone, and the overlying Benbolt Limestone.

Cave Sediment.—Chemical analyses are presented in table 2.

Air Temperature.—7.8 °C, no date specified (Kouts and Brace, 2000); 2.2. to 5.0 °C, February 20, 2010 (Masney, 2010).

WNS Detected.—March 2010 (Dasher, 2010b; Porter, 2010; Stihler, 2010a,b; West Virginia Division of Natural Resources, 2010b; Youngbaer, 2010).

(119) Sites Cave, Pendleton County, West Virginia

Geology.—Silurian Tonoloway Limestone (Davies, 1965; Anderson, 1981) or limestone of the Silurian-Devonian Helderberg Group (Dasher, 2001a).

WNS Detected.—March 2010 (Dasher, 2010b; Stihler, 2010a,b).

(120) Short Cave, Pendleton County, West Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Dasher, 2001a; Dove, 2012).

WNS Detected.—March 2010 (Dasher, 2010b).

(121) Sinnett Cave (Sinnett-Thorn Mountain Cave System), Pendleton County, West Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Davies, 1965; Swezey and others, 2004b; Swezey, 2014).

Cave Sediment.—Chemical analyses are presented in table 2. During the U.S. Civil War (from 1861 through 1865), sediment in Sinnett Cave was mined for nitrate to make gunpowder (Faust, 1949, 1964; Davies, 1965; Garton and Garton, 1970, 2001; Powers, 1981; Dasher, 2001b; Taylor, 2001).

Air Temperature.—6.7 to 15.6 °C, February 1, 2003 (Swezey and others, 2004b).

Relative Humidity.—66 to 88 percent, February 1, 2003 (Swezey and others, 2004b).

WNS Detected.—March 2010 (Dasher, 2010b; Stihler, 2010a,b).

(122) Dyers Cave, Hardy County, West Virginia

Geology.—Silurian Tonoloway Limestone (Davies, 1965; Speece, 1983).

Cave Sediment.—Before 1861, sediment in the cave was mined for nitrate to make gunpowder (Davies, 1965; Hauer, 1971; Hill and others, 1981; Plemons, 1995; Dasher, 2001b).

WNS Detected.—March 2010 (Dasher, 2010b; Stihler, 2010a,b).

(123) Cassell Cave, Pocahontas County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Davies, 1965; Duncan and others, 1967; Dasher, 2000).

WNS Detected.—March 2010 (Dasher, 2010b; Stihler, 2010a,b).

(124) Carpenters Pit (Carpenters-Swago Cave System), Pocahontas County, West Virginia

Carpenters Pit is part of the greater Carpenters-Swago Cave System, which contains at least seven entrances (Storrick, 1992).

Geology.—Mississippian Greenbrier Limestone (White and Dunn, 1957; Davies, 1965; Storrick, 1992).

WNS Detected.—March 2010 (Dasher, 2010b; Pearson, 2010; Stihler, 2010a,b).

(125) Friars Hole (Friars Hole-Snedegars Cave System), Greenbrier and Pocahontas Counties, West Virginia

Friars Hole is part of the greater Friars Hole-Snedegars Cave System, which has at least 10 entrances and includes Canadian Hole, Crookshank Cave, Rubber Chicken Cave, and Snedegars Cave (Storrick, 1992; Dasher and Medville, 2009). In March 2010, WNS infection was detected in the Friars Hole (site 125) and Snedegars Cave (site 126) parts of the Friars Hole-Snedegars Cave System. Water in the downstream part of the Friars Hole-Snedegars Cave System comes from caves named Cannon Hole, The Boar Hole, and The Portal (Dasher, 1995; Jones, 1997). In March 2011, WNS infection was detected in The Boar Hole (site 205) and in The Portal (site 212).

Geology.—Mississippian Greenbrier Limestone (Bicking, 1963; Davies, 1965; Medville, 1979, 1981; Jameson, 1983; Storrick, 1992).

WNS Detected.—March 2010 (Official Caving Forum of the National Speleological Society, 2010).

(126) Snedegars Cave (Friars Hole-Snedegars Cave System), Greenbrier and Pocahontas Counties, West Virginia

Snedegars Cave is part of the greater Friars Hole-Snedegars Cave System, which has at least 10 entrances and includes Canadian Hole, Crookshank Cave, Friars Hole, and Rubber Chicken Cave (Storrick, 1992; Dasher and Medville, 2009). In March 2010, WNS infection was detected in the Friars Hole (site 125) and Snedegars Cave (site 126) parts of the Friars Hole-Snedegars Cave System. Water in the downstream part of the Friars Hole-Snedegars Cave System comes from caves named Cannon Hole, The Boar Hole, and The Portal (Dasher, 1995; Jones, 1997). In March 2011, WNS infection was detected in The Boar Hole (site 205) and in The Portal (site 212).

Geology.—Mississippian Greenbrier Limestone (Davies, 1965; Medville, 1979).

Air Temperature.—8.9 °C, no date specified (Davies, 1965).

WNS Detected.—March 2010 (Dasher, 2010b; Stihler, 2010a,b).

(127) Norman Cave (Bone-Norman Cave System), Greenbrier County, West Virginia

Norman Cave is part of the greater Bone-Norman Cave System. In March 2011, WNS infection was detected in Norman Cave (site 127) and in Bone Cave (site 206).

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).

WNS Detected.—March 2010 (Dasher, 2010b; Pearson, 2010; Stihler, 2010a,b).

(128) Patton Cave, Monroe County, West Virginia

Geology.—Ordovician limestone (Davies, 1965; Whittemore, 1965), probably a Stones River Limestone equivalent (Reger and Price, 1926).

WNS Detected.—March 2010 (Dasher, 2010b; Pearson, 2010; Stihler, 2010a,b).

(129) Scott Hollow Cave, Monroe County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Dore, 1990, 1995; Norris, 1992; Check and others, 2006; Sasowsky and Bishop, 2006; Bishop and others, 2009).

WNS Detected.—March 2010 (Dasher, 2010b; Stihler, 2010b).

(130) Caldwell Cave, Mercer County, West Virginia

Geology.—Ordovician limestone (Davies, 1965; Balfour, 1993), probably a Stones River Limestone equivalent (Reger and Price, 1926).

WNS Detected.—March 2010 (Dasher, 2010b; Stihler, 2010a,b).

(131) Newcastle Murder Hole, Craig County, Virginia

Geology.—Limestone or dolomite, or both, of the Ordovician Beekmantown Group (Douglas, 1964).

WNS Detected.—March 2010 (Front Royal Grotto, 2010d).

(132) Shires Saltpeter Cave (Shires Cave, Saltpeter Cave), Craig County, Virginia

Geology.—Ordovician limestone (Holsinger, 1975), probably the Witten Limestone.

Cave Sediment.—Before 1870, sediment in the cave was mined for nitrate to make gunpowder (Faust, 1964; Hubbard, 1988).

WNS Detected.—March 2010 (Front Royal Grotto, 2010d; Blue Ridge Grotto, 2011).

(133) Pig Hole Cave, Giles County, Virginia

Geology.—Ordovician Witten Limestone (Douglas, 1964).

Air Temperature.—8.0 to 10.0 °C (Murray and Dietrich, 1956).

WNS Detected.—March 2010 (Front Royal Grotto, 2010d).

(134) Starnes Cave (Starnes Caverns), Giles County, Virginia

Geology.—Ordovician limestone (Schwartz and others, 2009), probably the Witten Limestone.

WNS Detected.—March 2010 (Front Royal Grotto, 2010d).

(135) Greises Cave, Allegany County, Maryland

Geology.—Silurian Tonoloway Limestone (Franz and Slifer, 1971).

WNS Detected.—March 2010 (Dasher, 2010b). WNS infection in a cave in Allegany County near the city of Cumberland (not shown) reported by Maryland Department of Natural Resources (2010). WNS infection in Allegany County confirmed by USGS NWHC (2010b,d).

(136) Unspecified Site near Flesherton, Grey County, Ontario, Canada

The Flesherton area is a karst landscape (Cowell and Ford, 1975), but the infected bats were detected not in a cave but at a rural property near the town of Flesherton (Crosby, 2010).

WNS Detected.—March 2010 (Crosby, 2010; Kennedy, 2010; Ontario Ministry of Natural Resources, 2012). WNS infection near Flesherton confirmed by USGS NWHC (2010b).

(137) Unspecified Site (Probably a Cave), Peterborough County, Ontario, Canada

Geology.—Cambrian-Ordovician limestone.

WNS Detected.—March 2010 (Kennedy, 2010). WNS infection in Peterborough County (not shown) confirmed by USGS NWHC (2010d).

(138) Abandoned Mine near Faraday, Hastings County, Ontario, Canada

Geology.—Precambrian igneous or metamorphic rock.

