WISCONSIN GRAY WOLF MONITORING REPORT
15 APRIL 2020 THROUGH 14 APRIL 2021

EXECUTIVE SUMMARY

This report describes gray wolf (*Canis lupus)* management and monitoring activities conducted in Wisconsin during the wolf monitoring year of April 15, 2020 to April 14, 2021. On January 4, 2021, gray wolves were removed from the federal list of endangered species, returning management authority to the lower 48 states and tribes. During winter 2020-21, WDNR personnel, volunteers, and tribes conducted a total of 12,408 miles of track surveys. A scaled occupancy model (Stauffer et al. 2021) was used to estimate the abundance of wolves in pack-occupied range. Wolf population abundance was estimated at 1,126 wolves with a 95% credible interval of 937 – 1,364 wolves. Zone-specific pack size estimates 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. Average wolf pack home range size was estimated at 164.3 km^2 (95% C.I. 139.1 km^2 – 189.5 km^2) or 63.4 mi^2 (95% C.I. 53.7 – 73.2 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 in Wisconsin during the wolf monitoring year of April 15, 2020 to April 14, 2021. On January 4, 2021, gray wolves were removed from the federal list of endangered species, returning management authority to the lower 48 states and tribes. This report is provided to the U.S. Fish and Wildlife Service as part of the state's post-delisting monitoring requirements.

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. However, 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 state's wolf population. Further details on the occupancy model development and approach can be found in Stauffer et al. 2021 (see literature cited).

For the past three years (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, giving DNR researchers greater confidence 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 transitioning to this new monitoring technique. Moving forward, the DNR will report the wolf population abundance estimate and associated uncertainty derived from the occupancy model. The DNR will no longer produce an overwinter minimum count.

Winter Carnivore Snow Tracking Program

Each winter, DNR staff conduct winter snow track surveys 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, tribal and federal 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 2020-21, WDNR and USDA personnel, volunteers, and tribes conducted a total of 12,408 miles of track surveys, averaging 33 miles per survey (Table 1, Figure 4). Of the total 12,408 miles tracked: DNR staff tracked 8,031 miles, USDA staff tracked 1,134 miles, Tribal staff tracked 129 miles, and Volunteers tracked 3,114 miles (Figure 4). Of the 164 active survey blocks, surveys were received for 145 (88%) (Figure 3). Surveys per block ranged from 0 to 11 (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 1,811 reports of wolf or wolf sign observations were recorded. This includes 174 (10%) Large Mammal Observation Reports and reports emailed directly to DNR staff, and 1,637 (90%) 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. 1,707 (94%) reports were verified as wolves by submitted evidence or field checks. 89 (5%) reports did not have sufficient evidence to definitively determine the species witnessed. Of the 89 indeterminant reports, 67 (4%) were submitted with no photos, and 22 (1%) contained photos or videos that were too poor of quality to determine species. Some of these reports were likely misidentifications. 15 (9%) 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 (10), domestic dogs or domestic dog tracks (4) Verified and indeterminate wolf observations are summarized in Table 2 and shown in Figure 1.

Wolf Radio-collaring Efforts

During the 2020-21 monitoring period, 43 wolves were monitored using GPS transmitted locations (Table 3). Research trapping resulted in telemetry GPS collars being deployed on a total of 18 wolves captured during the monitoring period including 4 adult and 2 yearling females, and 11 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 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 multiply that 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.

This year's population abundance estimate is defined as a pre-hunt abundance estimate as only tracking data collected between December 1, 2020 – February 21, 2021 was used to inform the models (the Feb. 2021 harvest season began February 22, 2021).

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 4.48 wolves per pack in Zone 1 to a low of 2.79 wolves per pack in Zone 6 (Table 3).

Range-wide average wolf pack home range size was estimated from GPS collar locations from 01 December 2019 – 15 April 2020 and 01 December 2020 – 21 February 2021, for 40 and 23 collared wolves, respectively. See addendum for detailed methodology. Average wolf pack home range size was estimated at 164.3 km^2 (95% C.I. 139.1 km^2 – 189.5 km^2); or 63.4 mi^2 (95% C.I. 53.7 – 73.2 mi^2). Note: while zone-specific estimates of home range size are desirable, it is not currently feasible given insufficient collar sample sizes that would result in highly imprecise estimates, which 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.

Estimated Abundance

The posterior mode (the most likely value) for wolf population abundance was 1,126 wolves, and the 95% credible interval was 937 – 1,364 wolves (Figure 9). The number of packs was estimated to be 292 with 95% credible intervals of 248 – 352 (Figure 9) In addition to the total pack-occupied range estimate, we produced estimates for each zone, ceded vs. non-ceded territory, and on-reservation vs. off-reservation (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.

See Figure 6 for the 2020–21 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.

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, mandatory harvest registration, and mandatory reporting of control 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 263 wolf mortalities were detected during the monitoring period (Table 5).

A total of 218 wolves were harvested by state license holders during the February 2021 regulated wolf season. Of the 218 wolves harvested, hunting accounted for 208 wolves (95% of total take) while trapping accounted for 10 wolves (5% of total take). Of the 208 wolves taken by hunters, 188 (86%) were taken with the aid of trailing hounds, 16 (7%) were taken with the aid of predator calls and 4 (2%) were taken by stand/still hunting. Of the 10 taken by trappers, 7 (3%) were taken with foothold traps and 3 (2%) were taken with cable restraints. Total harvest consisted of 102 females (47%) and 116 males (53%). Age class of harvested wolves was estimated by visual inspection of tooth wear and eruption of the cementum enamel juncture of an upper canine tooth (Gipson et al. 2000; K. Laudon, pers. comm.). Estimated age of harvested wolves consisted of 20 young of the year (9%), 110 subadults (51%) and 85 adults (39%). Age data was not collected on three wolves (1%). Wolf harvest was distributed across the 6 harvest zones (Table 5). See the February 2021 Wolf Season Report, available on the DNR webpage, for more information on the February 2021 wolf season.

Other mortality included 22 (8%) wolves killed by vehicle collisions, 10 (4%) wolves killed for control purposes, and 8 (3%) wolves killed illegally. Cause of death could not be determined for 4 wolves (1.5%). For 261 known cause mortalities detected, 260 (99%) were human caused and 1 (1%) was due to natural causes (Table 5).

16 collared wolf mortalities were detected during the monitoring period, of which 14 (87.5%) were being actively monitored at the time of death (Table 5). 8 collared wolves were harvested legally during the February 2021 wolf season. Cause of death could not be definitively determined for 1 actively monitored collared wolf. For the 7 where cause of death could be determined, 4 (25%) were illegally killed, 2 (12.5%) were killed by vehicle collision, and 1 (6%) died from unknown natural 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 18 wolves that were captured during the monitoring period (Table 4). All 18 were reported to be in good, very good, or excellent body condition. Average weight of 11 live-captured adult males was 82 lbs. (range 60 to 100 lbs.), and average weight of 4 adult females was 66 lbs. (range 60 to 70 lbs.). Monitoring for mange was conducted by inspection of 18 wolves live-captured for research monitoring, and inspection of 39 wolf mortalities (Table 4). Symptoms consistent with mange were not noted for any of the wolves inspected. Ticks were monitored by inspection of live-captured wolves. Ticks were noted on 13 (72%) captured wolves.

