WISCONSIN GRAY WOLF MONITORING REPORT
15 APRIL 2021 THROUGH 14 APRIL 2022

BUREAU OF WILDLIFE MANAGEMENT

EXECUTIVE SUMMARY

This report describes gray wolf (*Canis lupus*) management and monitoring activities conducted in Wisconsin during the wolf monitoring period of April 15, 2021 to April 14, 2022. Following a federal court ruling on Feb. 10, 2022, gray wolves were relisted as an endangered species in the lower 48 states (excluding the northern Rocky Mountains region). During winter 2021-2022, Wisconsin DNR, federal, tribal, and military biologists, along with numerous volunteer citizen scientists, conducted a total of 16,779 miles of track surveys. A scaled occupancy model (Stauffer et al. 2021) was used to estimate the overwinter abundance of pack-associated wolves in pack-occupied range. Wolf population abundance was estimated at 972 pack wolves with a 95% credible interval of 812 – 1,193 wolves. The number of packs was estimated to be 288 with 95% credible intervals of 243 – 352 packs. Zone-specific pack size estimates ranged from a high of 4.13 (95% C.I. = 3.8 – 4.46) wolves per pack in Zone 1 to a low of 2.70 (95% C.I. = 2.35 – 3.04) wolves per pack in Zone 6. Average wolf pack home range size was estimated at 171.5 km^2 (95% C.I. = 156.3 – 201.2 km^2) or 66.2 mi^2 (95% C.I. = 60.3 – 77.7 mi^2). Further information on wolf monitoring, wolf mortalities, health monitoring, depredation activity, law enforcement, and primary prey is included in this report.

ACKNOWLEDGEMENTS

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Introduction

This report describes gray wolf (*Canis lupus*) management and monitoring activities conducted by Wisconsin DNR in Wisconsin during the wolf monitoring period of April 15, 2021 to April 14, 2022. Following a federal court ruling on Feb. 10, 2022, gray wolves were listed as an endangered species in the lower 48 states (excluding the northern Rocky Mountains region). This report is provided to the U.S. Fish and Wildlife Service and summarizes wolf management in the state.

Wolf Population Monitoring Background

Since 1979, the DNR has monitored the state's wolf population using a territory mapping method which produces a minimum population count. The territory mapping method incorporated ground-based tracking, aerial observations and location data from radio-collared wolves to map pack areas and estimate pack size. Data were then combined to estimate the minimum number of wolves in the state each winter.

Territory mapping was a reliable method for producing a minimum wolf count in Wisconsin for 41 years. As Wisconsin's wolf population increased in distribution and abundance, the amount of effort and resources required to map every pack's territory and determine each pack's size also increased. While territory mapping was feasible and warranted when the population was smaller and scattered during the early years of recovery, the need for a new method of monitoring wolves in Wisconsin became evident.

Recognizing this need, researchers at the DNR and the University of Wisconsin-Madison developed a new population abundance estimate approach based on a scaled occupancy model. This model uses data from systematic winter tracking surveys and collared wolf packs to estimate the total area occupied by packs. The model then combines average pack territory size with the zone-specific average pack size to estimate the abundance of pack-associated wolves in pack-occupied range. Further details on the occupancy model development and approach can be found in Stauffer et al. 2021 (see literature cited).

From 2018-2020, the DNR calculated both the annual minimum count using the territory mapping method and the population abundance estimate using the scaled occupancy model. Each year, the minimum count fell within the occupancy model's population estimate range, reaffirming to DNR researchers that the new model was a reasonable and reliable alternative to territory mapping for Wisconsin's wolf population (Figure 8). The occupancy model offers several significant improvements over the minimum count methodology. For example, the approach does not rely on subjective pack assignments and accounts for the fact that wolves may be present, but undetected, in a sample unit. The final estimate also accounts for the uncertainty in all model parameters, including mean home range size and pack size. After multiple years of research and testing, DNR researchers are confident in this monitoring technique. Since 2021, the DNR has reported the wolf population abundance estimate and associated uncertainty derived from the occupancy model and no longer produces an overwinter minimum count.

Winter Carnivore Snow Tracking Program

Each winter, winter snow track surveys are conducted across much of the state to survey for various carnivore species, including wolves. Data collected from these structured surveys is a central input to the wolf monitoring program and scaled occupancy model.

In addition to surveys conducted by DNR, federal, tribal, and military wildlife biologists, the DNR has incorporated the use of trained citizen scientists to assist in monitoring important wildlife populations, including wolves, since 1995. The annual winter carnivore snow tracking survey was developed to offer interested people the opportunity to become involved in the state's wolf and wildlife monitoring program. To participate, individuals must complete a series of educational courses to become a certified volunteer tracker, and then complete regular recertification courses to ensure volunteers are kept up to date with any survey modifications. Volunteers are assigned one or more tracking blocks and asked to complete a minimum of three surveys over the winter months when conditions allow. Data collected by the volunteer tracking program is crucial to the wolf monitoring program. More information on this program can be found on the DNR website.

During winter 2021-2022, a total of 16,779 miles of track surveys were conducted, averaging 32 miles per survey (Table 1, Figure 4). Of the total 16,779 miles tracked: DNR staff tracked 10,902 miles, USDA staff tracked 1,457 miles, tribal staff tracked 129 miles, and volunteers tracked 4,165 miles (Figure 4). Of the 170 active survey blocks, surveys were received for 168 (98%) (Figure 3). Surveys per block ranged from 0 to 13 (Figure 5).

Public Observations and Reports

Observation reports were collected from the public and agency staff. Public reports are primarily collected via the Large Mammal Observation Report tool available on the DNR website, direct messages to DNR staff, and the Snapshot Wisconsin program. Snapshot Wisconsin is a partnership to monitor wildlife year-round using a statewide network of volunteer-managed trail cameras. More information on Snapshot Wisconsin is available on the DNR website. This data is used to help determine wolf occupied range across the state and direct winter tracking efforts. See addendum for more information.

A total of 1,783 reports of wolf or wolf sign observations were recorded. This includes 125 (7%) Large Mammal Observation Reports and reports emailed directly to DNR staff, and 1,658 (92%) Snapshot Wisconsin submissions.

Additional reports were received but lacked sufficient information on location or circumstances for recording or were confirmed to be species other than wolves. 1,667 (95%) reports were verified as wolves by submitted evidence or field checks. 45 (3%) reports did not have sufficient evidence to definitively determine the species witnessed. Of the 45 indeterminant reports, 37 (82%) were submitted with no photos, and 8 (18%) contained photos or videos that were too poor of quality to determine species. Some of these reports were likely misidentifications. 9 (2%) reports were confirmed as not wolves based on submitted evidence or the description being inconsistent with wolf. Photos or videos were submitted for 6 of these reports. Species found included coyotes or coyote tracks (8), domestic dogs or domestic dog tracks (1) Verified and indeterminate wolf observations are summarized in Table 2 and shown in Figure 1.

Wolf Radio-collaring Efforts

During the 2021-2022 monitoring period, 28 wolves were monitored using GPS transmitted locations (Table 3). Research trapping resulted in telemetry GPS collars being deployed on a total of 14 wolves captured during the monitoring period including 2 adult and 3 yearling females, and 8 adult and 1 yearling males (Table 4).

Model-based Estimates of Wolf Population Abundance

We used a scaled occupancy model (Stauffer et al. 2021) to estimate the abundance of pack associated wolves in pack-occupied range, defined as winter tracking blocks with confirmed pack activity during at least one of the previous four years. The scaled occupancy model has three components:

1. Area occupied by wolves as estimated by the occupancy model using winter track data derived detections and non-detections of wolf tracks within each grid cell.
2. Zone-specific average pack sizes derived from counts of wolves reported during winter tracking surveys.
3. Range-wide average home range size derived from GPS-collared wolves using data from the last two years.

To calculate abundance in pack-occupied range, we divided the area occupied by the range-wide average home range size and multiplied the resulting value by the zone-specific average pack size. The model incorporates uncertainty in all parameter estimates which are included in the variance of the abundance estimate, as represented by the reported credible interval.

Average Pack and Territory Sizes, Total Pack-Occupied Range, and Estimated Wolf Density

Zone-specific average pack sizes were estimated from winter track survey data (see Addendum for detailed methods). Zone-specific pack size estimates ranged from a high of 4.13 (95% C.I. = 3.80 – 4.46) wolves per pack in Zone 1 to a low of 2.70 (95% C.I. = 2.35 – 3.04) wolves per pack in Zone 6 (Table 3). Decreases in average pack size were observed among all zones from last year's pack size estimates which ranged from a high of 4.48 wolves per pack in Zone 1 to a low of 2.79 wolves per pack in Zone 6.

Range-wide average wolf pack home range size was estimated from GPS collar locations from December 1 2020 – February 21 2021 and December 1 2021 – April 12 2022, for 23 and 18 collared wolves, respectively. See addendum for detailed methodology. Average wolf pack home range size was estimated at 171.5 km^2 (95% C.I. = 156.3 – 201.2 km^2) or 66.2 mi^2 (95% C.I. = 60.3 – 77.7 mi^2). This result was similar to the previous year's estimate of 164.3 km^2 (95% C.I. 139.1 km^2 – 189.5 km2) or 63.4 mi2 (95% C.I. 53.7 – 73.2 mi2) Note: while zone-specific estimates of home range size are desirable, they are not currently feasible given insufficient collar sample sizes that would result in highly imprecise estimates. This would propagate considerable uncertainty into the abundance estimates. Therefore, we use the overall mean home rage size, rather than zone-specific values, for the abundance estimate. We are shifting the allocation of collaring effort among zones to improve our ability to produce robust zone-specific home range size estimates in the future.

See Figure 6 for the 2021–2022 map of occupancy probabilities across the pack-occupied range. Note: individual wolves may occur anywhere within the state. Wolf density (# wolves per 100 km^2) across pack-occupied range was then estimated by multiplying occupancy probabilities by zone-specific average pack sizes and scaling by mean pack territory size (Figure 7). Total areas with corresponding occupancy probability across pack-occupied range are included in Table 8.

Estimated Pack-Associated Wolf Abundance and Number of Packs

The posterior mode (the most likely value) for pack-associated wolf population abundance was 972 wolves, and the 95% credible interval was 812 – 1,193 wolves (Figure 9). The number of packs was estimated to be 288 with 95% credible intervals of 243 – 352 packs (Figure 9). This represents a decline in wolf abundance from last year's estimate (1,126 wolves, 95% credible interval of 937 – 1,364 wolves) whereas the estimated number of packs remained nearly unchanged from last year's estimate (292 packs, 95% credible interval of 248 – 352 packs).