WNS Detected.—March 2010 (Crosby, 2010; Kennedy, 2010; Ontario Ministry of Natural Resources, 2012). WNS infection in Hastings County (not shown) confirmed by USGS NWHC (2010d). WNS infection at an abandoned mine in the Bancroft-Minden area approximately 200 kilometers west of Ottawa reported by Crosby (2010) and confirmed by USGS NWHC (2010b).

(139) Tyendinaga Cave (Fifth Concession Cave), Hastings County, Ontario, Canada

Geology.—Ordovician limestone.

Air Temperature.—4.4 to 9.4 °C, November 27, 1947 (Hitchcock, 1949).

Relative Humidity.—78 to 87 percent, November 27, 1947 (Hitchcock, 1949).

WNS Detected.—March 2010 (Crosby, 2010; Kennedy, 2010). WNS infection near Belleville (Ontario) reported by Ontario Ministry of Natural Resources (2012).

(140) Craigmont Mine, Renfrew County, Ontario, Canada

Geology.—Precambrian pegmatite, granite, and gneiss (Moyd, 1950; Carlson, 1953; Masson and Gordon, 1981; Storey and Vos, 1981).

Air Temperature.—2.2 to 5.6 °C, November 28, 1947 (Hitchcock, 1949).

Relative Humidity.—85 to 96 percent, November 28, 1947 (Hitchcock, 1949).

WNS Detected.—March 2010 (Crosby, 2010; Kennedy, 2010; Ontario Ministry of Natural Resources, 2010, 2012).

(141) Renfrew Mine, Renfrew County, Ontario, Canada

Geology.—Precambrian granite and gneiss.

Air Temperature.—Negative (−) 15.0 to 8.4 °C, October 1966 through May 1967 and September 1967 through June 1968 (Fenton, 1970).

Relative Humidity.—Greater than 90 percent (Fenton, 1970).

WNS Detected.—March 2010 (Crosby, 2010; Kennedy, 2010; Ontario Ministry of Natural Resources, 2012).

(142) Bonnechere Caves, Renfrew County, Ontario, Canada

Geology.—Ordovician Trenton Group (Ford, 1961; MacGregor, 1976).

Air Temperature.—5.0 °C, November 29, 1947 (Hitchcock, 1949); −5.0 °C, January 4, 1947 (Hitchcock, 1949).

Relative Humidity.—90 to 92 percent, November 29, 1947 (Hitchcock, 1949).

WNS Detected.—March 2010 (Crosby, 2010; Kennedy, 2010; Ontario Ministry of Natural Resources, 2012).

(143) Abandoned Mine near Kirkland Lake, Timiskaming District, Ontario, Canada

Geology.—Precambrian metavolcanic rocks.

WNS Detected.—March 2010 (Crosby, 2010; Kennedy, 2010; USGS NWHC, 2010b; Ontario Ministry of Natural Resources, 2012). WNS infection at an abandoned mine near Kirkland Lake confirmed by USGS NWHC (2010b), and WNS infection in Timiskaming District of Ontario confirmed by USGS NWHC (2010d).

(144) White Oak Blowhole Cave (Blowhole Cave, Whiteoak Sink Cave), Great Smoky Mountain National Park, Blount County, Tennessee

Geology.—Dolomite of the Cambrian-Ordovician Knox Group (Barr, 1961).

Cave Sediment.—Before 1870, sediment in the cave was mined for nitrate to make gunpowder (Hill and others, 1981; Plemons, 1995; Smith, 1996; Matthews, 2008).

Air Temperature.—7.4 to 10.3 °C, October 1998 through April 1999 and October 1999 through April 2000 (Tuttle and Kennedy, 2002).

WNS Detected.—March 2010 (Dasher, 2010b; Lamb and Wyckoff, 2010a,b; U.S. National Park Service, 2010a,b; Samoray, 2011). WNS infection in Blount County (not shown) confirmed by USGS NWHC (2010c).

(145) Camps Gulf Cave, Van Buren County, Tennessee

Geology.—Mississippian Ste. Genevieve Limestone and Gasper Limestone (Barr, 1961) or Mississippian Monteagle Limestone and Bangor Limestone (Palmer, 2009).

Cave Sediment.—Before 1870, sediment in the cave was mined for nitrate to make gunpowder (Hill, 1982; Plemons, 1995).

WNS Detected.—March 2010 (Lamb and Wyckoff, 2010a,b; Samoray, 2011).

(146) Dunbar Cave (Commercial Cave) (Dunbar-Woodard Cave System), Montgomery County, Tennessee

Geology.—Mississippian St. Louis Limestone (Barr, 1961) or along the contact of the Mississippian Warsaw Limestone and the overlying St. Louis Limestone (Geer, 1980).

Cave Sediment.—Before 1870, sediment in the cave was mined for nitrate to make gunpowder (Plemons, 1995).

WNS Detected.—March 2010 (Dasher, 2010b; Lamb and Wyckoff, 2010a,b; Samoray, 2011). WNS infection at Dunbar Cave confirmed by USGS NWHC (2010b).

(147) Caverne Lafleche (Caverne de Wakefield), Outaouais Region, Municipality of Val-des-Monts, Quebec, Canada

Geology.—Ordovician carbonate strata (Beaupré and others, 1976) or Precambrian marble (Peck, 1988).

Air Temperature.—2.2 °C, November 25, 1939 (Hitchcock, 1949); 2.8 °C, April 4, 1942 (Hitchcock, 1949); 0.0 °C, December 19, 1942 (Hitchcock, 1949).

Relative Humidity.—90 percent, April 4, 1942 (Hitchcock, 1949).

WNS Detected.—April 2010 (Hoag, 2010; Ministère des Ressources naturelles et de la Faune—Québec, 2010). WNS infection at Les Collines-de-l'Outaouais County (not shown) in Quebec confirmed by USGS NWHC (2010d).

(148) Summer Roost Site #1, New Castle County, Delaware

Bats at two summer roost sites in New Castle County (not shown) were confirmed to be positive for the presence of *P. destructans* (Delaware Department of Natural Resources and Environmental Control, 2010).

WNS Detected.—April 2010 (Delaware Department of Natural Resources and Environmental Control, 2010).

(149) Summer Roost Site #2, New Castle County, Delaware

Bats at two summer roost sites in New Castle County were confirmed to be positive for the presence of *P. destructans* (Delaware Department of Natural Resources and Environmental Control, 2010).

WNS Detected.—April 2010 (Delaware Department of Natural Resources and Environmental Control, 2010).

(150) Hupman's Saltpeter Cave, Highland County, Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group.

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Faust, 1964; Lucas and Lucas, 2009).

WNS Detected.—April 2010 (Blue Ridge Grotto, 2011; Front Royal Grotto, 2010a).

(151) Starr Chapel Saltpeter Cave, Bath County, Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Cooper, 1962; Douglas, 1964).

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Faust, 1964).

WNS Detected.—April 2010 (Blue Ridge Grotto, 2011; U.S. Department of Agriculture, U.S. Forest Service–Southern Region, 2014).

(152) Clark's Cave, Bath County, Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (McGill, 1946; Holsinger, 1961; Douglas, 1964; Palmer, 1975; Hubbard, 1994; Hubbard and others, 1986).

Cave Sediment.—Chemical analyses are presented in table 2. During the War of 1812 (from 1812 through 1815) and the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Clark, 1942; Douglas, 1964; Faust, 1964; Hubbard and others, 1986).

WNS Detected.—April 2010 (Blue Ridge Grotto, 2011).

(153) East Fork Saltpeter Cave, Fentress County, Tennessee

Geology.—Mississippian Monteagle Limestone (Sasowsky and others, 1995).

Cave Sediment.—Before 1870, sediment in the cave was mined for nitrate to make gunpowder (Hill and others, 1981; Plemons, 1995).

WNS Detected.—April 2010 (Lamb and Wyckoff, 2010a,b; Samoray, 2011).

(154) Unspecified Cave on Private Property, Pike County, Missouri

Geology.—Mississippian limestone.

WNS Detected.—April 2010 (USGS NWHC, 2010c; Missouri Department of Conservation, 2012).

May 2010 through September 2010 (Summer Nonhibernating Season)

During this season, 3 infected sites were detected (157 total infected sites to date [by end of September 2010]). One of these new sites is a "suspected site" rather than a "confirmed site." This suspected site is James Selman Cave (Woodward County [not shown], Oklahoma), where a bat was present that was "equivocal" for having the genetic markers for *P. destructans* but did not display symptoms of WNS (Caire and others, 2010; Stark, 2010; Sleeman, 2014). Reliable data are sparse, but James Selman Cave has the lowest recorded relative humidity of any WNS-infected site identified before October 2011 (table 1).

(155) Bat Cave, Ozark National Scenic Riverways, Shannon County, Missouri

Geology.—Cambrian Eminence Dolomite (Webster, 1966).

Air Temperature.—Negative (−) 8.3 to 9.0 °C, October through April 1998–2000 (Tuttle and Kennedy, 2002).