Necropsy reports were received for 3 wolves that died in Central Wisconsin during the monitoring period. A 33kg male was found dead on the side of the road. The nutritional body condition was determined to be fair 4/9 with 5/9 being ideal. Trauma from vehicle collision was determined as the cause of death. The remaining two wolves reported were found together in a cranberry marsh in October 2020. One was a collared male and the other was an uncollared female. Heartworm was detected in both necropsied wolves, though neither died as a result of the infestation. The female had two old gunshot wounds to the chest and shoulder, but they were not considered to be the cause of death. Being found in such close proximity to each other with no evidence of drowning, no recent outward trauma to the bodies, and blood being found in nose and mouth of both wolves, a toxin was suspected to be the cause of death and was later confirmed in the male to be pentobarbital, the females results were still pending at the writing 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 monitoring period, Wildlife Services confirmed 115 wolf complaints of the 155 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.

58 incidents of wolf depredation to livestock and 14 incidents of wolf threat to livestock were confirmed on 35 different farms during the monitoring period (Table 6, Figure 2). This is an increase in the number of confirmed livestock depredations and the number of farms affected compared to 2019-2020 (Figure 10). Farms with confirmed incidents in 2020-2021 included 17 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 28 cattle killed and 2 injured, 3 horses killed and 7 injured, 14 sheep killed, 1 goat killed, and 40 laying hens killed. Most wolf depredations on livestock occur during the months of May, July, August, and September.

37 incidents of non-livestock depredation and 6 incidents of non-livestock threats were confirmed during the monitoring period (Table 6, Figure 2). This included 14 dogs killed and 12 injured while actively engaged in hunting activities, and 4 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 to prevent conflicts. Lethal control measures 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, 6 wolves were lethally removed through these conflict controls.

Regulatory Changes Affecting Wolf Management

Following an approximately 18-month evaluation, the U.S. Fish & Wildlife Service published a rule in the Federal Register on November 3, 2020 which removed the gray wolf from the federal list of endangered species across the lower 48 states. The rule took effect on January 4, 2021, returning management authority of gray wolves to the lower 48 states and tribes.

Ahead of the delisting on January 4, 2021, the Wisconsin DNR announced in December 2020 that a wolf harvest season would begin in November 2021. On February 11, 2021, a state circuit court judge ordered the Wisconsin DNR to schedule a wolf harvest season in February 2021. The Wisconsin Department of Justice filed an appeal and requested a stay, which was denied on February 19, 2021. The DNR complied with the circuit court order to implement a wolf harvest season in February 2021.

Law Enforcement

Law enforcement efforts were conducted statewide and throughout the monitoring period. To achieve a successful enforcement program that promotes voluntary compliance, DNR Conservation Wardens appropriately utilize 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. During the February 2021 wolf season, DNR Conservation Wardens throughout the state were on the landscape completing proactive patrol, compliance checks, and complaint response. The nature of encountered enforcement events remained generally consistent with hunting seasons for other species, as well as prior wolf seasons in 2012, 2013, and 2014.

Law enforcement efforts detected a total of six wolves killed illegally, seven vehicle-killed wolves, and three wolves with unknown cause of death during the monitoring period. Law enforcement staff conducted 115 wolf related investigations and issued 19 citations (Table 7).

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 and Stenglein 2020).

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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 2020-2021 winter tracking season.

Wolf Harvest Zone	Total Miles Tracked	Average Miles per Survey	Number of Surveys Completed
Zone 1	4,143	33	124
Zone 2	3,292	32	104
Zone 3	1,714	44	39
Zone 4	486	27	18
Zone 5	681	31	22
Zone 6	2,092	31	38
Volunteer	3,114	25	125
DNR	8,031	35	228
USDA	1,134	66	18
Tribal	129	32	4
Total (Statewide)	**12,408**	**33**	**375**

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 2020 to 14 April 2021.

Wolf Harvest Zone	Total Number of Observation Reports	Total Number of Verified Reports	Reported Number of Wolves Observed	Reported Track or Sign Observations	Number of Verified Reports via Snapshot Wisconsin	Total Verified Wolf Observations
1	27	17	45	2	682	699
2	49	20	37	0	205	226
3	14	5	10	0	128	133
4	7	5	12	3	38	43
5	14	9	22	0	520	529
6	63	14	34	1	63	77
Statewide	**174**	**70**	**158**	**6**	**1,637**	**1,707**

Table 3. Wolf abundance estimates for the 2020-21 monitoring period. These estimates are considered pre-harvest and were calculated prior to the February 2021 harvest season. See page 4 of this report for more information.

Wolf Harvest Zone	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	**401**	*334*	*483*	**4.48**	*4.09*	*4.87*	21
WHZ 2	**288**	*227*	*369*	**4.11**	*3.47*	*4.75*	9
WHZ 3	**173**	*129*	*224*	**4.04**	*3.35*	*4.73*	7
WHZ 4	**70**	*49*	*98*	**3.00**	*2.12*	*3.88*	0
WHZ 5	**94**	*66*	*127*	**3.30**	*2.58*	*4.02*	5
WHZ 6	**101**	*62*	*150*	**2.79**	*1.96*	*3.62*	1
Statewide	**1,126**	*937*	*1,364*	-	-	-	43
Ceded Territory	**952**	*797*	*1,151*	-	-	-	-
Non-ceded Territory	**181**	*138*	*233*	-	-	-	-
Off-Reservation	**1,091**	*910*	*1,321*	-	-	-	-
On-Reservation	**41**	*32*	*52*	-	-	-	-

[a] Tribal reservations include Bad River, Lac Courtes 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 2020 to 14 April 2021.

		n	Body Condition Good	Fair	Poor	Age	% w/Mange	% w/Ticks
Zone 1								
Research Captures		10						
Sex	male	70%	7	--	--	1 Yearling 6 Adults	0%	71%
	female	30%	3	--	--	3 Adults	0%	67%
Zone 2								
Research Captures		1						
Sex	male	--	--	--	--			
	female	100%	1	--	--	1 Yearling	0%	100%
Zone 3								
Research Captures		4						
Sex	male	50%	2	--	--	2 Adults	0%	100%
	female	50%	2	--	--	1 Yearling 1 Adults	0%	100%
Zone 4								
Research Captures		0						
Sex	male	--	--	--	--	--	--	--
	female	--	--	--	--	--	--	--
Zone 5								
Research Captures		3						
Sex	male	100%	3	--	--	3 Adults	0%	33%
	female	--	--	--	--	--	--	--
Zone 6								
Research Captures		0						
Sex	male	--	--	--	--	--	--	--
	female	--	--	--	--	--	--	--
STATEWIDE								
Research Captures		18						
Sex	male	67%	100%	--	--	1 Yearling 11 Adults	0%	67%
	female	33%	100%	--	--	2 Yearlings 4 Adults	0%	83%