In addition to the total pack-occupied range estimate, we produced estimates for each wolf management zone, the Ceded Territory (approximately 22,400 square miles of northern Wisconsin that were ceded to the United States by the Lake Superior Ojibwe Tribes through treaties in 1837 and 1842) versus non-Ceded Territory and defined on-reservation areas versus off-reservation areas (Table 3). Note: The sums of the zone-specific, Ceded Territory, and reservation estimates do not, and are not expected to, equal the total pack-occupied range estimate because each is a summary statistic of a posterior probability distribution. However, we do expect them to be similar, i.e., if we sum the zone-specific posteriors, the resulting distribution should largely overlap with the range-wide posterior as is the case here.

Summer Howl Surveys

Annual summer howl surveys were discontinued in 2020. This decision followed a critical evaluation of current howl survey methodology and a review of data needed for management decisions.

Wolf Mortality

Wolf mortality was monitored through field observation and reporting of all known mortalities. Cause of death for wolves reported dead in the field was determined through field investigation or by necropsy when illegal activity was suspected or where cause of death was not evident during field investigation. A total of 92 wolf mortalities were detected during the monitoring period (Table 5).

Sources of mortality included 15 (16%) wolves killed by vehicle collisions, 65 (71%) wolves killed for depredation control purposes, 9 (10%) wolves killed illegally, and 2 (2%) wolves killed by other wolves. Cause of death could not be determined for 1 wolf (1%). For known-cause mortalities detected, 89 (98%) were human caused and 2 (2%) were due to natural causes (Table 5).

Six radio-collared wolf mortalities were detected during the monitoring period. Two (33%) were killed illegally, 2 (33%) were killed for depredation control, 1 (17%) was killed by vehicle collision, and 1 (17%) died of unknown causes. For an analysis of estimated rates of undetected mortality in Wisconsin wolves see Stenglein et al. 2015.

Disease / Parasite Occurrence in Wolves & Body Condition

General body condition was reported for 14 wolves that were captured during the monitoring period (Table 4). All 14 were reported to be in good, excellent, and fair body condition. Average weight of 8 live-captured adult males was 76.5 lbs. (range 60 to 85 lbs.) and average weight of 2 adult females was 73 lbs. (range 70 to 76 lbs.). Monitoring for mange was conducted by inspection of 14 wolves live-captured for research monitoring (Table 4). Symptoms consistent with mange were noted for 1 of the wolves inspected. Ticks were monitored by inspection of live-captured wolves. Ticks were noted on 9 (64%) captured wolves.

Necropsy reports were received for 1 adult female wolf that was found dead by local law enforcement during the monitoring period. There was suspicion that this animal was illegally trapped and relocated to the roadside. There was an open investigation regarding this animal and the necropsy results were not complete at the time of this report.

Wolf Depredation Management

Wisconsin DNR contracts with the United States Department of Agriculture – Wildlife Services (WS) to investigate wildlife damage complaints, including wolf depredation complaints. During the onsite visit, WS will determine a confirmation status based upon the evidence during their investigation. During the monitoring period, Wildlife Services confirmed wolf depredations in 77 of the 165 wolf complaints investigated (Table 6, Figure 10). Unconfirmed complaints were either confirmed to be due to causes other than wolves or lacked sufficient evidence to attribute a cause.

There were 50 incidents of wolf depredation to livestock and 18 incidents of wolf threat to livestock were confirmed on 43 different farms during the monitoring period (Table 6, Figure 2). This is a decrease in the number of confirmed livestock depredations but an increase in the number of farms affected compared to 2020-2021 (Figure 10). Farms with confirmed incidents in 2021-2022 included 24 farms classified as chronic wolf depredation farms. A chronic farm is a farm with verified wolf depredation in 2 or more years in the past 5 year-period. Livestock depredations included 41 cattle killed and 5 injured, 3 horses killed, and 17 sheep killed. Most wolf depredations on livestock occurred during the months of May, July, August, and September.

There were 22 incidents of non-livestock depredations and 5 incidents of non-livestock threats were confirmed during the monitoring period (Table 6, Figure 2). This included 15 dogs killed and 3 injured while actively engaged in hunting activities, and 5 dogs killed and 1 injured outside of hunting situations (Figure 10).

Wisconsin implements an integrated conflict management program that utilizes both non-lethal as well as lethal control measures to address verified wolf complaints. Non-lethal abatement measures include public education and awareness, a variety of auditory and visual deterrents, and barriers like electric fencing and permanent woven-wire fencing. In addition, many livestock producers will adjust their animal husbandry practices attempting to prevent conflicts. Lethal control measures (available when wolves are not listed as endangered on the federal ESA) include the issuance of lethal removal permits to landowners with conflicts, the removal of wolves by WS at conflict sites, and the authority for owners or occupants of private lands to shoot wolves in the act of killing, wounding, or biting domestic animals. During the monitoring period, 65 wolves were lethally removed through these conflict controls. Of these, 58 (89%) were removed by WS, 4 (6%) were killed by landowners under the authority of a landowner removal permit, and 3 (5%) were killed while in the act of killing, wounding, or biting domestic animals on private land by individuals without a permit (NR. 10.02).

Regulatory Changes Affecting Wolf Management

On February 10, 2022, a federal district court for the District of Northern California vacated the U.S. Fish and Wildlife Service (USFWS) final rule which removed the gray wolf from the Federal List of Threatened and Endangered Species (ESA). As a result, federal ESA protections were restored for wolves in Wisconsin and much of the lower 48 states. Pursuant to s. 29.604(3)(a), Wis. Stats., and s. NR 27.03, Wis. Admin. Code, state ESA protections were also restored for wolves by virtue of their federally listed status.

While no other regulatory changes occurred during the wolf monitoring period which affected wolf management, multiple lawsuits related to wolf management were active during the monitoring period.

On February 2, 2021, a lawsuit was filed by Hunter Nation in the Jefferson County Circuit Court seeking a Writ of Mandamus requiring the DNR to hold a hunt during the Winter 2020-2021 wolf season, and an injunction against any similar alleged violations of state statute requiring a wolf hunt in any future seasons when the wolf is removed from the Endangered Species list during a wolf season. A Writ was issued on February 12, 2021, and a permanent injunction was granted on November 18, 2021.

On August 31, 2021, a lawsuit was filed by a coalition of groups in Dane County Circuit Court seeking to enjoin the fall 2021 Wisconsin wolf season which was set to begin on November 6, 2021. On October 22, 2021, a Dane County Circuit Court judge issued a temporary injunction in the case which ultimately set the fall 2021 Wisconsin wolf season quota at zero and the number of wolf harvest licenses to be issued at zero. This effectively stopped the season from occurring and no wolf harvest licenses were awarded. The temporary injunction was lifted, and the case was voluntarily dismissed on April 26, 2022.

On September 21, 2021, a lawsuit was filed by six Ojibwe tribes in the US. District Court for the Western District of Wisconsin seeking to enjoin the fall 2021 Wisconsin wolf season which was set to begin on November 6, 2021. A hearing on the case occurred on October 29, 2021, and the federal judge did not take further action due to the temporary injunction issued a week earlier in state court. The temporary injunction was lifted, and the case was dismissed without prejudice on April 26, 2022.

Two pieces of federal legislation which would directly affect wolf management in Wisconsin were also active but not enacted during the monitoring period:

- The Managing Predators Act (H.R. 286) was introduced in the 117th Congress on January 12, 2021, referred to subcommittee on February 18, 2021, and remained there through the end of the monitoring period.
- Senate Bill 3738, titled “A bill to direct the Secretary of the Interior to reissue final rules relating to listing the gray wolf in the Western Great Lakes and Wyoming under the Endangered Species Act of 1973”, was introduced in the 117th Congress on March 2, 2022. It was read twice and referred to committee on the same day and remained there through the end of the monitoring period.

Law Enforcement

Law enforcement efforts were conducted statewide throughout the monitoring period. DNR Conservation Wardens throughout the state were on the landscape completing proactive patrol, compliance checks, and complaint response. To achieve a successful enforcement program that promotes voluntary compliance, DNR Conservation Wardens utilize tools including community involvement, education, and enforcement. The nature of a particular enforcement outcome is based on the totality of the circumstances, including the needs for specific and general deterrence. In addition to the summary of law enforcement activity (Table 7), DNR Conservation Wardens were also involved in various wolf management activities and public interactions/contacts without a specific law enforcement component or formal investigation. These efforts are not included in Table 7.

Law enforcement efforts detected 8 wolves killed illegally during the monitoring period. Law enforcement staff conducted 10 wolf related investigations, issued 3 verbal warnings, and issued 2 citations (Table 7). Investigations do not always result in enforcement action by the state of Wisconsin due to a number of potential factors such as a lack of evidence or the investigation being led by another state, federal, or tribal law enforcement agency.

Information on Wolf Prey Species

White-tailed deer are the primary prey species for wolves in Wisconsin. Units used for monitoring Wisconsin deer are counties, or in some cases, partial counties. Because wolf management zones do not follow county boundaries, we report white-tail deer population abundance data by deer management unit and county-specific post-hunt deer density estimates with wolf management zones overlaid (Figures 11 and 12). White-tailed deer population estimates were based on county-specific Sex-Age-Kill model calculations (Wojcik et.al 2021).

Literature Cited

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Table 1. Total miles tracked, average miles tracked per survey, and the number of surveys completed by wolf harvest zone and personnel type during the 2021-2022 winter tracking season.

Wolf Management Unit	Total Miles Tracked	Average Miles per Survey	Number of Surveys Completed
Zone 1	5,689	35	163
Zone 2	3,764	30	128
Zone 3	2,189	38	57
Zone 4	903	26	35
Zone 5	1,219	30	41
Zone 6	3,015	33	92
Volunteer	4,165	29	142
DNR	10,902	33	332
USDA	1,457	47	31
Tribal	129	26	5
Military	126	21	6
Total (Statewide)	16,779	32	516

Table 2. Verified and indeterminate wolf observations reported by natural resource agency personnel and private citizens in Wisconsin through large mammal observation reports, Snapshot Wisconsin, and direct messages, 15 April 2021 to 14 April 2022.

Wolf Harvest Zone	**Total Number of Observation Reports**	**Total Number of Verified Reports**	**Total Number of Probable Reports**	**Reported Number of Wolves Observed**	**Reported Track or Sign Observations**	**Number of Verified Reports via Snapshot Wisconsin**	**Total Verified Wolf Observations**
1	15	10	0	24	2	718	733
2	31	11	1	64	8	165	196
3	2	1	1	2	1	48	50
4	3	0	1	3	3	22	25
5	7	0	1	8	0	448	455
6	67	18	1	101	10	257	324
Statewide	**125**	**42**	**5**	**202**	**24**	**1,658**	**1,783**

Table 3. Wolf abundance and average pack size estimates for the 2021-2022 monitoring period.