WNS Detected.—May 2010 (U.S. National Park Service, 2010c; Mabry and others, 2011; Missouri Department of Conservation, 2012).

(156) James Selman Cave (Selman Cave System), Woodward County, Oklahoma

This cave has multiple entrances. Initial reports stated that the fungus *G. destructans* [*P. destructans*] was isolated from a bat collected in a mist net at one entrance to the cave, but this bat did not display symptoms of WNS (Caire and others, 2010; Stark, 2010). A subsequent report stated that the bat was "equivocal for the presence" of *P. destructans* (Sleeman, 2014).

Geology.—Gypsum and dolomite of the Permian Blaine Formation (Looney, 1968; Bozeman, 2002; Caire and others, 2010).

Air Temperature.—0.6 to 17.0 °C, October through March 1979–86 (Caire and Loucks, 2010).

Relative Humidity.—50 to 90 percent, October through March 1979–86 (Caire and Loucks, 2010).

WNS Detected.—May 2010 (Caire and others, 2010; Stark, 2010; Sleeman, 2014).

(157) Pocahontas State Park, Chesterfield County, Virginia

A bat in the park was confirmed positive for the presence of *G. destructans* [*P. destructans*].

WNS Detected.—June 2010 (Dasher, 2010c; USGS NWHC, 2010f; Virginia Department of Game and Inland Fisheries, 2010).

October 2010 through April 2011 (Winter Hibernating Season)

During this season, 77 infected sites were detected (234 total infected sites to date [by end of April 2011]). In Canada, the range of WNS expanded to New Brunswick and Nova Scotia (fig. 1). In the United States, the range of WNS expanded to North Carolina, Indiana, Ohio, and Kentucky (fig. 1). Although the highest known elevation of a WNS-infected site with a specific known location is Hitchcock Cave in New York at approximately 1,107 meters above sea level (fig. 7), in January 2011, WNS was documented in an unspecified cave at Grandfather Mountain State Park in North Carolina (Andrew, 2011; North Carolina Wildlife Resources Commission, 2011; U.S. Fish and Wildlife Service, 2011), where elevations are approximately 1,800 meters above sea level. During March 2011, WNS was documented at the following three commercial caves: Organ Cave in West Virginia (Dasher, 2011; Stihler, 2011), Grand Caverns in Virginia (Front Royal Grotto, 2011g; Virginia Cave Board, 2011), and Dixie Caverns in Virginia (Front Royal Grotto, 2011g; Virginia Cave Board, 2011).

(158) Bowden Cave, Randolph County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Davies, 1965; Medville and Medville, 1971; Garton, 1977; Gulden, 2000).

Cave Sediment.—Chemical analyses are presented in table 2.

Air Temperature.—5.6 °C, January 24, 1998 (Gulden, 1998).

WNS Detected.—January 2011 (Stihler, 2011).

(159) Culverson Creek Cave—Culverson Creek entrance, Greenbrier County, West Virginia

Culverson Creek Cave is a vast cave system that has 10 known entrances (Zokaites, 1995b; Dasher and Medville, 2009). One of these entrances is the Culverson Creek entrance

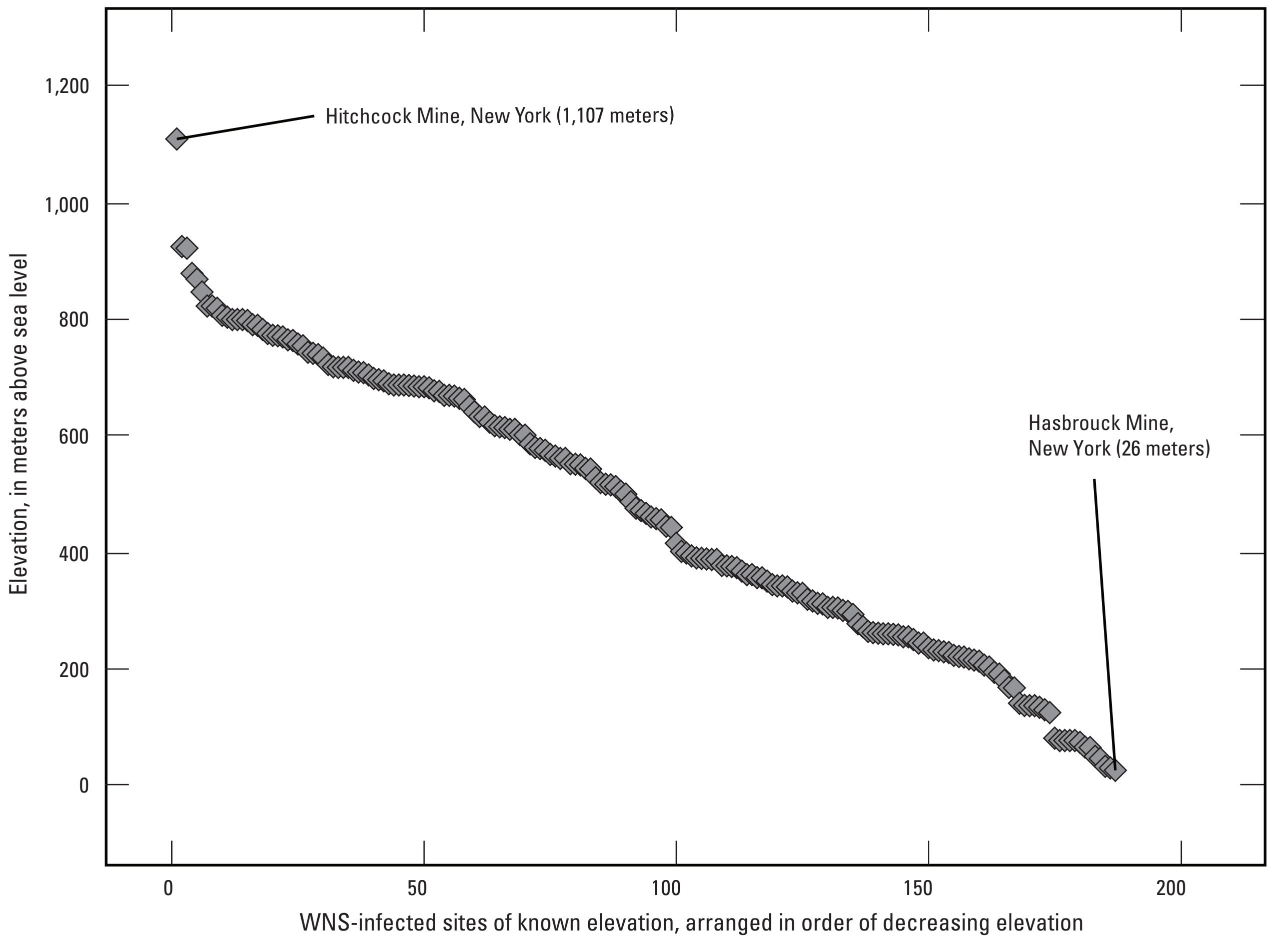

Figure 7. Elevation (meters above sea level) of sites infected with white-nose syndrome (WNS) before October 2011, arranged in order of decreasing elevation. Elevation data and site names are given in table 1.

(site 159), where WNS infection was detected in January 2011. Another entrance is named Wild Cat Cave (site 170), where WNS infection was detected in February 2011.

Geology.—Mississippian Greenbrier Limestone (Davies, 1965; Dasher and Medville, 2009).

WNS Detected.—January 2011 (Stihler, 2011).

(160) Crossroads Cave, Bath County, Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Douglas, 1964; Holsinger, 1975).

WNS Detected.—January 2011 (Richard A. Lambert, oral commun., January 2011).

(161) Rufe Caldwell Cave, Craig County, Virginia

Geology.—Ordovician limestone (Douglas, 1964), probably a Stones River Limestone equivalent (Reger and Price, 1926).

WNS Detected.—January 2011 (Front Royal Grotto, 2011f).

(162) Mill Creek Cave, Montgomery County, Virginia

Geology.—Cambrian Elbrook Dolomite.

WNS Detected.—January 2011 (Front Royal Grotto, 2011f).

(163) James Cave, Pulaski County, Virginia

Geology.—Cambrian Conococheague Limestone (Holsinger, 1975).

WNS Detected.—January 2011 (Front Royal Grotto, 2011e).

(164) Hamilton Cave, Bland County, Virginia

Geology.—Ordovician limestone (Douglas, 1964), probably a Stones River Limestone equivalent (Reger and Price, 1926).

Cave Sediment.—Before 1870, sediment in the cave was mined for nitrate to make gunpowder (Faust, 1964).

WNS Detected.—January 2011 (Front Royal Grotto, 2011f; Springston, 2011).

(165) Unspecified Cave, Grandfather Mountain State Park, Avery County, North Carolina

Geology.—Precambrian strata (Bryant and Reed, 1970).
WNS Detected.—January 2011 (Andrew, 2011; North Carolina Wildlife Resources Commission, 2011; U.S. Fish and Wildlife Service, 2011).