Table 5. All detected wolf mortality in Wisconsin 15 April 2020 to 14 April 2021 (inclusive of mortalities detected by 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	6		3		1		10	3.8%
Legally Harvested	53[b]	43[b]	42[b]	4	31	45[b]	218	82.8%
Vehicle Collision	3[b]	6	1		3	9	22	8.3%
Illegally Killed	4[c]		1		1[a]	2	8	3.0%
Capture Related							0	0.0%
Unknown Human Caused					2 [a]		2	0.7%
Total Human Caused	66	49	47	4	38	56	260	**98.6%**
Natural Mortality								
Disease / Injury					1[a]		1	0.4%
Intra-specific Aggression							0	
Euthanized (non-control)							0	
Total Natural Causes	0	0	0	0	1	0	1	**0.4%**
Unknown Causes	0	1	0	0	0	1	2	**0.7%**
Total Detected Mortality	**66**	**50**	**47**	**4**	**39**	**57**	**263**	**100.0%**

[a]Includes 1 radio collared wolf
[b]Includes 2 radio collared wolves
[c]Includes 3 radio collared wolves
[d]Includes 4 radio collared wolves
16 radio-collared wolf mortalities, 14 being monitored at time of death

Table 6. Wolf depredation management in Wisconsin, 15 April 2020 to 14 April 2021.

	Wolf Harvest Zone						State
	1	**2**	**3**	**4**	**5**	**6**	**Total**
Livestock Cases							
Confirmed Depredation Incidents	39	2	8		6	3	**58**
Confirmed Threat Incidents	7	1	3		3		**14**
Chronic Farms Affected	12		4		1		**17**
Total Farms Affected	15	3	8		7	2	**35**
Cattle Killed	15	2	2		8	1	**28**
Cattle Injured	1	1					**2**
Deer Killed							**0**
Deer Injured							**0**
Sheep Killed	2					12	**14**
Sheep Injured							**0**
Goats Killed			1				**1**
Alpacas Killed							**0**
Alpacas Injured							**0**
Horses Killed	3						**3**
Horses Injured	6					1	**7**
Poultry Killed	40						**40**
Non-Livestock Cases							
Confirmed Depredation Incidents	16	9	6	3	2	1	**37**
Confirmed Threat Incidents	3	0	1	2	0	0	**6**
Dogs Killed While Actively Engaged in Hunting Activities	7	4	1		1	1	**14**
Dogs Injured While Actively Engaged in Hunting Activities	7	3			2		**12**
Dogs Killed While Not Engaged in Hunting Activities	2	1			1		**4**
Dogs Injured While Not Engaged in Hunting Activities				1			**1**

Table 7. Summary of wolf-related law enforcement activity 15 April 2020 to 14 April 2021.

Wolf hunting related complaints received:	90
Wolf trapping related complaints received:	15
Wolf related investigations conducted:	115
Verbal warnings issued:	21
Number of wolf related citations issued:	19
Number of illegally killed wolves recovered:	6
Number of vehicle-killed wolves recovered:	7
Number of unknown cause of death wolves recovered:	3

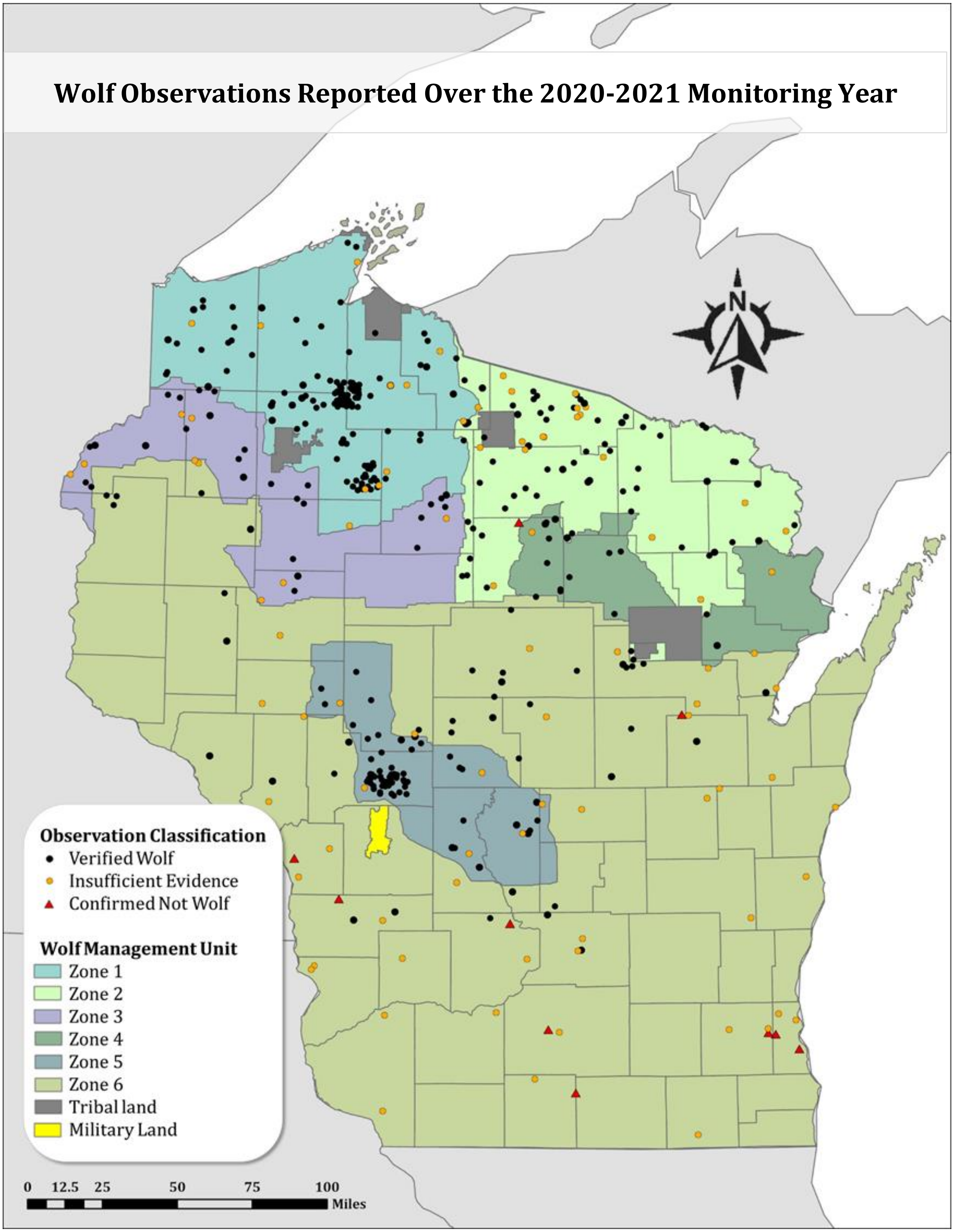


Figure 1. Wolf observation reports submitted through Large Mammal Observation Reports, Snapshot Wisconsin, and direct messages to wildlife staff over the monitoring year, 15 April 2020 to 14 April 2021.