Wolf Harvest Zone	Pack-Associated Wolf Abundance Estimate (mode value)	Lower 95% Credible Limit	Upper 95% Credible Limit	Average Pack Size	Lower 95% Credible Limit	Upper 95% Credible Limit	# of Telemetry Monitored Wolves[b]
WHZ 1	**363**	*304*	*450*	**4.13**	*3.80*	*4.46*	9
WHZ 2	**232**	*188*	*288*	**3.31**	*2.98*	*3.63*	4
WHZ 3	**130**	*98*	*168*	**3.22**	*2.63*	*3.79*	6
WHZ 4	**66**	*50*	*88*	**2.77**	*2.26*	*3.27*	2
WHZ 5	**92**	*68*	*121*	**2.85**	*2.25*	*3.43*	6
WHZ 6	**90**	*66*	*124*	**2.70**	*2.35*	*3.04*	1
Statewide	**972**	*812*	*1,193*	-	-	-	28
Ceded Territory	**801**	*668*	*976*	-	-	-	-
Non-Ceded Territory	**179**	*141*	*227*	-	-	-	-
Off-Reservation	**940**	*788*	*1,151*	-	-	-	-
On-Reservation[a]	**37**	*29*	*48*	-	-	-	-

[a] Tribal reservations for this estimate include Bad River, Lac Courte Oreilles, Lac du Flambeau, Menominee, Red Cliff, and Stockbridge-Munsee lands.

[b] Refers to the number of radio-collared wolves monitored during at least part of the monitoring year.

Note: The sums of the zone-specific, Ceded Territory, and reservation estimates do not, and are not expected to equal the pack-occupied range estimate because each is a summary statistic of a posterior probability distribution. However, we do expect them to be similar, i.e., if we sum the zone-specific posteriors, the resulting distribution should largely overlap with the range-wide posterior.

Table 4. Research capture summary, body condition, and detection of ectoparasites in captured wolves and mortalities in Wisconsin from 15 April 2021 to 14 April 2022.

		n	Body Condition Good	Fair	Poor	Age	% w/Mange	% w/Ticks
Zone 1								
Research Captures		3						
Sex	male	2	2	--	--	1 Yearling 1 Adults	0	0
	female	1	1	--	--	1 Yearling	0	0
Zone 2								
Research Captures		1						
Sex	male	1	1	--	--	1 Adult	0	0
	female	--	--	--	--	--		
Zone 3								
Research Captures		5						
Sex	male	4	3	1	--	4 Adults	25	100
	female	1	--	1	--	1 Yearling	0	100
Zone 4								
Research Captures		2						
Sex	male	1	1	--	--	1 Adult	0	100
	female	1	1	--	--	1 Adult	0	100
Zone 5								
Research Captures		2						
Sex	male	--	--	--	--	--	0	0
	female	2	2	--	--	1 Yearling 1 Adult	0	50
Zone 6								
Research Captures		1						
Sex	male	1	1	--	--	1 Adult	0	100
	female	--	--	--	--	--	--	--
STATEWIDE								
Research Captures		14						
Sex	male	9	8	1	--	1 Yearling 8 Adults	11	66
	female	5	4	1	--	3 Yearlings 2 Adults	0	60

Table 5. All detected wolf mortality in Wisconsin 15 April 2021 to 14 April 2022 (inclusive of mortalities detected by DNR law enforcement listed in Table 7).

Cause of Death	Wolf Management Unit						State	% of Total
	1	2	3	4	5	6	Total	
Human Caused Mortality								
Agency Control	52[b]	0	9	0	2	2	65	70.7%
Vehicle Collision	2	4[a]	0	0	5	4	15	16.3%
Illegally Killed	4[a*]	1	2[a]	0	1	1	9	9.8%
Capture Related	0	0	0	0	0	0	0	0.0%
Total Human Caused	58	5	11	0	8	7	89	**96.7%**
Natural Mortality								
Disease / Injury	0	0	0	0	0	0	0	0.0%
Intra-specific Aggression	1	0	1	0	0	0	2	2.2%
Euthanized (non-control)	0	0	0	0	0	0	0	0.0%
Total Natural Causes	1	0	1	0	0	0	2	**2.2%**
Unknown Causes	0	0	0	0	1[a]	0	1	**1.1%**
Total Detected Mortality	**59**	**5**	**13**	**0**	**9**	**7**	**92**	**100.0%**

[a] Includes 1 radio collared wolf
[b] Includes 2 radio collared wolves
*Note: illegally killed radio collared mortalities were animals collared by Red Cliff natural resources staff and investigated by Red Cliff staff.

Table 6. Wolf depredation management in Wisconsin, 15 April 2021 to 14 April 2022.

	Wolf Harvest Zone						State
	1	**2**	**3**	**4**	**5**	**6**	**Total**
Livestock Cases							
Confirmed Depredation Incidents	28	2	6	1	5	8	**50**
Confirmed Threat Incidents	13		3	1		1	**18**
Chronic Farms Affected	18	1	4		1		**24**
Total Farms Affected	24	1	5	2	5	6	**43**
Cattle Killed	27		6	1	4	3	**41**
Cattle Injured	5						**5**
Captive Deer Killed		4					**4**
Captive Deer Injured							**0**
Sheep Killed	1					16	**17**
Sheep Injured							**0**
Goats Killed							**0**
Alpacas Killed							**0**
Alpacas Injured							**0**
Horses Killed	1				1	1	**3**
Horses Injured							**0**
Poultry Killed							**0**
Non-Livestock Cases							
Confirmed Depredation Incidents	17	1	3	0	1	0	**22**
Confirmed Threat Incidents	4	0	0	1	0	0	**5**
Dogs Killed While Actively Engaged in Hunting Activities	12		2		1		**15**
Dogs Injured While Actively Engaged in Hunting Activities	2		1				**3**
Dogs Killed While Not Engaged in Hunting Activities	5						**5**
Dogs Injured While Not Engaged in Hunting Activities		1					**1**

Table 7. Summary of DNR wolf-related law enforcement activity April 15, 2021 to April 14, 2022. The nature of a particular enforcement outcome is based on the totality of the circumstances, including the needs for specific and general deterrence. In addition to this summary of law enforcement activity, DNR Conservation Wardens were also involved in various wolf management activities and public interactions/contacts without a specific law enforcement component or formal investigation.

Wolf related investigations conducted:	10
Verbal warnings issued:	3
Number of wolf related citations issued:	2
Number of illegally killed wolves recovered:	8*

*The total number of illegally killed wolves in Table 7 only includes DNR investigations and does not include any illegally killed wolves investigated by tribal or federal entities.

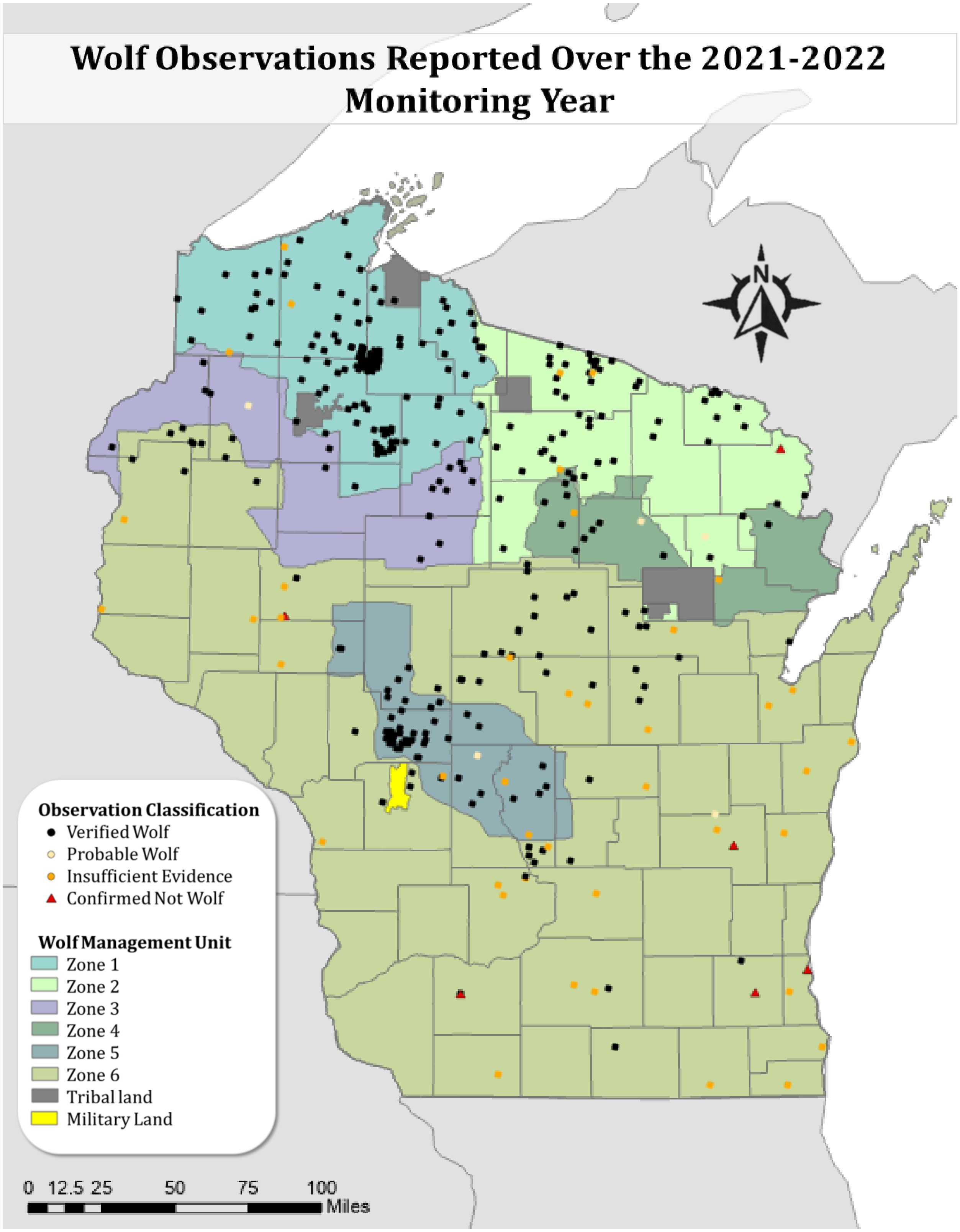

Figure 1. Wolf observation reports submitted through Large Mammal Observation Reports, Snapshot Wisconsin, and direct messages to wildlife staff over the monitoring year, 15 April 2021 to 14 April 2022.