(166) Endless Cave, Washington County, Indiana

Geology.—Mississippian Salem Limestone (Powell, 1961).
WNS Detected.—January 2011 (Front Royal Grotto, 2011a; Indiana Department of Natural Resources, 2011; USGS NWHC, 2011a).

(167) Unspecified Cave #1, Crawford County, Indiana

Geology.—Probably Mississippian limestone.
WNS Detected.—January 2011 (Caudell and Zimmerman, 2011). WNS infection in Crawford County (not shown) confirmed by USGS NWHC (2011b).

(168) Unspecified Cave #2, Crawford County, Indiana

Geology.—Probably Mississippian limestone.
WNS Detected.—January 2011 (Caudell and Zimmerman, 2011). WNS infection in Crawford County confirmed by USGS NWHC (2011b).

(169) Unspecified Site, New London County, Connecticut

WNS Detected.—February 2011 (USGS NWHC, 2011a).

(170) Culverson Creek Cave—Wild Cat Cave entrance (Wildcat Cave entrance), Greenbrier County, West Virginia

Wild Cat Cave (or Wildcat Cave) is one of the entrances to the greater Culverson Creek Cave System (Jones, 1973). This cave system has 10 known entrances (Zokaites, 1995b; Dasher and Medville, 2009). One of these entrances is the Culverson Creek entrance (site 159), where WNS infection was detected in January 2011.
Geology.—Mississippian Greenbrier Limestone.
WNS Detected.—February 2011 (Stihler, 2011).

(171) Steeles Cave, Monroe County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).
Air Temperature.—11.7 °C, no date specified (Davies, 1965).
WNS Detected.—February 2011 (Stihler, 2011).

(172) Honaker Cave, Mercer County, West Virginia

Geology.—Dolomite of the Ordovician Beekmantown Group (Davies, 1965).
WNS Detected.—February 2011 (Stihler, 2011).

(173) Honaker Cave #2, Mercer County, West Virginia

Geology.—Dolomite of the Ordovician Beekmantown Group (Davies, 1965).
WNS Detected.—February 2011 (Stihler, 2011).

(174) Witheros Cave, Bath County, Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Holsinger, 1975; Hubbard, 1981; Hubbard and others, 1986).
Cave Sediment.—Chemical analyses are presented in table 2. During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Faust, 1964; Hubbard, 1981).
Air Temperature.—2.7 to 6.3 °C, February 25, 1978 (Hubbard, 1981).
WNS Detected.—February 2011 (Front Royal Grotto, 2011c).

(175) Higginbotham #1 and #2 Caves (Corkscrew-Higginbotham Cave System), Tazewell County, Virginia

Geology.—Limestone or dolomite, or both, of the Ordovician Beekmantown Group (Whittemore, 1966) or perhaps the Ordovician Witten Limestone.
WNS Detected.—February 2011 (Front Royal Grotto, 2011b) or December 2010 (Blue Ridge Grotto, 2011).

(176) Rocky Hollow Cave, Wise County, Virginia

Geology.—Mississippian Greenbrier Limestone (Holsinger, 1975).

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Fleenor, 1959; Douglas, 1964; Faust, 1964).

Air Temperature.—5.6 to 7.5 °C, October through April 1998–2000 (Tuttle and Kennedy, 2002).

WNS Detected.—February 2011 (Front Royal Grotto, 2011d; Virginia Cave Board, 2011). WNS infection in Wise County (not shown) confirmed by USGS NWHC (2011b).

(177) Abandoned Mine, Avery County, North Carolina

Geology.—Precambrian strata.

WNS Detected.—February 2011 (North Carolina Wildlife Resources Commission, 2011; U.S. Fish and Wildlife Service, 2011; USGS NWHC, 2011a; Weeks, 2012).

(178) Abandoned Mine, Yancey County, North Carolina

Geology.—Precambrian strata.

WNS Detected.—February 2011 (Andrew, 2011; Asheville Citizen-Times, 2011).

(179) Unspecified Site, Fairfield County, Connecticut

WNS Detected.—March 2011 (USGS NWHC, 2011a).

(180) Abandoned Mine near Val-d'Or, Abitibi Témiscamingue (Temiscaming) Region, Quebec, Canada

Geology.—Precambrian igneous or metamorphic rock.

WNS Detected.—March 2011 (Ministère des Ressources naturelles et de la Faune—Québec, 2010). WNS infection in Abitibi Témiscamingue (Temiscaming) region of Quebec confirmed by USGS NWHC (2011d).

(181) Unspecified Site (Probably a Mine), Nipissing Township, Ontario, Canada

Geology.—Probably Precambrian igneous or metamorphic rock.

WNS Detected.—March 2011 (USGS NWHC, 2011c).

(182) Unspecified Site (Probably a Mine), Mattawa Area, Ontario, Canada

Geology.—Probably Precambrian igneous or metamorphic rock.

WNS Detected.—March 2011 (Ontario Ministry of Natural Resources, 2012).

(183) Unspecified Site (Probably a Mine), Timmons Area, Ontario, Canada

Geology.—Probably Precambrian igneous or metamorphic rock.

WNS Detected.—March 2011 (Ontario Ministry of Natural Resources, 2012).

(184) Berryton Cave (Stewart Cave, Stuart Cave, Turtle Brook Cave, Turtle Creek Cave), Albert County, New Brunswick, Canada

Geology.—Limestone of the Mississippian Windsor Group (McAlpine, 1983; Arseneault and others, 1997) or Mississippian limestone and gypsum (Vanderwolf and others, 2012).

Air Temperature.—Negative (−) 0.8 to 4.4 °C near cave entrance, November 2009 through November 2010 (Vanderwolf and others, 2012); 3.1 to 5.6 °C far from cave entrance, November 2009 through November 2010 (Vanderwolf and others, 2012).

WNS Detected.—March 2011 (Bangor Daily News, 2011; McAlpine and others, 2011; New Brunswick Museum, 2011; Vanderwolf and others, 2012). WNS infection in Albert County (not shown) of New Brunswick confirmed by USGS NWHC (2011b).

(185) Unspecified Site, Tioga County, Pennsylvania

WNS Detected.—March 2011 (USGS NWHC, 2011c).

(186) Unspecified Site, Fulton County, Pennsylvania

WNS Detected.—March 2011 (USGS NWHC, 2011a).

(187) Coon Cave (Coon Cavern), Forbes State Forest, Westmoreland County, Pennsylvania

Geology.—Mississippian Loyalhanna Member of the Mauch Chunk Formation (Guilday, 1948; Stone, 1953; Dunn, 1960; Ashbrook, 1995a,b). This unit is a calcite-cemented sandstone that consists of predominantly quartz grains and a substantial component of carbonate grains (Krezoski and others, 2005, 2006).

Air Temperature.—9.4 °C, no date specified (Guilday, 1948; Metzgar, 1995).

WNS Detected.—March 2011 (Pennsylvania Department of Conservation and Natural Resources, 2011; USGS NWHC, 2011a).

(188) Barton Cave, Forbes State Forest, Fayette County, Pennsylvania

Geology.—Mississippian Loyalhanna Member of the Mauch Chunk Formation (Guilday, 1948; Stone, 1953; Dunn, 1960; Ashbrook, 1995a,b). This unit is a calcite-cemented sandstone that consists of predominantly quartz grains and a substantial component of carbonate grains (Krezoski and others, 2005, 2006).

WNS Detected.—March 2011 (Pennsylvania Department of Conservation and Natural Resources, 2011).

(189) Eliza Cave (Elisha Davis Cave, Reed's Creek Cave), Pendleton County, West Virginia

Geology.—Silurian Tonoloway Limestone (Davies, 1965) or limestone of the Silurian-Devonian Helderberg Group (Dasher, 2001a).

WNS Detected.—March 2011 (Stihler, 2011).

(190) Hoffman School Cave, Pendleton County, West Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Davies, 1965; Dasher, 2001a).

Cave Sediment.—Chemical analyses are presented in table 2. During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Faust, 1964; Davies, 1965; Garton and Garton, 1970, 2001; Dasher, 2001b; Taylor, 2001).

Air Temperature.—6.7 to 11.7 °C, April 26, 1952 (Peckham, 1952); 10.6 °C, no date specified (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(191) Minor Rexrode Cave, Pendleton County, West Virginia

Geology.—Limestone of the Silurian-Devonian Helderberg Group (Davies, 1965).

Cave Sediment.—Chemical analyses are presented in table 2. Before 1870, sediment in the cave was mined for nitrate to make gunpowder (Stephenson, 1950; Dasher, 2001a,b; Garton and Garton, 2001; Taylor, 2001).

Air Temperature.—7.8 °C, no date specified (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(192) Schoolhouse Cave, Pendleton County, West Virginia

Geology.—Ordovician Mosheim Limestone and the overlying Ordovician Lenoir Limestone (Davies, 1965), or limestone of the Ordovician Big Valley Formation and limestone of the overlying McGlone Formation (Dasher and Sites, 2000), or limestone of the McGlone Formation and the overlying McGraw Limestone (Dasher, 2001a).