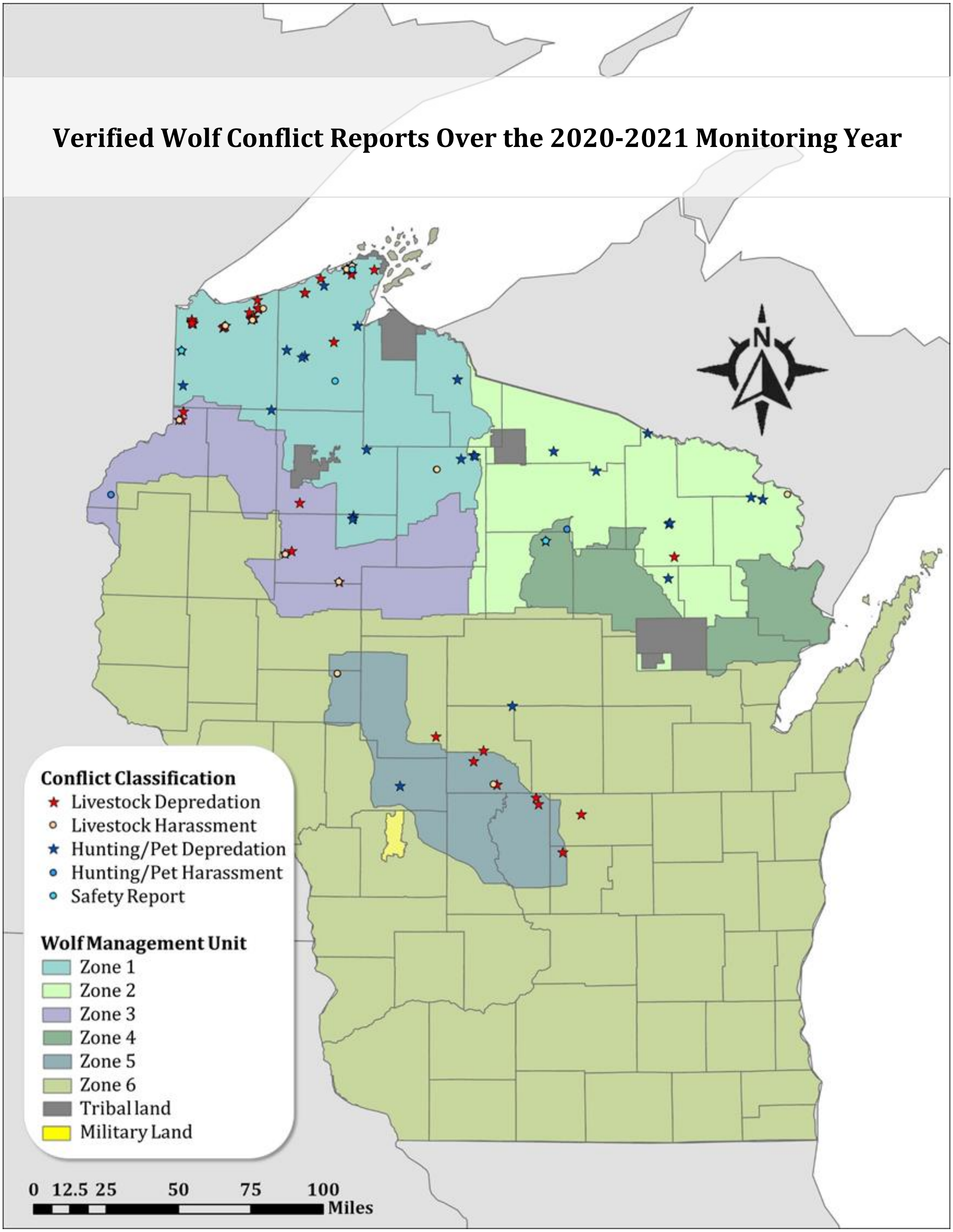


Figure 2. Verified wolf conflicts over the monitoring year, 15 April 2020 to 14 April 2021.