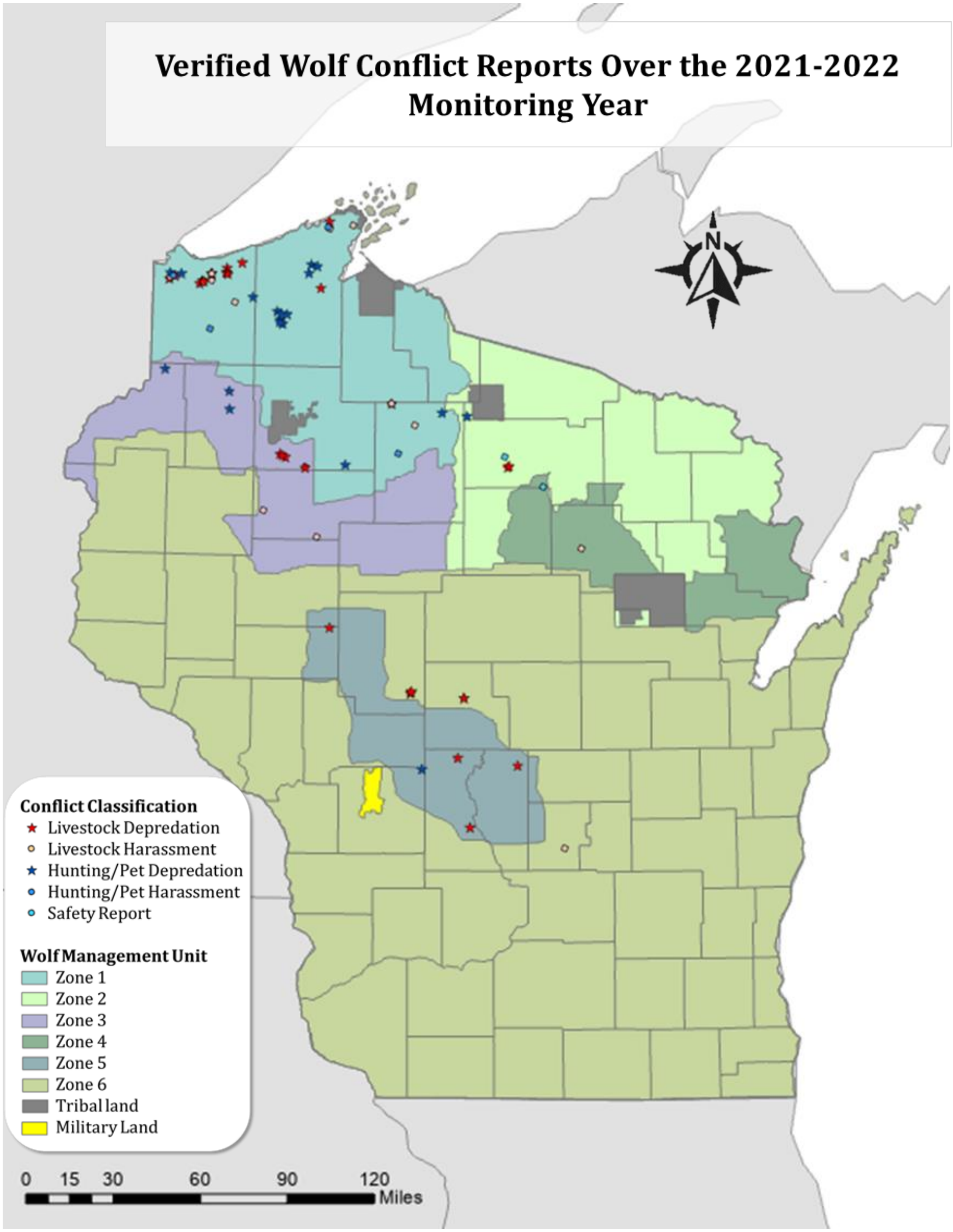

Figure 2. Verified wolf conflicts over the monitoring year, 15 April 2021 to 14 April 2022.

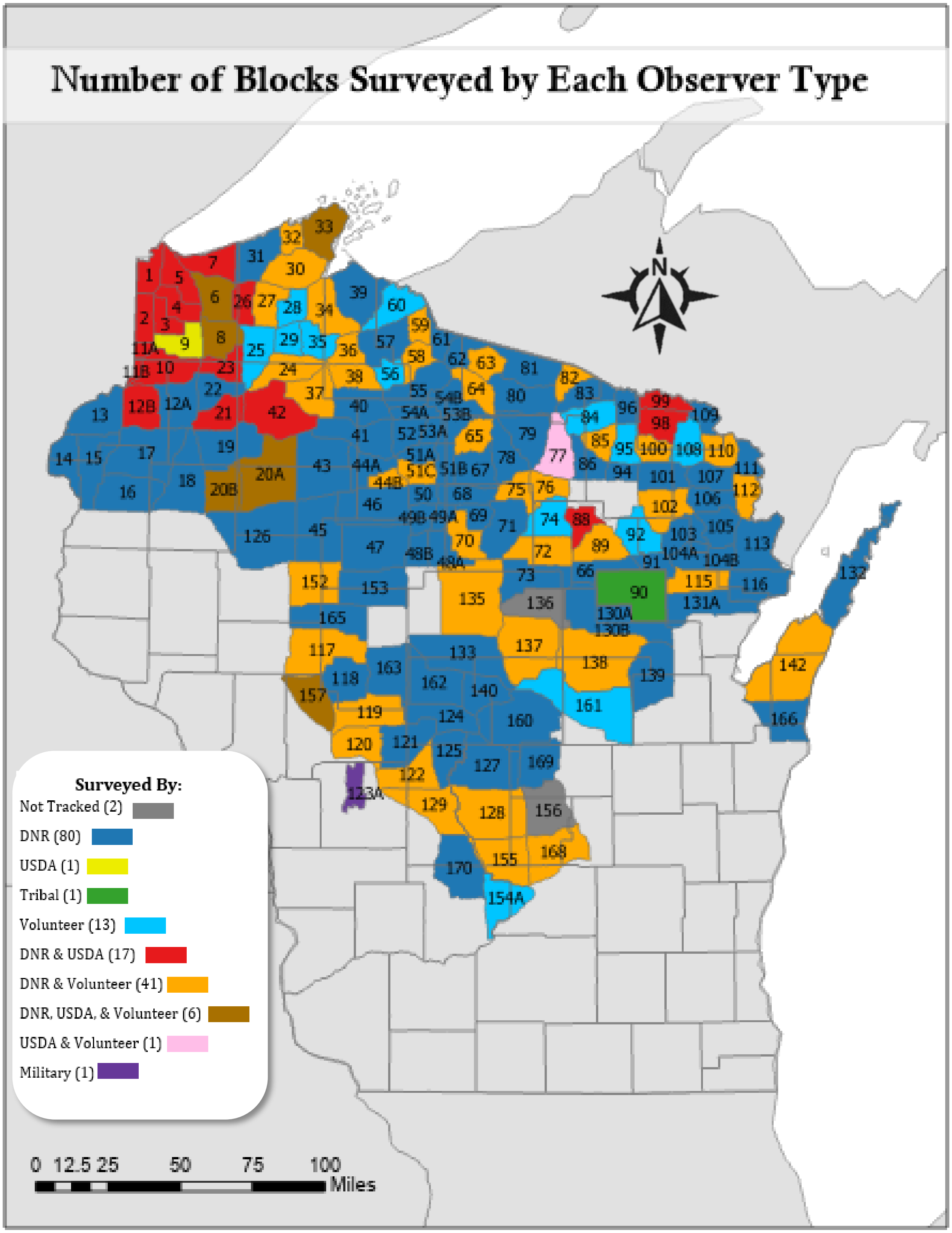

Figure 3. Number of Wisconsin carnivore survey blocks surveyed by each observer type during winter 2021-2022.

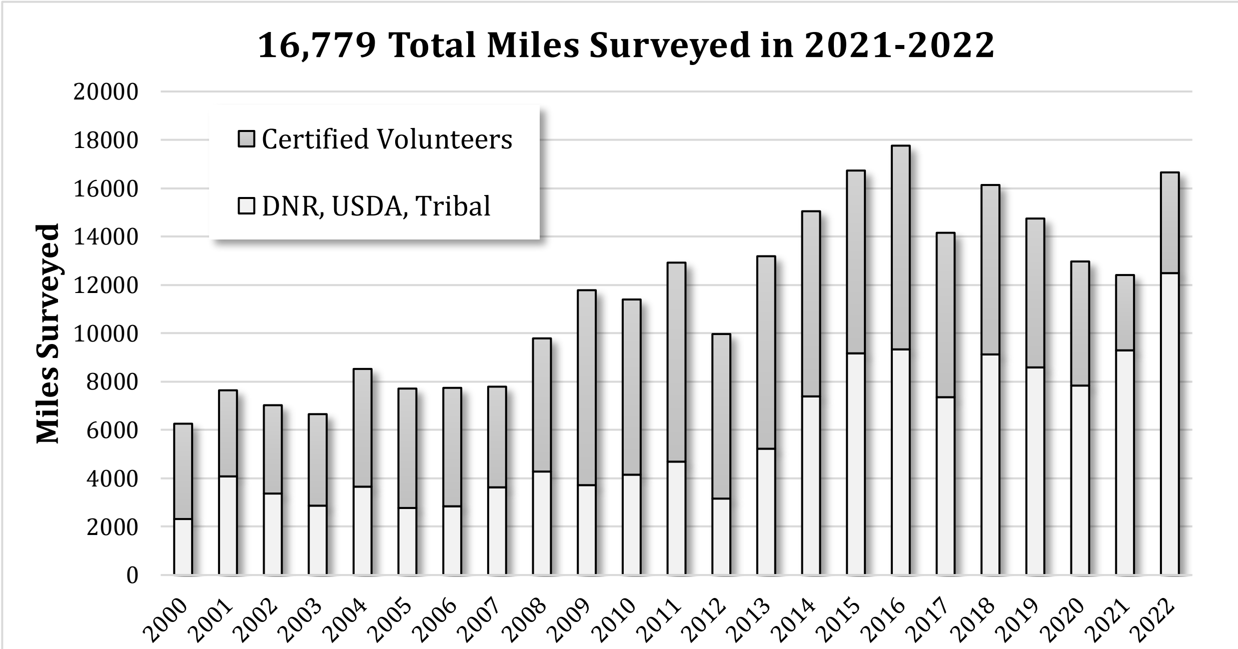

Figure 4. Number of miles surveyed by volunteers and natural resource professionals during the monitoring year 2021-2022.