Cave Sediment.—Chemical analyses are presented in table 2. Before and during the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Yoe, 1948; Faust, 1964; Davies, 1965; Garton and Garton, 1970, 2001; Dasher and Sites, 2000; Dasher, 2001a,b; Taylor, 2001).

Air Temperature.—5.0 °C, July 4–5, 1953 (Lutz, 1954); 5.0 °C, no date specified (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(193) Lobelia Saltpeter Cave, Pocahontas County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Davies, 1965; Dasher, 2001b).

Air Temperature.—8.9 °C, no date specified (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(194) Martha's Cave (Martha Clark's Cave, Upper Martha's Cave), Pocahontas County, West Virginia

Martha's Cave has one entrance that provides access to an upper cave named Upper Martha's Cave and to a lower cave named Lower Martha's Cave (Storrick, 1992).

Geology.—Mississippian Greenbrier Limestone (Davies, 1965; Storrick, 1992).

Air Temperature.—9.4 °C, no date specified (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(195) Beethoven's Symphony Cave, Hardy County, West Virginia

Geology.—Silurian-Devonian limestone.

WNS Detected.—March 2011 (Stihler, 2011).

(196) Carol's Crack, Hardy County, West Virginia

Geology.—Silurian Tonoloway Limestone (Dasher, 2000).

WNS Detected.—March 2011 (Stihler, 2011).

(197) Kline Gap Cave (Klines Gap Cave), Grant County, West Virginia

Geology.—Silurian Tonoloway Limestone (Medville, 1975; Dasher, 2010d).

Cave Sediment.—Reports indicate that before 1870, sediment in the cave was mined for nitrate to make gunpowder (Medville, 1975; Hill and others, 1981; Plemons, 1995; Dasher, 2001b, 2010d).

Air Temperature.—10.0 °C, no date specified (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(198) Arbogast Cave (Cave Hollow-Arbogast Cave System), Tucker County, West Virginia

Arbogast Cave is part of the greater Cave Hollow-Arbogast Cave System, which has at least five entrances (McCarty and Masney, 2011). In March 2011, WNS infection was detected near the entrance of Arbogast Cave (site 198) and near the entrance of Cave Hollow Cave (site 201).

Geology.—Mississippian Greenbrier Limestone (Ganter, 1983, 1984; McCarty and Masney, 2011).

WNS Detected.—March 2011 (Stihler, 2011).

(199) Blackwater Cave (Blackwater Pit), Tucker County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Povirk, 1970).

WNS Detected.—March 2011 (Dasher, 2011; Stihler, 2011).

(200) Big Spring Cave (Blowing Cave), Tucker County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).

WNS Detected.—March 2011 (Dasher, 2011; Stihler, 2011).

(201) Cave Hollow Cave (Cave Hollow-Arbogast Cave System), Tucker County, West Virginia

Cave Hollow Cave is part of the greater Cave Hollow-Arbogast Cave System, which has at least five entrances (McCarty and Masney, 2011). In March 2011, WNS infection was detected near the entrance of Arbogast Cave (site 198) and near the entrance of Cave Hollow Cave (site 201).

Geology.—Mississippian Greenbrier Limestone (Davies, 1965; Ganter, 1983, 1984; McCarty and Masney, 2011).

Cave Sediment.—Chemical analyses are presented in table 2.

WNS Detected.—March 2011 (Stihler, 2011).

(202) Alpena Cave, Randolph County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(203) Falling Spring Cave, Randolph County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Davies, 1965; Medville and Storage, 1986; Medville and Medville, 1995).

WNS Detected.—March 2011 (Stihler, 2011).

(204) My Cave (Simmons-Mingo Cave System), Pocahontas County and Randolph County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Medville and Medville, 1976; Medville, 1977, 2000b; Medville and Storage, 1986; Dasher, 2000).

WNS Detected.—March 2011 (Stihler, 2011).

(205) The Boar Hole (Cave), Greenbrier County, West Virginia

The Boar Hole is connected to another cave named The Portal (Balfour, 2003; Droms, 2003). In March 2008, WNS infection was detected in The Boar Hole (site 205) and in The Portal (site 212). Water in The Portal flows south to Cannon

Hole and to the downstream part of the Friars Hole-Snedegars Cave System (Dasher, 1995; Jones, 1997). In March 2010, WNS infection was detected in the Friars Hole (site 125) and Snedegars Cave (site 126) parts of the Friars Hole-Snedegars Cave System.

Geology.—Mississippian Greenbrier Limestone.

WNS Detected.—March 2011 (Stihler, 2011).

(206) Bone Cave (Bone-Norman Cave System), Greenbrier County, West Virginia

Bone Cave is part of the greater Bone-Norman Cave System (Handley, 1995). In March 2011, WNS infection was detected in Bone Cave (site 206) and in Norman Cave (site 127).

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(207) Buckeye Creek Cave (Buckeye Creek Cave System, Buckeye Creek-Rapps Cave System), Greenbrier County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Davies, 1965; Dasher and Handley, 1994).

Cave Sediment.—Soil in the cave consists of sand and silt that consists of 99 percent quartz and 1 percent charcoal (Springer and others, 2012). Rutherford and Huang (1994) identified the following fungi in sediments sampled in the cave: *Aspergillus versicolor*, *Gliocladium roseum*, *Monocillium humicola*, *Paecilomyces* sp., *Penicillium frequentans*, *Penicillium notatum*, *Penicillium roqueforti*, and *Penicillium steckii*.

Air Temperature.—10.7 °C, no date specified (Hardt and others, 2010).

WNS Detected.—March 2011 (Stihler, 2011).

(208) Higginbotham #1 Cave, Greenbrier County, West Virginia

Higginbotham #1 Cave has two entrances, one of which is sometimes called McClungs Cave (Vipond, 1959; Davies, 1965). Higginbotham #1 Cave (site 208) is connected to Higginbotham #4 Cave (site 209), which has a primary entrance approximately 150 meters south-southeast of the primary entrance to Higginbotham #1 Cave (Davies, 1965).

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).

Cave Sediment.—Rutherford and Huang (1994) identified the following fungi in sediments sampled in Higginbotham #1 Cave (McClungs Cave): *Hormiactis candida*, *Humicola grisea*, *Monocillium* sp., *Mortierella alpina*, and sterile mycelium.

WNS Detected.—March 2011 (Stihler, 2011).

(209) Higginbotham #4 Cave, Greenbrier County, West Virginia

Higginbotham #4 Cave (site 209) is connected to Higginbotham #1 Cave (site 208), which has a primary entrance approximately 150 meters north-northwest of the primary entrance to Higginbotham #4 Cave (Davies, 1965).

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(210) Organ Cave (Greenbrier Caverns) (Commercial Cave), Greenbrier County, West Virginia

Organ Cave has at least 10 entrances (Stevens, 1988), one of which is a commercial entrance.

Geology.—Mississippian Greenbrier Limestone (Davies, 1965; Rutherford and Handley, 1976; Deike, 1988a,b).

Cave Sediment.—Chemical analyses are presented in table 2. During the War of 1812 (from 1812 through 1815) and the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Faust, 1964; Davies, 1965; Rutherford and Handley, 1976; Dasher, 2001b; Smith, 2003). Rutherford and Huang (1994) identified the following fungi in sediments sampled at four locations in the cave: *Acremonium cerealis*, *Acremonium* sp., *Acremonium strictum*, *Aspergillus aureolatus*, *Aspergillus sclerotiorum*, *Aspergillus caespitosus*, *Aureobasidium pullulans*, *Byssochlamys fulva*, *Chrysosporium* sp., *Cladosporium cladosporioides*, *Fusarium oxysporum*, *Geomyces pannorum*, *Gliomastix murorum*, *Humicola grisea*, *Paecilomyces variotii*, *Penicillium brevicompactum*, *Penicillium chrysogenum*, *Penicillium roqueforti*, *Penicillium* sp., *Penicillium steckii*, *Pythium* sp., *Rhodotorula* sp., *Scolecobasidium constrictum*, *Ulocladium botrytis*, and sterile mycelium.

Air Temperature.—5.1 to 9.9 °C, February 1, 1963, March 12, 1963, and April 2, 1963 (Cropley, 1965).

WNS Detected.—March 2011 (Dasher, 2011; Stihler, 2011).

(211) Piercys Cave, Greenbrier County, West Virginia

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(212) The Portal (Cave), Greenbrier County, West Virginia

The Portal is connected to another cave named The Boar Hole (Balfour, 2003; Droms, 2003). In March 2008, WNS infection was detected in The Boar Hole (site 205) and in The

Portal (site 212). Water in The Portal flows south to Cannon Hole and to the downstream part of the Friars Hole-Snedegars Cave System (Dasher, 1995; Jones, 1997). In March 2010, WNS infection was detected in the Friars Hole (site 125) and Snedegars Cave (site 126) parts of the Friars Hole-Snedegars Cave System.