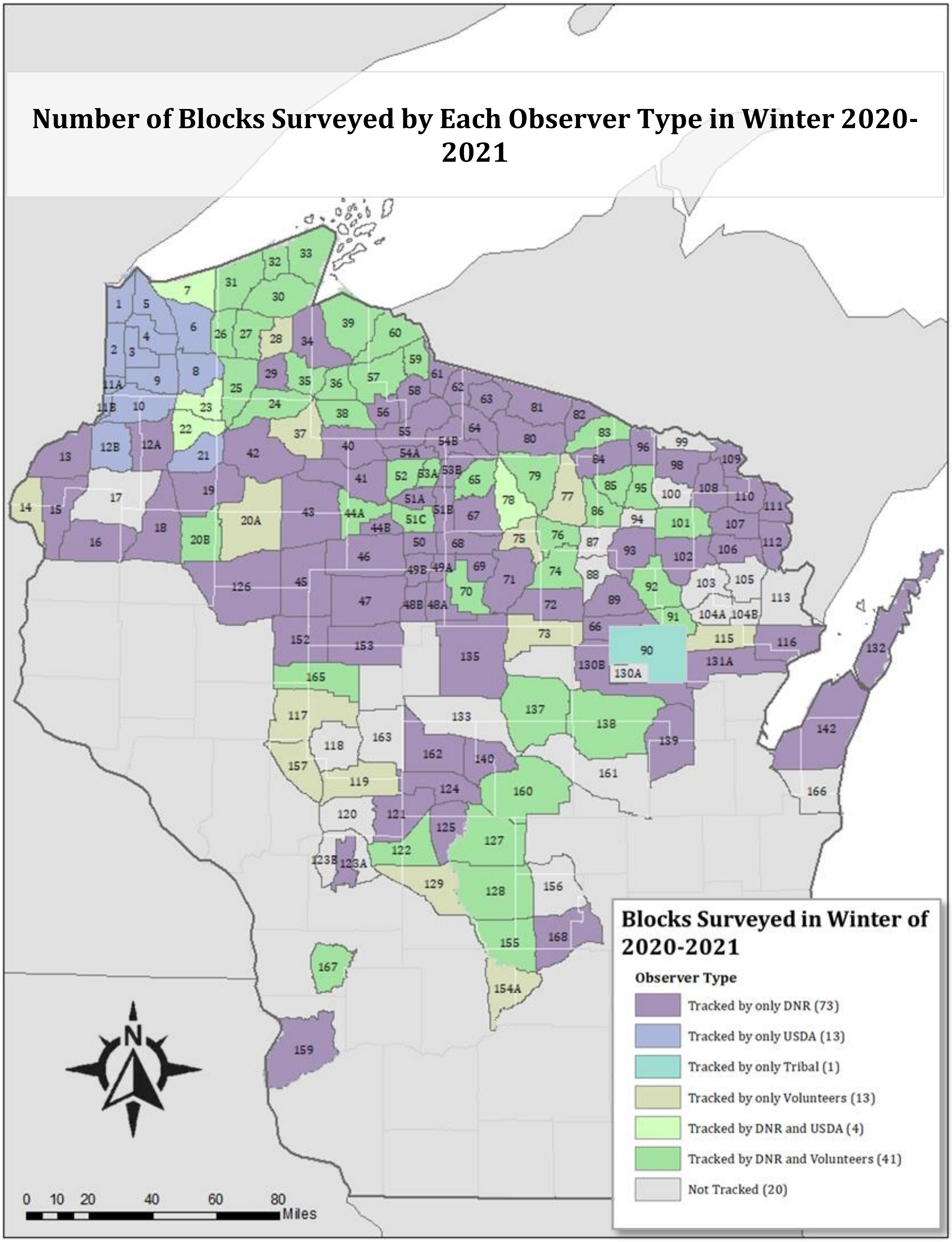


Figure 3. Number of Wisconsin carnivore survey blocks surveyed by each observer type during winter 2020-2021.

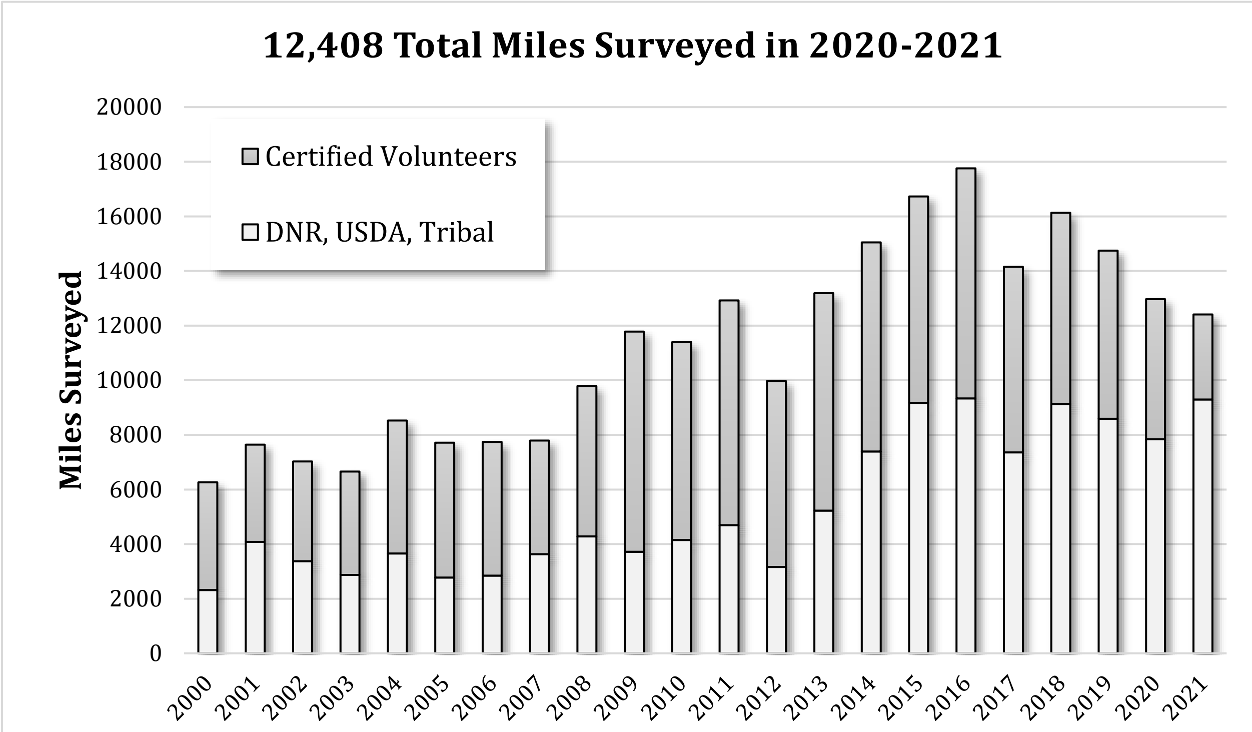


Figure 4. Number of miles surveyed by volunteers and natural resource professionals during the monitoring year 2020-21.