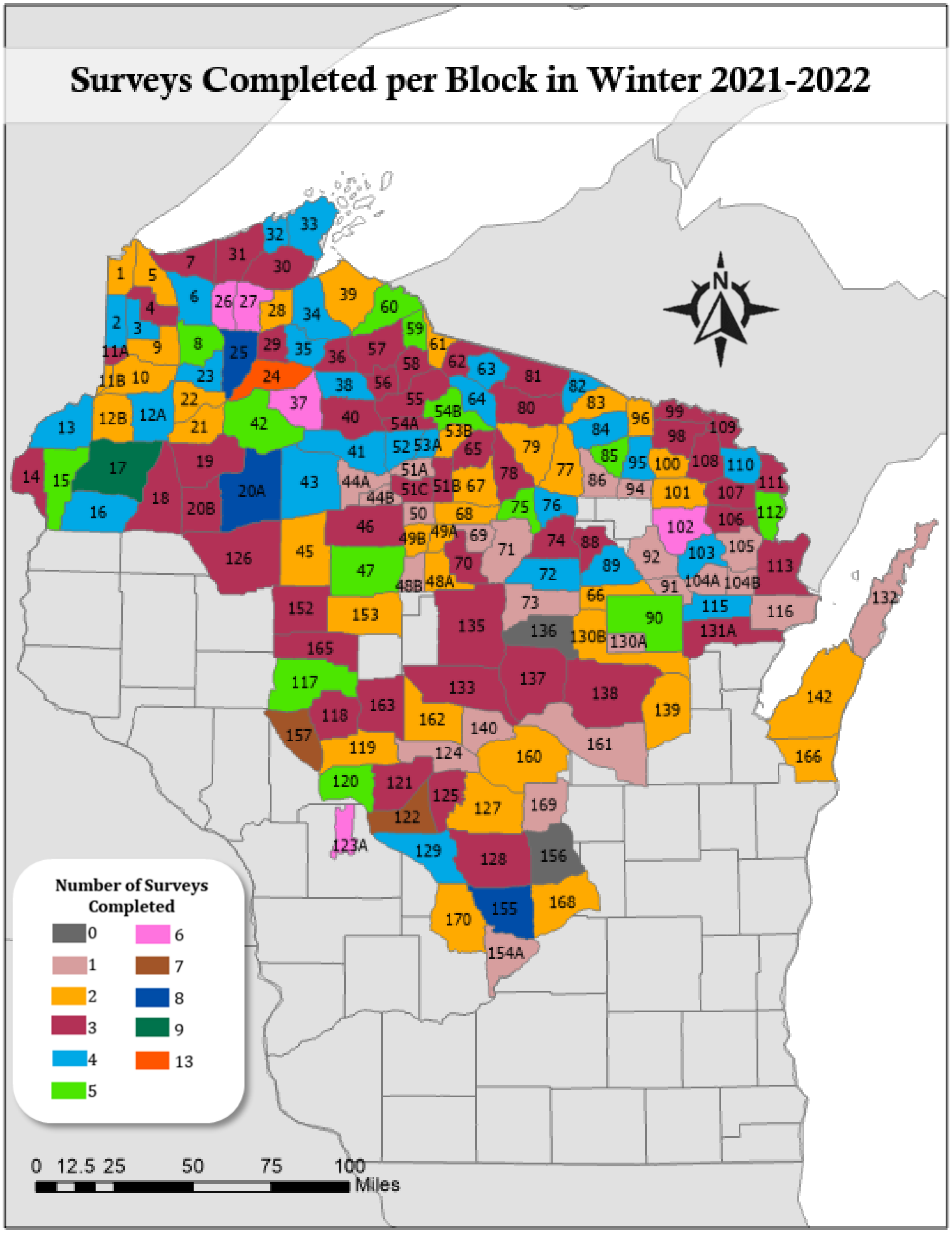

Figure 5. Number of surveys completed per Wisconsin carnivore survey block during winter 2021-2022.

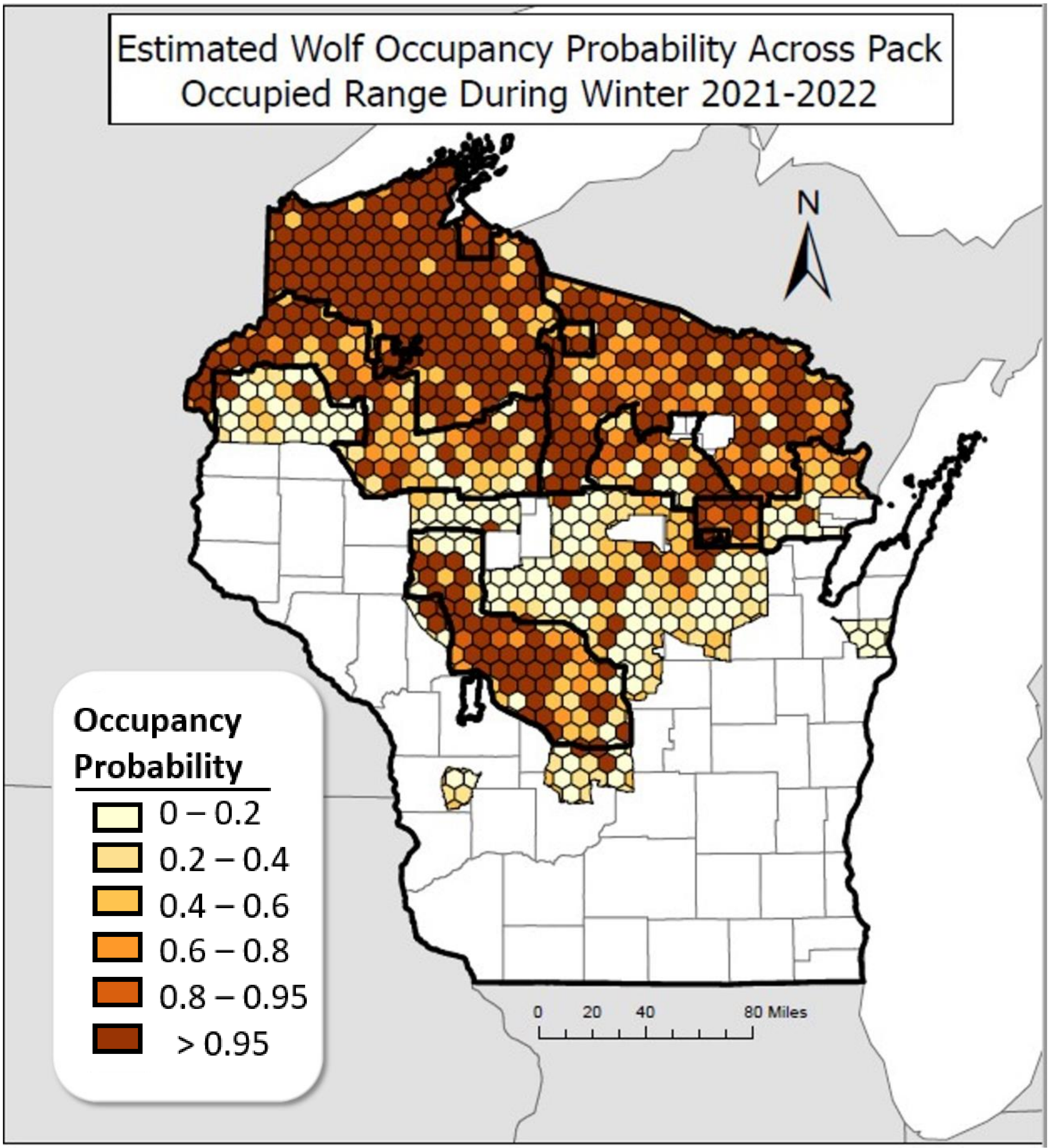

Figure 6. Wolf occupancy probability for pack-occupied range during winter 2021-2022. Note: individual wolves may occur anywhere in the state.

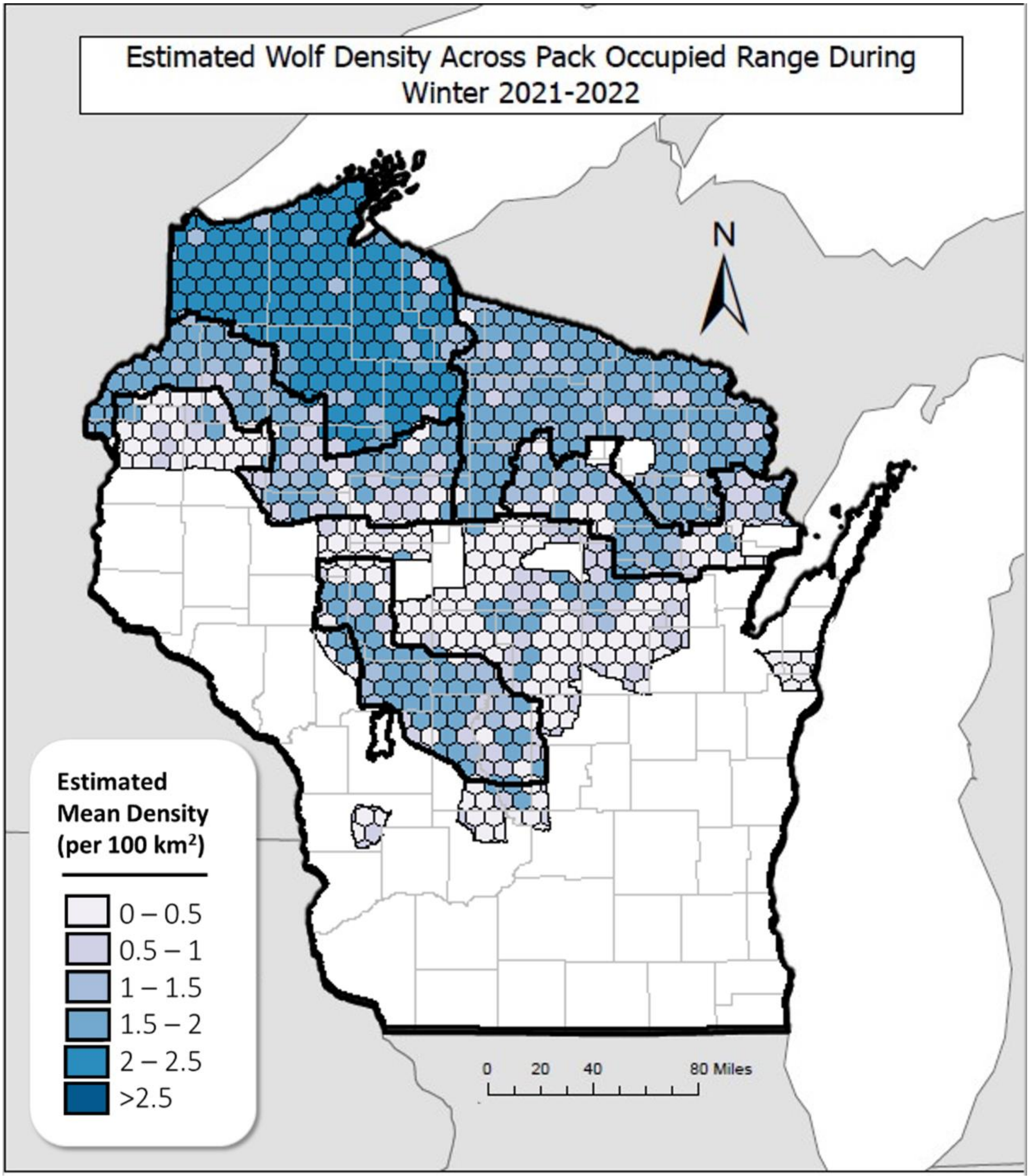

Figure 7. Estimated density of wolves across pack-occupied range during winter 2021-2022. Note: individual wolves may occur anywhere in the state.