Geology.—Mississippian Greenbrier Limestone.

WNS Detected.—March 2011 (Stihler, 2011).

(213) Brooklyn Mine, New River Gorge National River, Fayette County, West Virginia

Geology.—Sewell coal bed of the Pennsylvanian New River Formation.

WNS Detected.—March 2011 (Stihler, 2011; U.S. National Park Service, 2011).

(214) Greenville Saltpeter Cave, Monroe County, West Virginia

Greenville Saltpeter Cave is part of a subterranean drainage network that connects Laurel Creek with Indian Creek, via Laurel Creek Cave (Davies, 1965). In March 2011, WNS infection was detected in Greenville Saltpeter Cave (site 214) and in Laurel Creek Cave (site 215).

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).

Cave Sediment.—Before and during the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Davies, 1965; Dasher, 2001b).

WNS Detected.—March 2011 (Stihler, 2011; although the cave is named incorrectly as Greenbrier Saltpeter Cave).

(215) Laurel Creek Cave, Monroe County, West Virginia

Laurel Creek Cave is part of a subterranean drainage network that connects Laurel Creek with Indian Creek, via Greenville Saltpeter Cave (Barr, 1953; Davies, 1965). In March 2011, WNS infection was detected in Greenville Saltpeter Cave (site 214) and in Laurel Creek Cave (site 215).

Geology.—Mississippian Greenbrier Limestone (Davies, 1965).

Cave Sediment.—A “white fungus growing conspicuously on the bodies of dead crickets on the floor of Laurel Creek Cave … resemble *Beauveria* which is known to grow on insects” (Emmons, 1951, p. 1).

Air Temperature.—11.1 °C, no date specified (Davies, 1965).

WNS Detected.—March 2011 (Stihler, 2011).

(216) Beacon Cave, Mercer County, West Virginia

Geology.—Ordovician limestone (Saunders and Balfour, 1991), probably the Beekmantown Group.

WNS Detected.—March 2011 (Stihler, 2011).

(217) Noncave site, Jefferson County, West Virginia

WNS Detected.—March 2011 (Stihler, 2011).

(218) Crabtree Cave, Garrett County, Maryland

Geology.—Mississippian Greenbrier Limestone (Davies, 1950).

Cave Sediment.—Chemical analyses are presented in table 2.

Air Temperature.—10.0 °C, no date specified (Davies, 1950); 3.0 to 11.5 °C, no date specified (Miller and Franz, 1963).

Relative Humidity.—100 percent, no date specified (Davies, 1950); 60 to 100 percent, no date specified (Miller and Franz, 1963).

WNS Detected.—March 2011 (Cumberland Times-News, 2011; Maryland Department of Natural Resources, 2011; Porter, 2011; USGS NWHC, 2011a).

(219) Round Top Mines, Washington County, Maryland

The name Round Top Mines is given to several abandoned limestone mines and small caves along railroad cuts and the canal associated with the Chesapeake and Ohio Railroad near Round Top, Maryland (Franz and Slifer, 1971). Some of the caves and mines have been mapped and given individual names such as Roundtop #1 Cave (Plummer, 1958) and Round Top Mine #2 and Round Top Mine #5 (Franz and Slifer, 1971).

Geology.—Limestone of the Silurian Wills Creek Formation (Franz and Slifer, 1971).

WNS Detected.—March 2011 (Dasher, 2011; Porter, 2011; USGS NWHC, 2011a).

(220) Ogdens Cave, Ogdens Cave Natural Area Preserve, Frederick County, Virginia

Geology.—Dolomite of the Ordovician Beekmantown Group.

WNS Detected.—March 2011 (Front Royal Grotto, 2011g).

(221) Grand Caverns (Commercial Caverns), Cave Hill, Augusta County, Virginia

Geology.—Cambrian-Ordovician Conococheague Limestone (McGill, 1933; Douglas, 1964; Kastning, 1991; Hubbard, 1995a).

WNS Detected.—March 2011 (Front Royal Grotto, 2011g). In addition, the Virginia Cave Board (2011) stated that Cave Hill is infected with WNS.

(222) Dixie Caverns (Commercial Caverns), Roanoke County, Virginia

Geology.—Cambrian Elbrook Dolomite (McGill, 1933; Douglas, 1964).

WNS Detected.—March 2011 (Front Royal Grotto, 2011g; Virginia Cave Board, 2011).

(223) Buddy Penley Cave, Bland County, Virginia

Geology.—Ordovician limestone (Holsinger, 1975), probably the Witten Limestone.

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (Hubbard, 1995b).

WNS Detected.—March 2011 (Blue Ridge Grotto, 2011).

(224) Concrete Tank Cave, Russell County, Virginia

Geology.—Dolomite of the Cambrian-Ordovician Knox Group.

WNS Detected.—March 2011 (Front Royal Grotto, 2011g).

(225) Cooper Creek/Foster Cave, Barnett Woods State Natural Area, Montgomery County, Tennessee

Geology.—Mississippian Warsaw Limestone (Barr, 1961).

Cave Sediment.—Before 1870, sediment in the cave was mined for nitrate to make gunpowder (Barr, 1961).

WNS Detected.—March 2011 (USGS NWHC, 2011a; Samoray, 2011; Holliday, 2012).

(226) Bellamy Cave, Montgomery County, Tennessee

Geology.—Mississippian Warsaw Limestone (Barr, 1961).

Cave Sediment.—During the U.S. Civil War (from 1861 through 1865), sediment in the cave was mined for nitrate to make gunpowder (McDowell, 1976).

WNS Detected.—March 2011 (Samoray, 2011; Gorman, 2012; Holliday, 2012; Thogmartin and others, 2012).

(227) Unspecified Cave near Linville Caverns, McDowell County, North Carolina

Geology.—Linville Caverns are in the Cambrian Shady Dolomite (Hawkins, 1942; Brown, 1961).

Air Temperature.—11.1 °C in Linville Caverns, no date specified (Holler and Holler, 1989).

WNS Detected.—March 2011 (Andrew, 2011; North Carolina Wildlife Resources Commission, 2012; Weeks, 2012).

(228) Abandoned Limestone Mine, Wayne National Forest, Lawrence County, Ohio

WNS Detected.—March 2011 (Dasher, 2011; Ohio Department of Natural Resources, 2011; USGS NWHC, 2011a).

(229) Unspecified Site, Peel County, Ontario, Canada

WNS Detected.—April 2011 (Ontario Ministry of Natural Resources, 2012).

(230) Unspecified Site, Halton County, Ontario, Canada

WNS Detected.—April 2011 (Ontario Ministry of Natural Resources, 2012).

(231) Unspecified Site, Simcoe County, Ontario, Canada

WNS Detected.—April 2011 (Ontario Ministry of Natural Resources, 2012).

(232) Frenchman's Cave, Hants County, Nova Scotia, Canada

Geology.—Gypsum of the Mississippian Windsor Group (Bleakney, 1965; Calder and Bleakney, 1965, 1967).

Cave Sediment.—Although chemical characteristics of the cave sediment have not been published, the pH of forest litter at the top of the sinkhole entrance to the cave is 5.2, the pH of detritus at the bottom of the sinkhole entrance is 7.4, and the pH of detritus within the cave ranges from 5.1 to 6.3 (Calder and Bleakney, 1965).

Air Temperature.—0.0 to 6.7 °C, January 18, 1964, through July 28, 1964 (Calder and Bleakney, 1965, 1967).

Relative Humidity.—82 to 94 percent, January 18, 1964, through July 28, 1964 (Calder and Bleakney, 1965, 1967).

WNS Detected.—April 2011 (Nova Scotia Department of Natural Resources, 2011). WNS infection in Hants County (not shown) in Nova Scotia confirmed by USGS NWHC (2011c).

(233) Unspecified Site near Pisgah Center for Wildlife Education, Transylvania County, North Carolina

WNS Detected.—April 2011 (North Carolina Wildlife Resources Commission, 2012; South Carolina Department of Natural Resources, 2012).

(234) Cool Spring Cave (Cool Springs Cave), Trigg County, Kentucky

Geology.—Mississippian limestone (Mylroie and Dyas, 1985).

Cave Sediment.—Analyses of seven samples of layered sediments from the cave revealed organic matter contents ranging from 1.59 to 7.44% and $CaCO_3$ contents ranging from 5.16 to 7.23% (Chisholm and Hart, 1980).

WNS Detected.—April 2011 (Kentucky Department of Fish and Wildlife Resources, 2011; Verant, 2016).

May 2011 through September 2011 (Summer Nonhibernating Season)

During this season, 7 infected sites were detected (241 total infected sites to date [by end of September 2011]). In the United States, the range of WNS expanded to Maine (fig. 1). Although new infected sites were reported after September 2011, the reporting has not been reliable or consistent. For example, results indicate that some new infection sites (identified after September 2011) have not been reported for counties that already contained a known WNS infection.