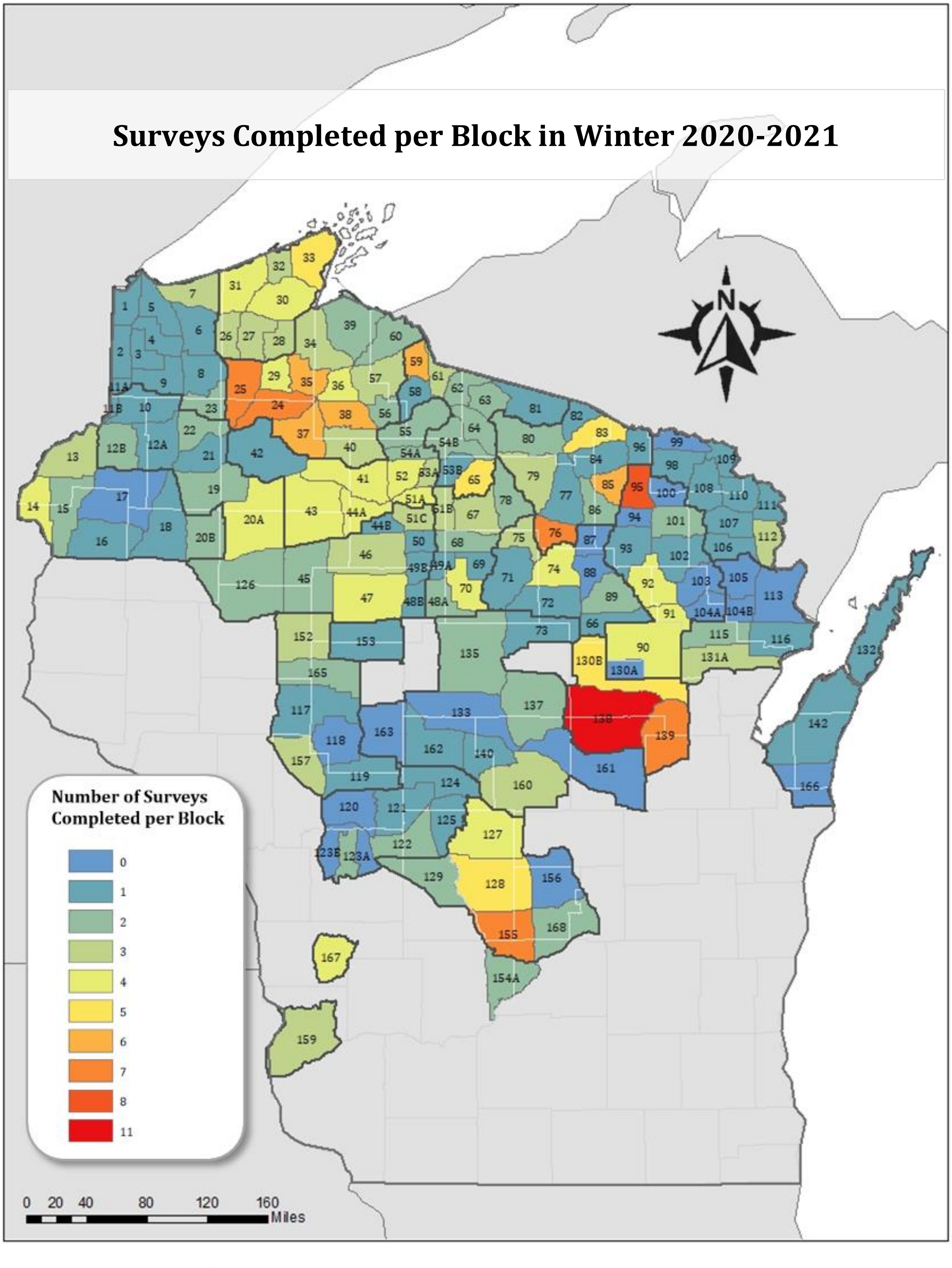


Figure 5. Number of surveys completed per block: winter 2020-2021.

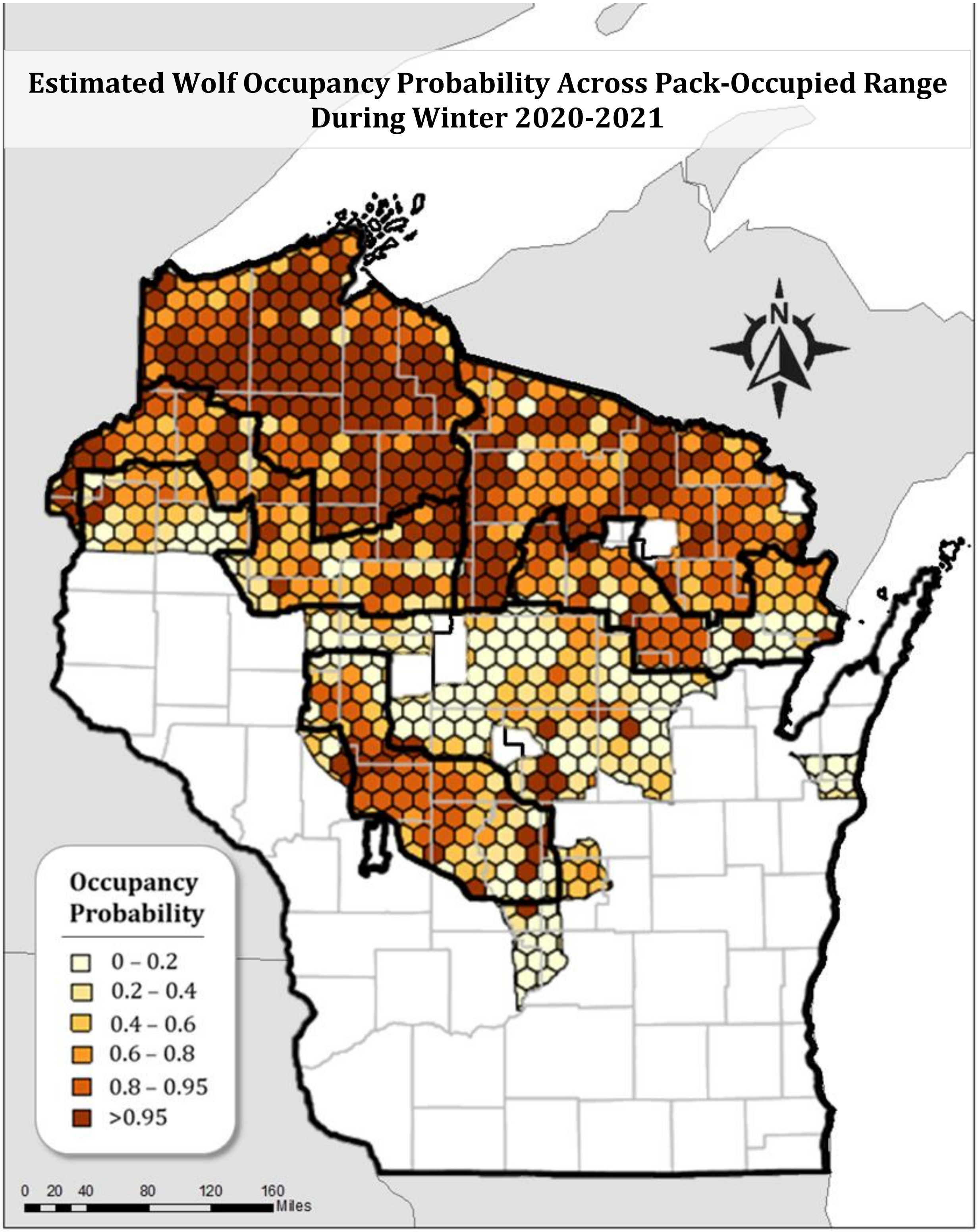


Figure 6. Wolf occupancy probability for pack-occupied range during winter 2020-2021. Estimates are considered pre-harvest as only tracking data collected between 01 December 2020 and 21 February 2021 (i.e. prior to the February 2021 wolf season which began 21 February 2021) was utilized in modeling**.** Note: individual wolves may occur anywhere in the state.