Table 8. Total area and corresponding wolf occupancy probability as estimated by the occupancy model across pack-occupied range for the winter 2021-2022. Corresponds to Figure 6.

Wolf Occupancy Probability	Total Area (km^2) as estimated by Occupancy Model	Total Area (mi^2) as estimated by Occupancy Model
0.0 – 0.2	12,984	5,013
0.2 – 0.4	7,498	2,894
0.4 – 0.6	9,356	3,612
0.6 – 0.8	7,950	3,069
0.8 – 0.95	2,040	787
>0.95	34,834	13,449
Total Pack-Occupied Range	74,662 km^2	28,824 mi^2

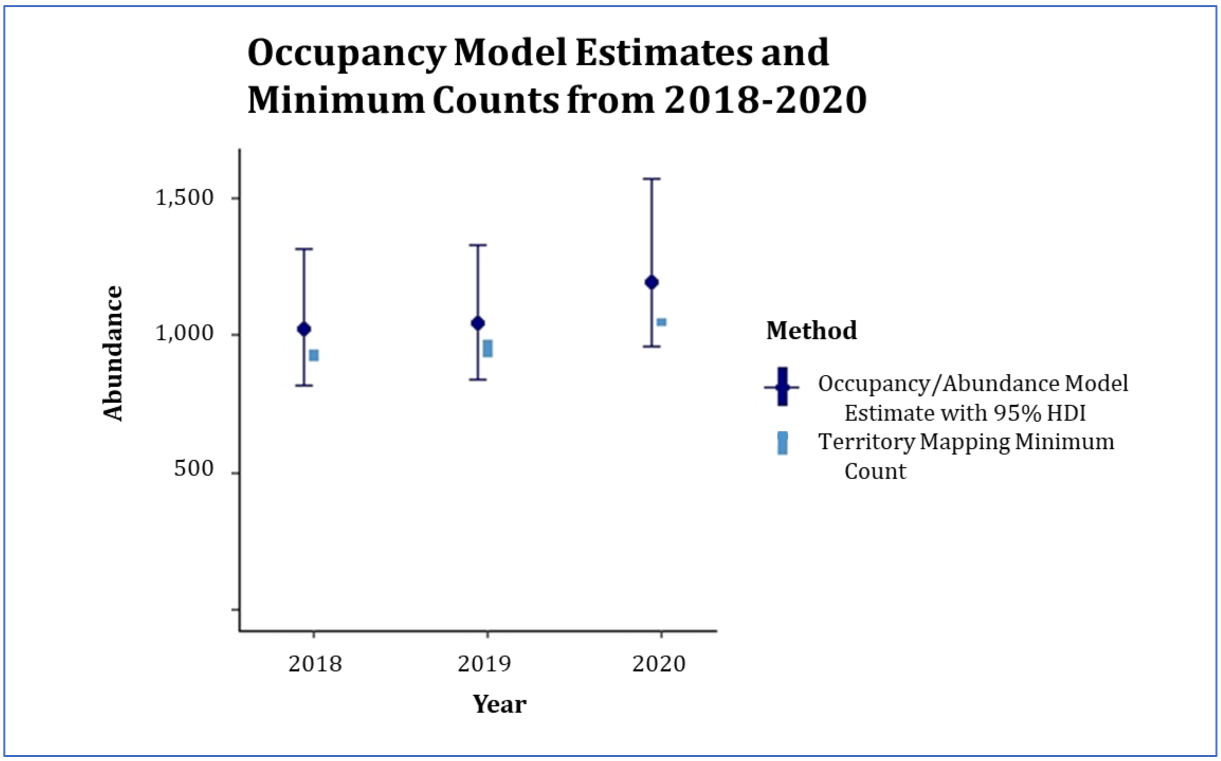

Figure 8. Comparison of occupancy model estimates and overwinter minimum counts 2018-2020.

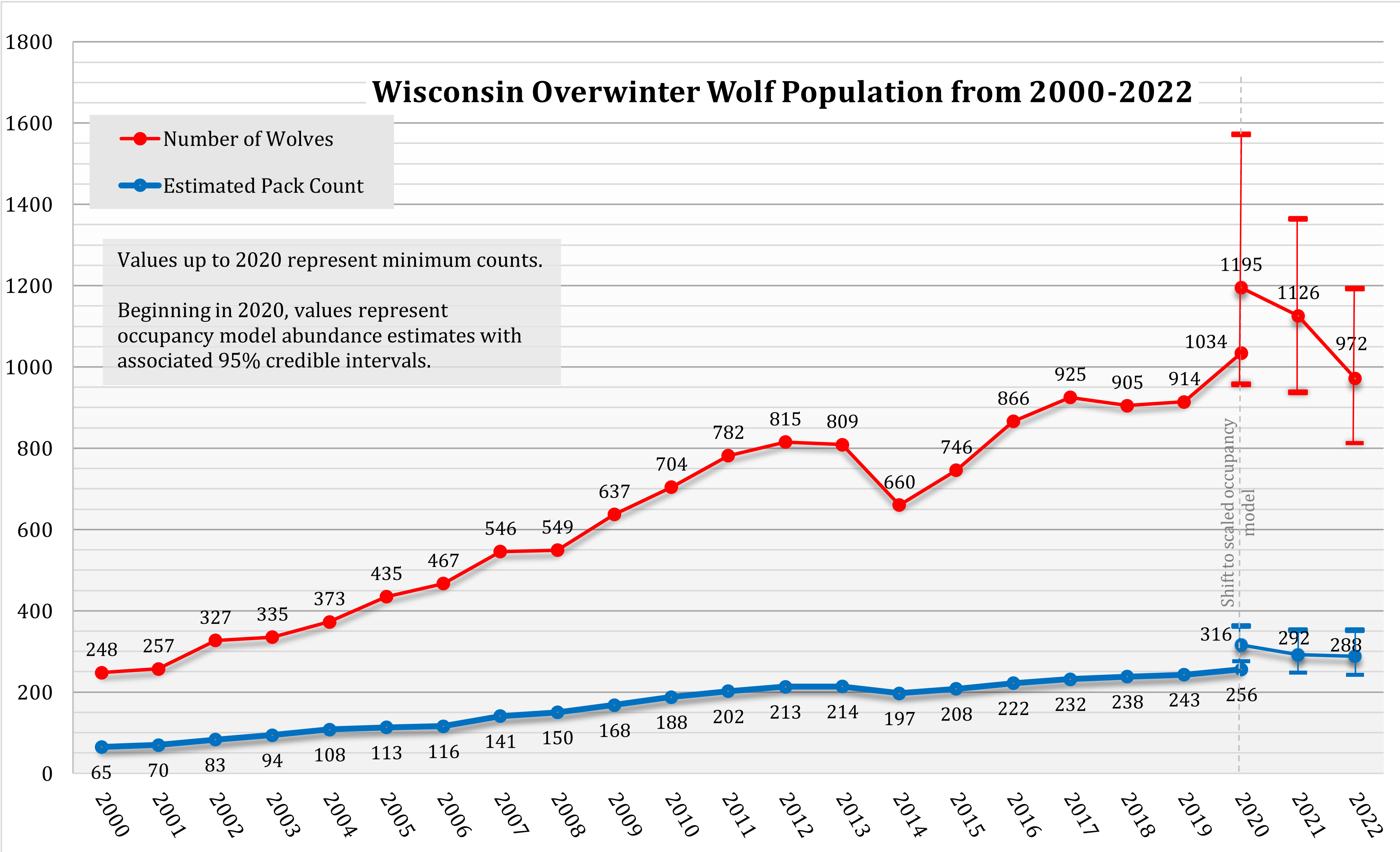

Figure 9. Changes in Wisconsin overwinter gray wolf population 2000-2022.