(235) Unspecified Site near Wawa, Algoma District, Ontario, Canada

WNS Detected.—May 2011 (Ontario Ministry of Natural Resources, 2012).

(236) Unspecified Site (Probably a Mine), Jamésie Region (James Bay Region) of Quebec, Canada

Geology.—Probably Precambrian igneous or metamorphic rock.

WNS Detected.—May 2011 (USGS NWHC, 2011d).

(237) Unspecified Cave, Oxford County, Maine

This site (site 237) is not the same as the unspecified site in Oxford County (not shown; site 238).

Geology.—Probably limestone in the Silurian Sangerville Formation.

WNS Detected.—May 2011 (Maine Department of Inland Fisheries and Wildlife, 2011). WNS infection in Oxford County confirmed by USGS NWHC (2011c).

(238) Unspecified Site, Oxford County, Maine

This site (site 238) is not the same as the unspecified cave in Oxford County (site 237).

WNS Detected.—May 2011 (Maine Department of Inland Fisheries and Wildlife, 2011). WNS infection in Oxford County confirmed by USGS NWHC (2011c).

(239) Battered Bar Cave, Burnsville Cove, Bath County, Virginia

Geology.—Silurian Tonoloway Limestone or the Silurian-Devonian Keyser Limestone (Lucas, 2004; White, 2015).

WNS Detected.—May 2011 (Michael J. Ficco, oral commun., Butler Cave Conservation Society meeting, May 2011).

(240) Blind Faith Cave, Burnsville Cove, Bath County, Virginia

Geology.—Silurian Tonoloway Limestone or the Silurian-Devonian Keyser Limestone (White, 2015).

WNS Detected.—May 2011 (Michael J. Ficco, oral commun., Butler Cave Conservation Society meeting, May 2011).

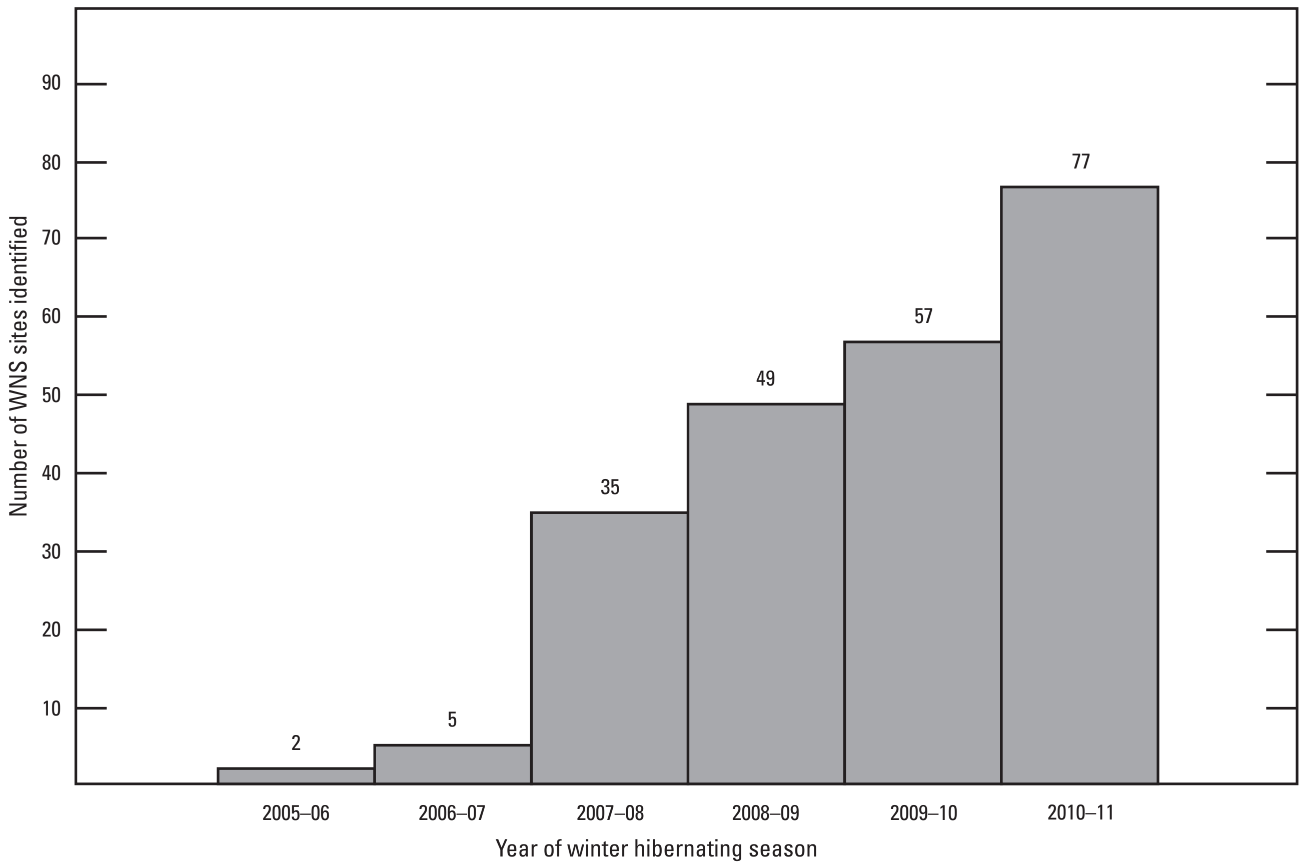

Figure 8. Number of white-nose syndrome (WNS)-infected sites identified per winter hibernating season.

(241) Bobcat Cave (Chestnut Ridge Blowing Cave, Chestnut Ridge Cave System), Burnsville Cove, Bath County, Virginia

Geology.—Silurian Tonoloway Limestone or the Silurian-Devonian Keyser Limestone (White, 2015).

WNS Detected.—May 2011 (Michael J. Ficco, oral commun., Butler Cave Conservation Society meeting, May 2011).

Discussion

The data presented in this paper indicate that WNS spread rapidly across North America from February 2006, when WNS was first documented in North America, through September 2011. During this time, most detections of WNS occurred during October through April, which is the winter season of bat hibernation in North America. Furthermore, the number of WNS-infected sites identified per winter hibernating season increased progressively (2 sites during the 2005–06 season, 5 sites during the 2006–07 season, 35 sites during the 2007–08 season, 49 sites during the 2008–09 season, 57 sites during the 2009–10 season, and 77 sites during the 2010–11 season). This progressive increase in the number of infected sites per winter season indicates that the number of WNS infections had not peaked as of the 2010–11 winter season (fig. 8).

The data presented in this paper indicate some trends with respect to geography. For example, the first infected site was identified during the 2005–06 winter hibernating season in Schoharie County, New York. During the subsequent hibernating season (2006–07), WNS spread beyond Schoharie County to Albany County, New York. During the 2007–08 hibernating season, WNS spread to Massachusetts, Vermont, and Connecticut. During the 2008–09 hibernating season, WNS spread to Pennsylvania, New Hampshire, New Jersey, West Virginia, and Virginia. By the end of the 2008–09 hibernating season, 91 infected sites were identified, all of which were on the east side of the Appalachian Mountains. During the 2009–10 hibernating season, WNS spread to Delaware, Maryland, Tennessee, and Missouri, as well as Canada (Ontario and Quebec). One of these new sites (Dunbar Cave, Montgomery County, Tennessee), was the first WNS-infected site to be documented west of the Appalachian Mountains. During 2009–10, the nearest known WNS-infected site was Worley's Cave (Morrill Cave, Morrell Cave) in Sullivan County of eastern Tennessee, approximately 290 kilometers from Dunbar Cave (most bats typically migrate distances of less than 100 kilometers; Krauel and others, 2018). During the

2010–11 hibernating season, WNS spread to Ohio, Kentucky, Indiana, and North Carolina, as well as New Brunswick and Nova Scotia. By the end of September 2011, the southernmost WNS-infected site was White Oak Blowhole Cave in Tennessee, and the westernmost WNS-infected site was either Bat Cave in Missouri or James Selman Cave in Oklahoma (in James Selman Cave, a bat was "equivocal" for the presence of *P. destructans* but did not display symptoms of WNS).

The data presented in this paper do not indicate any significant restrictions or preferences with respect to site elevation. The elevations of sites infected with WNS before October 2011 range from approximately 25 to 1,800 meters above sea level (although the 1,800-meter elevation site is not located precisely and, thus, not shown in fig. 7 or table 1). Furthermore, the known site elevations do not cluster around any specific value or range of values (table 1, fig. 7). Thus, the calculation of an elevation mean and standard deviation would not yield useful information.