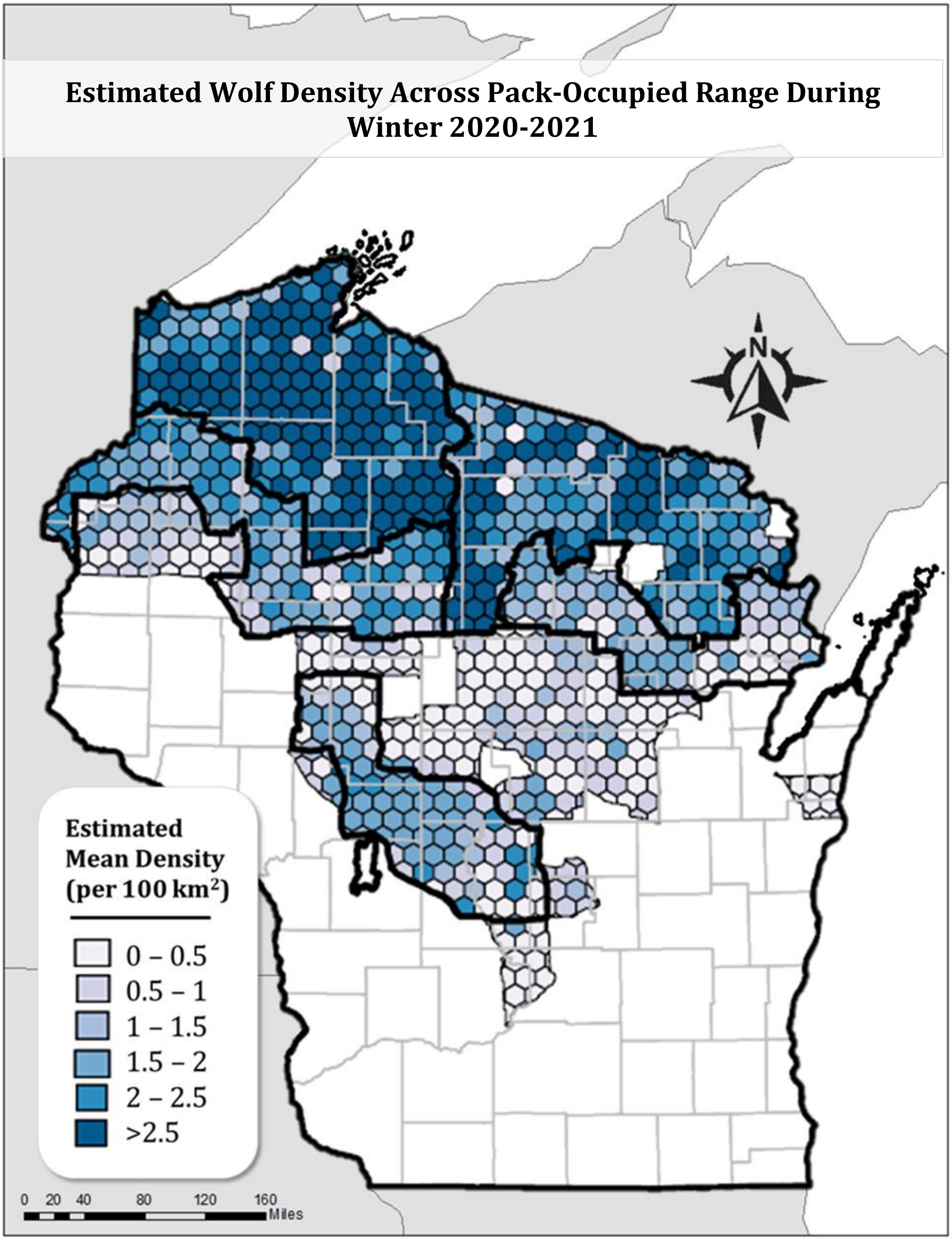


Figure 7. Estimated wolf densities across pack-occupied range during winter 2020-2021. Estimates are considered pre-harvest as only tracking data collected between 01 December 2020 and 21 February 2021 (i.e. prior to the February 2021 wolf season which began 21 February 2021) was utilized in modeling**.** 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 2020-21. 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	12,070	4,660
0.2 – 0.4	6,504	2,511
0.4 – 0.6	9,498	3,667
0.6 – 0.8	13,250	5,116
0.8 – 0.95	9,724	3,754
>0.95	22,750	8,783
Total Pack-Occupied Range	73,796	28,493

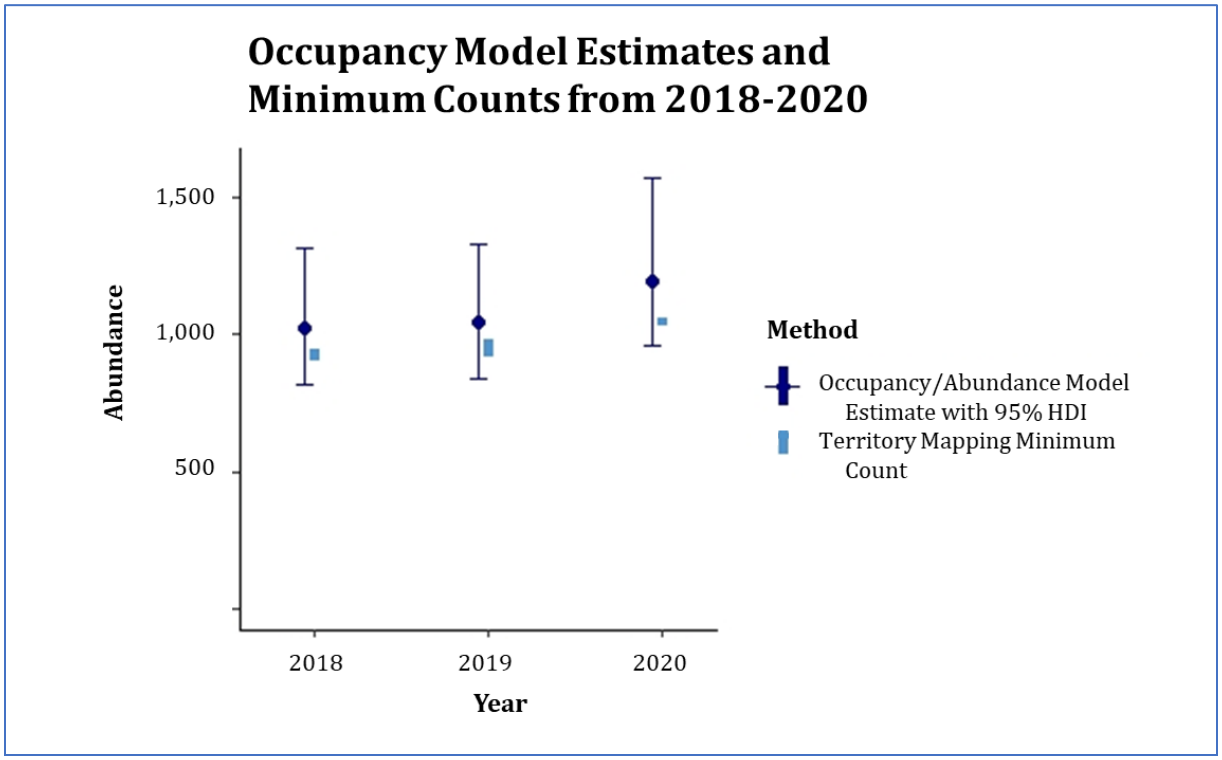


Figure 8. Comparison of occupancy model estimates and overwinter minimum counts 2018-2020.