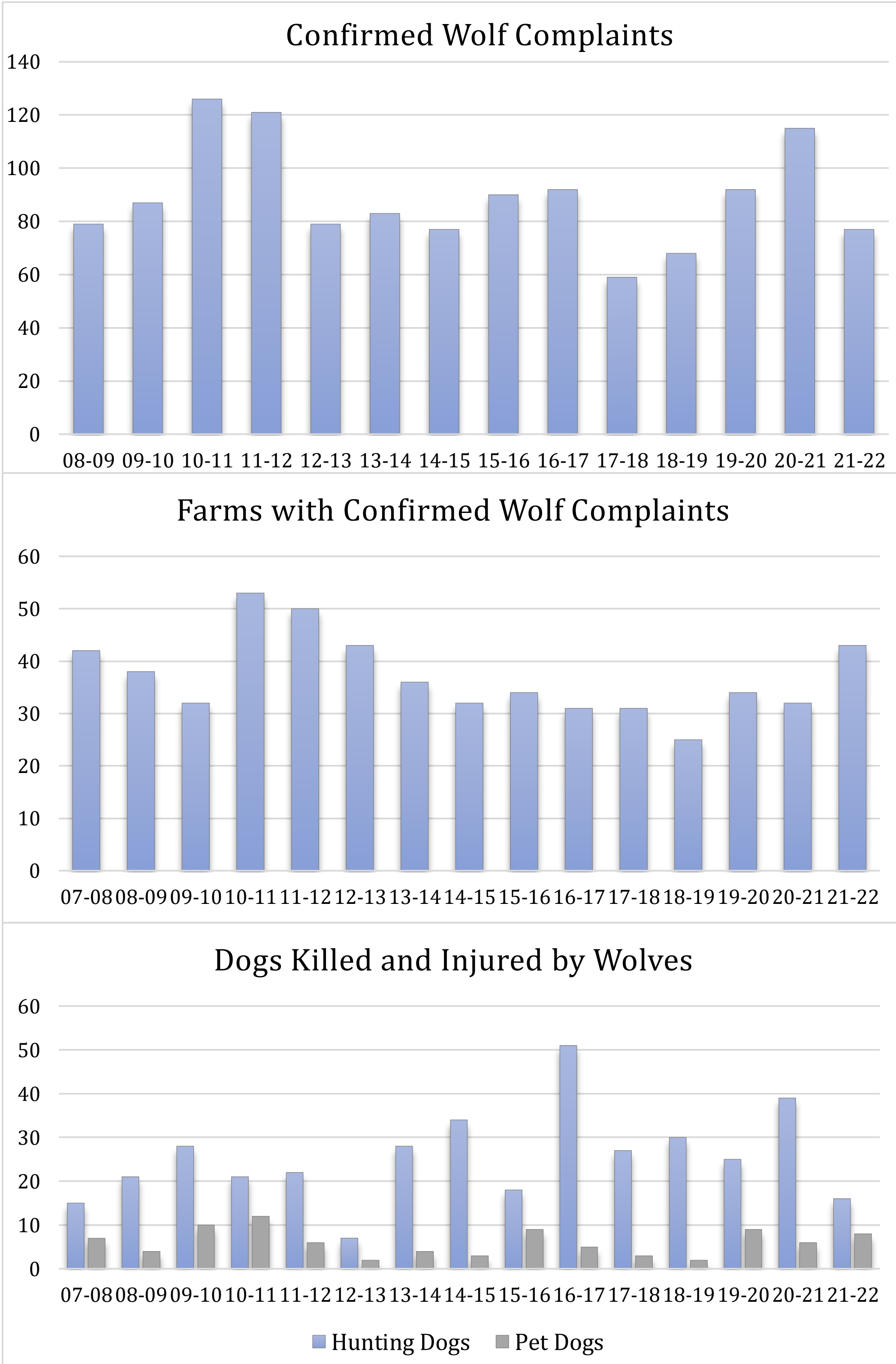

Figure 10. Total confirmed wolf complaints, number of farms with at least one confirmed wolf complaint, and total number of dogs killed and injured by wolves during the 2007-2008 to 2021-2022 wolf monitoring years.

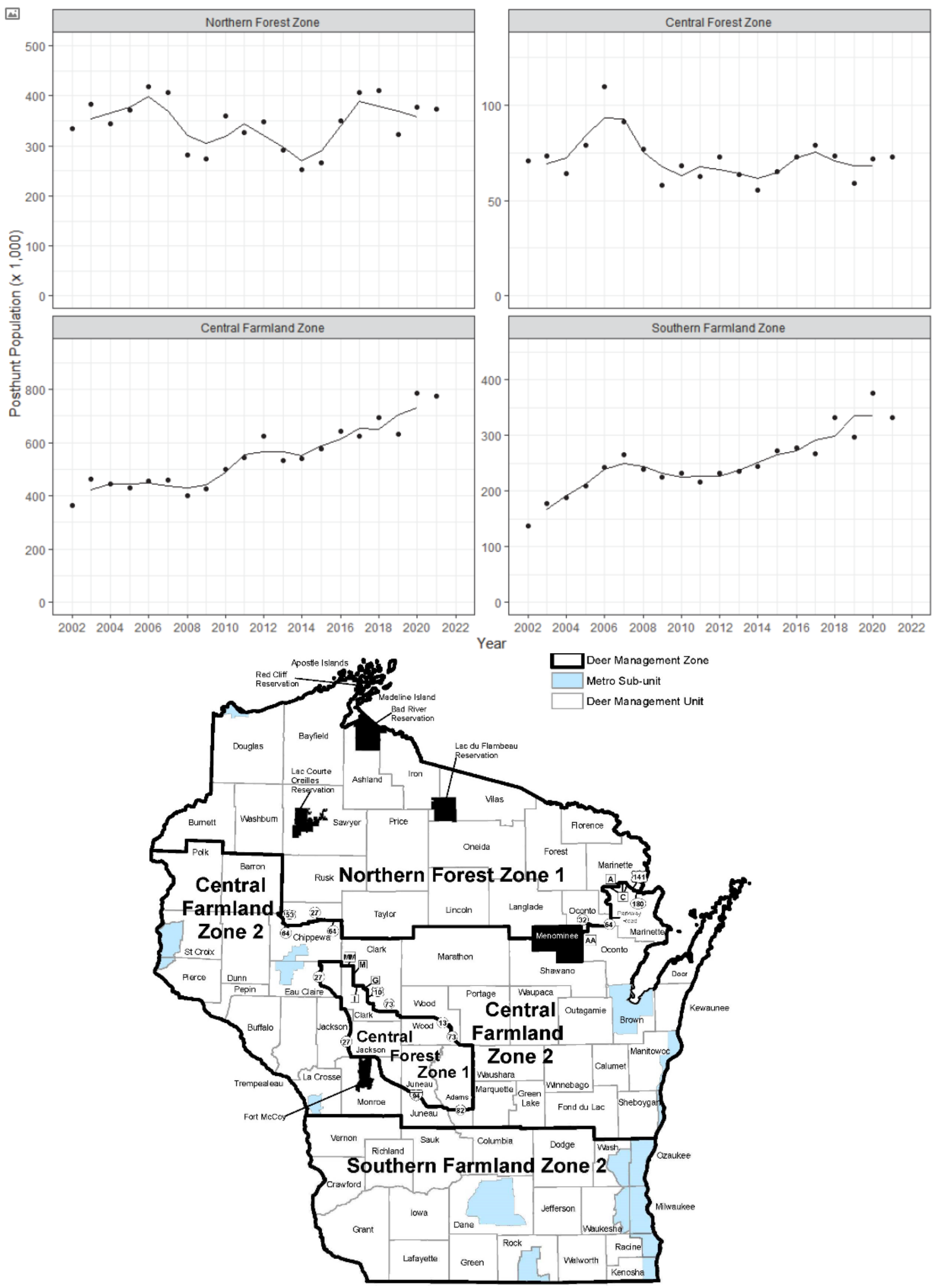

Figure 11. White-tailed deer post-hunt population estimate trends in deer management units (see map for zone boundaries) from 2002 through 2021. Figures from WDNR White-tailed Deer Population Status 2021 report by Beth Wojcik, Sean Lee, Grace Freeman, and Daniel Storm.

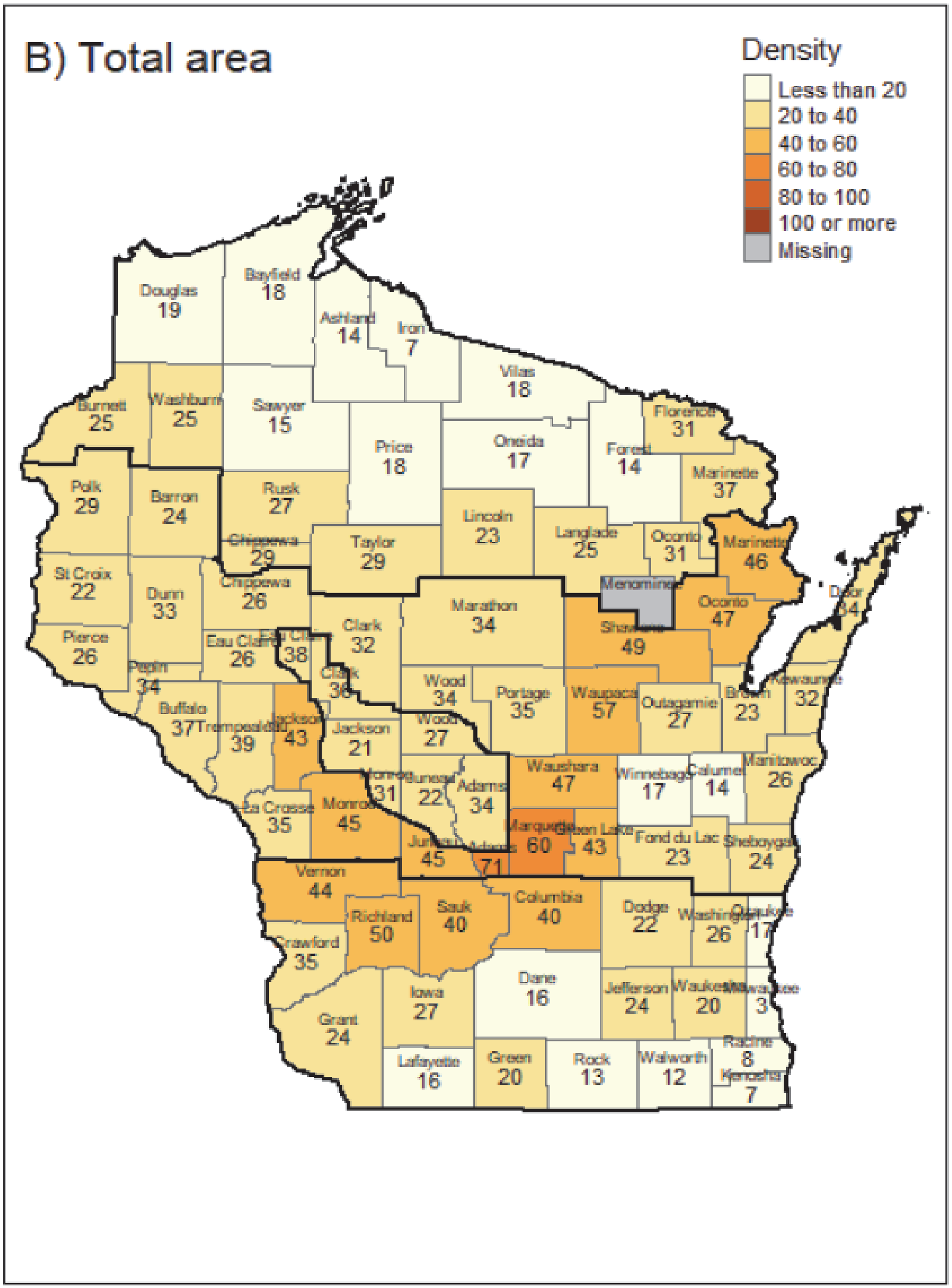

Figure 12: Estimated 2021 mean post-hunt white-tailed deer density estimates for each deer management unit shown as deer per square mile (total area).