The data presented in this paper do not indicate any significant restrictions with respect to site geology. For example, 152 of the 241 sites presented in this paper are caves and 53 are mines. At least 115 of the infected caves are in limestone, and other infected caves are in dolomite, marble, gypsum, sandstone, gneiss, and schist. At least 14 of the infected mines are in limestone, and other infected mines are in diverse rock types that include dolomite, sandstone, schist, gneiss, granite, amphibolite, serpentinite, and coal. The ages of these strata range from Precambrian to Triassic.

Because the fungus *P. destructans* is a terrestrial saprophyte, data on the sediment composition at infected sites might provide some insight regarding environmental parameters that might be conducive to WNS. Unfortunately, such data are incredibly sparse. Chemical analyses of sediments, for example, are available from only 13 of the 241 WNS-infected sites reported in this paper (table 2). Of these 13 sites, 2 are caves in Ordovician limestone (Schoolhouse Cave and Hellhole in West Virginia), 7 are caves in Silurian-Devonian limestone (Clark's Cave and Witheros Cave in Virginia; Cave Mountain Cave, Hoffman School Cave, Minor Rexrode Cave, Sinnett Cave, and Trout Cave in West Virginia), and 4 are caves in Mississippian limestone (Bowden Cave, Cave Hollow Cave, and Organ Cave in West Virginia; Crabtree Cave in Maryland). Although sediments with different chemical properties might be expected on different geological substrates, the available data do not indicate any differentiation with respect to substrate. Where data are available, the chemical concentrations indicate a wide range of values (table 2). For example, calcium concentrations range from 684 to more than 15,000 parts per million (ppm), magnesium concentrations range from 64 to 713 ppm, phosphorus concentrations range from 24 to 131 ppm, potassium concentrations range from 24 to 1,044 ppm, and pH values range from 6.7 to 8.0. In addition to these chemical analyses, 30 of the WNS-infected sites are caves where sediment was mined for nitrate to make gunpowder. These caves are in West Virginia, Virginia, and Tennessee. Specific concentrations of nitrate range from 300 to 2,200 ppm, but these concentrations are reported from only four of these caves (Cave Mountain Cave, Trout Cave, Sinnett Cave, and Organ Cave in West Virginia). Because of the sparseness of the data on sediment composition, the wide range of values is probably a more significant observation than any specific value or mean value. This wide range of values supports the statement by Reeder and Moore (2013) that caves and mines may contain a great range of microenvironments, and this environmental variability is still poorly understood.

Fungi within sediment have been reported from only 3 of the 241 WNS-infected sites described in this paper (Buckeye Creek Cave, Higginbotham #1 Cave, and Organ Cave in West Virginia). The fungi at these sites were described by Rutherford and Huang (1994), before WNS was detected in North America. One of the identified fungi in Organ Cave is *Geomyces pannorum*, which has been reclassified by Minnis and Lindner (2013) as *Pseudogymnoascus pannorum* and is considered to be closely related to *P. destructans*. In a world review of fungi, yeasts, and slime molds in caves, Vanderwolf and others (2013) indicated that most caves in the northern hemisphere have environments that favor communities of oligotrophic, psychrotolerant fungi.

The published air temperature values from WNS-infected sites range from −15.0 to 33.0 °C (table 1, fig. 5). This temperature range encompasses the range of −10.0 to 21.0 °C that has been suggested as the temperature range of most bat hibernacula in the wild (Webb and others, 1996), although subsequent studies have suggested that "not all bats within a species choose (or likely require) microsites with the same microclimatic conditions" (Boyles and others, 2017, p. 9). The air temperatures of 26.0 to 33.0 °C measured at Breathing Cave (site 75) on January 9, 1943, seem to be anomalous, and the presence of people in the cave may have affected these values. If this one set of temperature measurements is disregarded, then the published air temperature values from WNS-infected sites range from −15.0 to 17.0 °C (fig. 5). At most of the sites, the available temperature data are individual measurements taken during 1 day or during a few days and are not continuous records of temperature variability. The range of temperature variability at infected sites possibly is more significant than the calculation of mean values and standard deviations. Some preliminary studies by Forsythe and others (2018) have suggested that temperature is likely to have played an important role in the distribution of *P. destructans*.

Published measurements of relative humidity from WNS-infected sites range from 50 to 100 percent (table 1, fig. 6). This observation is consistent with anecdotal evidence suggesting that the fungus prefers high relative humidity (Swezey and Garrity, 2011b). Of the sites reported in this paper, James Selman Cave (Oklahoma) has the lowest recorded relative humidity; and a bat at this site was "equivocal" for the presence of *P. destructans*, but the symptoms of WNS were not detected. Hamilton Cave (West Virginia) and Trout Cave are infected; however, nearby New Trout Cave is not infected. Although these three caves are in the same hillside at the same stratigraphic interval, New Trout Cave is notably dry and dusty whereas Hamilton Cave and Trout Cave are not dry and dusty, suggesting that relative humidity may control the distribution of WNS (Swezey and Brent, 2020). As with the air temperature data, the available relative humidity data are individual measurements taken during 1 day or during a few days and are not continuous records of relative humidity variability. Thus, the range of relative humidity variability at infected sites is more significant than the calculation of mean values and standard deviations.

Results from the data presented in this paper indicate that many individual caves and mines display notable variations in air temperature and relative humidity. One well-documented reason is that caves with more than one entrance are known to have more complex meteorology (Wigley and Brown, 1976). Other possible reasons for such variations are discussed in Swezey and Garrity (2011b) and Perry (2013). This meteorological variability indicates that many caves and mines are not homogenous environments. As stated by Reeder and Moore (2013), caves and mines that are more complex contain a greater range of microclimates (microenvironments), and this environmental variability, although still poorly understood, is likely to affect the progression of WNS as well as cave and mine suitability as hibernacula for different bat species.

Finally, the data presented in this paper provide a few clues for predicting the future spread of WNS. Specifically, the spread of WNS does not seem to be restricted by site elevation or site geology. However, site air temperature or relative humidity, or both, may impose some restrictions to the spread of WNS. Disregarding the one set of anomalously warm temperatures (site 75; January 9, 1943), the temperature data presented in this paper are consistent with previous laboratory experiments, which have shown that *P. destructans* does not grow at temperatures greater than 20 °C (Blehert and others, 2009). Therefore, the spread of WNS could be restricted by a cave or mine temperature threshold of 20 °C. Although published data on cave and mine temperatures are notably sparse, various data compiled by Moore and Sullivan (1978), Rodríguez-Durán (1998), and Swezey and Garrity (2011b) suggest that the 20 °C temperature threshold is likely to be south of most of the continental United States and north of Mexico and Puerto Rico (fig. 1). As of August 30, 2019, WNS had been documented as far south as southern Mississippi and south-central Texas, but not farther south; https://www.whitenosesyndrome.org/static-spread-map (accessed March 17, 2020). Likewise, the recorded relative humidity values at infected sites are not less than 50 percent and, thus, the future spread of WNS conceivably may be restricted by some (as yet undetermined) threshold of low relative humidity.

Summary

The various environmental conditions that are conducive to *P. destructans*, bat hibernacula, and white-nose syndrome (WNS) are poorly understood. As viewed within the context of the “disease triangle,” most previous studies of WNS have focused on the pathogen properties or the host dynamics, or both, whereas the third apex of environmental conditions has received less attention. Furthermore, the few publications that have presented environmental data from WNS-infected sites have been hampered by the lack of a comprehensive and publicly available list of infected sites and the lack of detailed environmental data from these sites. This paper presents a list of 241 WNS-infected sites that were identified in North America before October 2011, a chronology of when these WNS infections were identified, and a description of associated environmental data including site elevation, geology, sediment chemistry and biota, air temperature, and relative humidity. Analysis of these data indicates that most detections of WNS infections occurred during the winter hibernating season for bats, and that the number of WNS infections per winter season had not peaked as of the 2010–11 season. Furthermore, the data presented in this paper suggest that some environmental parameters may affect the distribution of WNS, whereas other environmental parameters may not. Specifically, the distribution of WNS does not seem to be governed by site elevation, bedrock lithology, or strata age. Available data on site sediment chemistry are sparse but the data present a wide range of values, suggesting that caves and mines may contain a great range of microenvironments that are still poorly understood. Most published air temperature values from WNS-infected sites range from −15.0 to 17.0 °C, and the values are consistent with previously published laboratory experiments demonstrating that *P. destructans* does not grow at temperatures greater than 20 °C. If the temperature threshold of 20 °C is a viable constraint on the movement of WNS, then the disease may not spread south into Mexico or to Puerto Rico. Published measurements of relative humidity from WNS-infected sites range from 50 to 100 percent and are consistent with anecdotal evidence suggesting that the fungus prefers high relative humidity. Finally, the data presented in this paper indicate that many WNS-infected caves and mines display notable variations in air temperature and relative humidity, indicating that these sites are not homogenous environments. Although still poorly understood, this environmental variability is likely to affect the progression of WNS as well as cave and mine suitability as hibernacula for different bat species.

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