Observation data

We used snow tracking data to construct encounter histories to fit to the occupancy model. Observers drove roads during the wintertime, and recorded locations of wolf tracks, and the number of wolf tracks that were observed. Survey routes were recorded either from GPS track-lines or were digitized post hoc from a combination of traced maps and verbal descriptions of surveys. Survey effort was allocated based on survey blocks conveniently delineated by roads and natural features such as rivers. Analysis sample units were 100 hexagonal cells placed over the union of all tracking blocks in the wolf core range (or domain of inference - see below), which was the optimal size identified by a simulation analysis (Stauffer et al. 2021). We accounted for survey effort using the length of geo-referenced tracking routes surveyed in each grid cell. Repeat surveys in tracking blocks usually were ≥ 7 days apart. Therefore, we defined survey occasions as 7-day periods over the duration of the tracking season. The first survey was conducted on 23 November 2021 and the final survey on 01 April 2022, resulting in 19 survey occasions. In total, survey effort was more than 27,000 km, compared to 19,900 km the previous year (because of the Feb 2021 hunt, only 14,000 km of pre-hunt survey effort were considered in the model). For each occasion, we collapsed all detection data within cells to detection/non-detection data, and if multiple surveys were conducted in a cell within one 7-day period, we also likewise collapsed those data.

Defining core wolf range

The scaled occupancy approach is intended to provide an abundance estimate for pack- associated wolves, and consequently it is important to delineate the domain of inference (or core range) to which the estimate applies, and to avoid predicting wolf occupancy into areas where there may be transient wolf presence but no evidence of pack activity. DNR uses data from previous tracking seasons and other confirmed reports of pack activity to define core wolf range. The 2021–2022 core range is shown in Figure 3, and this area represents the area of inference for the population estimate produced from the 2021–2022 tracking data. While there may be additional wolves outside the core range, and evidence of such wolves may influence management recommendations from the wolf advisory committees, those wolves are not included in the core range model estimate.

The core range is defined based on data prior to the current tracking season, and further adjustments are implemented in the following year. For example, if a wolf pack is observed outside of the core range during the 2021–2022 tracking season, then that tracking block will be added to the core range for the 2022–2023 tracking season. The total area of the core range in 2022 was 74,663 km^2, comprising 156 tracking blocks (there were additional surveys in one block outside the core area), as compared to 73,797 km^2 in 2021, comprising 154 tracking blocks.

The criteria for inclusion in core wolf range based on tracking data during the previous 4 seasons. Four years was identified as the number of years which allowed the core range to respond to possible expansions and contractions of wolf range, while minimizing inclusion or exclusion based on transient wolf movements or imperfect detection of wolves in pack- occupied areas. The criteria for inclusion are as follows (with any criteria being met resulting in inclusion):

- Tracks from at least two wolves were observed within a block during a single tracking event
- Single wolf tracks were observed in a grid during separate surveys within a tracking season

Beyond track observations, only confirmed evidence of pack activity in a block will trigger its addition to the core wolf range. Requiring evidence of pack activity reduces the potential for positive bias that may result from adding blocks based on observations of lone wolves whose occupancy within a grid cell is often transitory. Evidence of pack activity is defined as any of the following:

- Confirmed depredation events that included multiple wolves
- A photo with multiple wolves
- Multiple photos of single wolves reported within a block and year

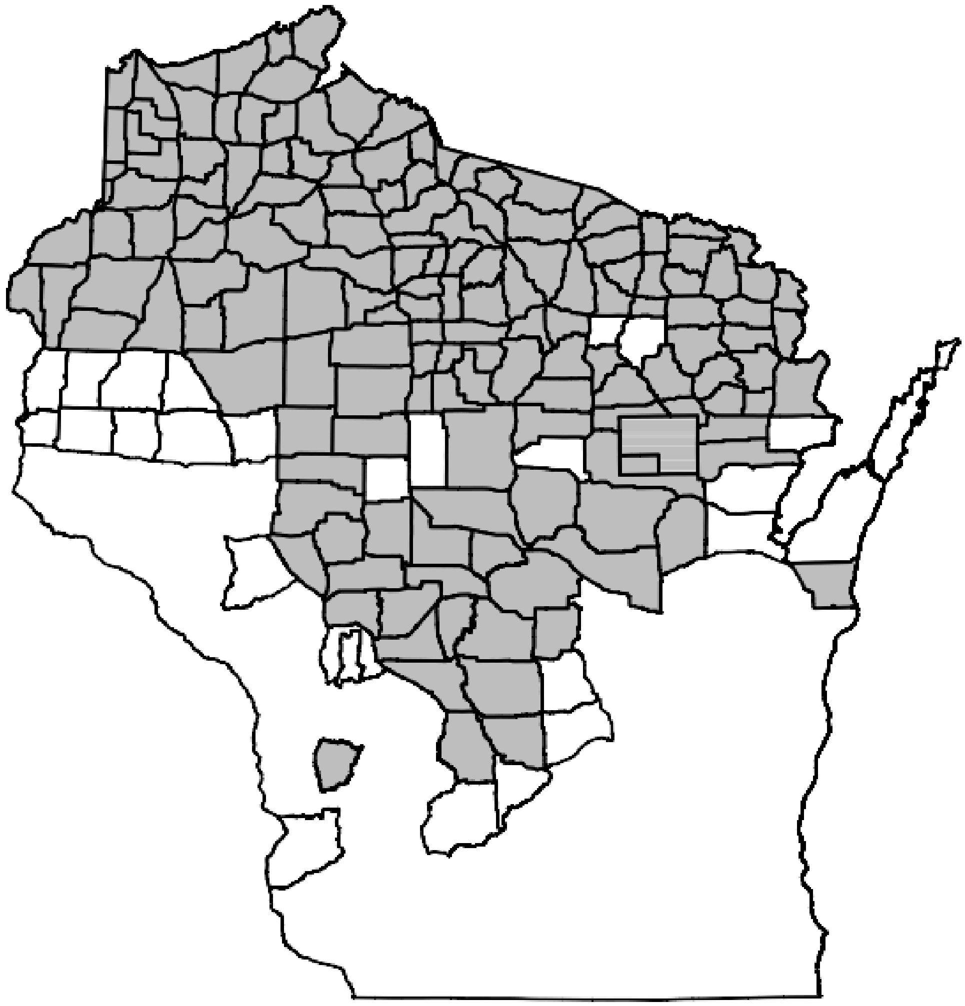

Figure 13. Core wolf range for winter 2021–2022, with tracking blocks included (gray) and excluded (white).

The occupancy model

We used a Bayesian modeling approach which provides flexibility for developing models, facilitates easy propagation forward into the posterior distribution of all the uncertainty contained in the various model inputs, and produces a posterior estimate for straight-forward interpretation. We fitted our data to the model, using the tools found in the R package NIMBLE. The model had the following structure:

$$z_i \sim Bernoulli(\psi_i)$$
$$logit(\psi_i) = b_0 + b_1 \times forest_i + b_2 \times ag_i + b_3 \times road\_density_i$$
$$y_{it} \sim Bernoulli(z_i p_{it})$$
$$logit(p_{it}) = \beta_0 + log(effort_{it})$$

where ψ_i is as described above; ag_i and $forest_i$ are the proportion of agriculture and developed land, and forest cover, respectively, in sample grid i, as calculated from the 2016 NLCD data; and $road\_density$ is the density of primary, secondary, and forest roads in sample grid i, in km/km^2. All covariates for ψ were scaled and centered to facilitate better model convergence. In the detection model, p_{it} is the probability that any wolf tracks are detected in grid cell i during survey t, and $effort_{it}$ is the number of kilometers traversed in grid cell i during survey t.

Mean pack size

We calculated zone-specific pack size using the following approach:

1. Divide the area into hexagonal grids, as described above, but of a size matching mean home-range size (171 km^2).
2. Eliminate any observation where tracks indicate only a single wolf.
3. Eliminate any cells where tracks (or tracks of size > 1) were not observed.
4. For the remaining cells, determine the largest enumerated set of tracks in each cell.
5. Calculate statistics.

We used this method to calculate zone-specific mean pack sizes using the 2021–2022 tracking data.

Mean home range size

Mean home range size was estimated from GPS locations from 01 Dec 2020 — 21 Feb 2021 and 01 December 2021 -– 15 April 2022 for 23 and 18 collared wolves, respectively. Our goal was to estimate the size of the area reasonably appropriated by each pack, rather than to strictly estimate the actual area used by each pack. Maximum convex polygons (MCPs) often underestimate home range size and are very sensitive to the inclusion or exclusion of potential outliers. Kernel density estimators (KDEs), on the other hand, can result in fragmented or convoluted home ranges, depending on the choice of a smoothing parameter h. Consequently, we used the following combination approach. We used the kernelUD function from the R package adehabitatHR to calculate kernel density estimates for each pack. For each pack we:

1. Calculated a standard reference smoothing parameter $href = \sigma \times n^{-1/6}$, where $\sigma = 0.5(\sigma_x + \sigma_y)$ was the mean of the standard deviations of the x and y coordinates of the n GPS locations. This is the default h used by the kernelUD function.
2. Iteratively estimated the utilization distribution (UD) and computed the 95% KDE for a range of values $h = href\ p$, where p was incremented by 0.1 from 0.4 to 2.5.
3. Identified the first value of p that resulted in a 95% KDE polygon that was contiguous (this can be done automatically in an R script without visually inspecting the KDE polygon). In many cases, the home range at this point still had an inadvisably irregular shape.
4. Increased p by 0.2, and calculated the area of the resulting 95% KDE home range.
5. Compared the calculated area with the area of the corresponding MCP, and

considered max(95%KDE, MCP) to be the appropriate area co-opted by the pack. We considered that, if area(MCP) > area(95% KDE), then selecting the MCP was justified on the grounds that the MCP was likely including an area of the landscape excluded by a concave portion of the KDE home range, but probably also largely excluded from use by adjacent packs.

6. Individually examined exceptional cases where the KDE or MCP was implausibly large (> 400 km^2, or about 2.5X the previous year's mean HR size). For very large, over- smoothed KDEs, we instead used the smaller MCP as more reasonable representations of home ranges.

Using the above approach, we estimated a mean pack home range size of 171.45 km^2 ($SE = 15.17$). While zone-specific estimates of home range size are desirable, it is not currently feasible given insufficient samples sizes that would result in highly imprecise estimates, which would propagate considerable extra uncertainty into the abundance estimates. Therefore, we use the overall mean, rather than zone-specific values, for the abundance estimate. However, collaring effort is allocated among zones to produce home range estimates that are broadly representative of the core range.

Scaled occupancy estimate

Abundance was estimated as □=Σ□□□□□□□□/□, where □□ was the probability of occupancy in sample unit *i*, □□ was the area of sample unit *i*, □ is the mean two-year home range size, and □*i* is the cell-specific (zone-specific) mean pack size. The uncertainty captured in each of the intermediate estimates is propagated into the abundance estimates, resulting in a posterior distribution which we report as a posterior model (most likely value) and 95% credible intervals.