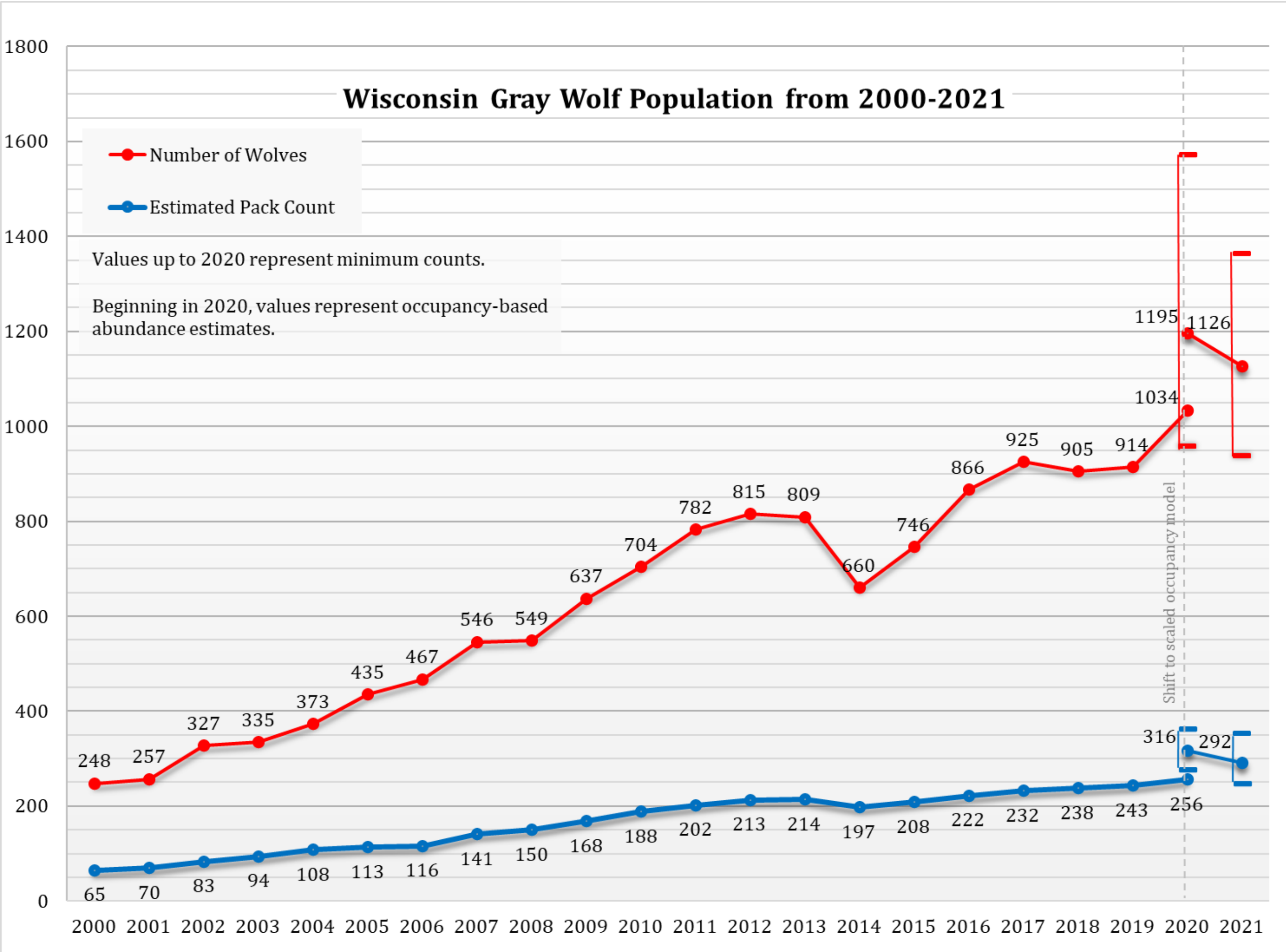


Figure 9. Changes in Wisconsin overwinter gray wolf population 2000-2021.

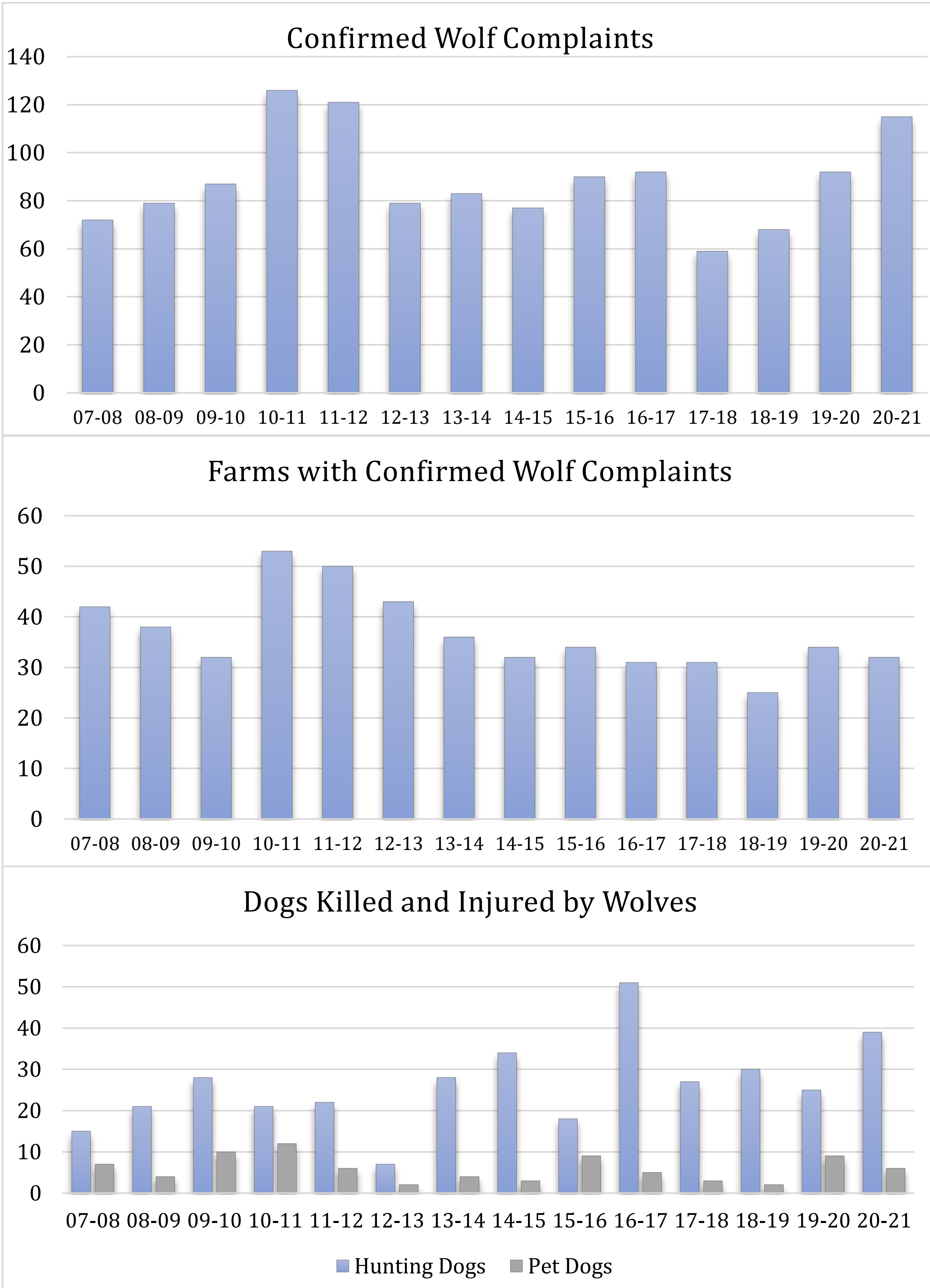


Figure 10. Total confirmed wolf complaints, number of farms with at least one confirmed wolf complaint, and total number of dogs killed and injured by wolves during the 2007-08 to 2020-21 wolf monitoring years.

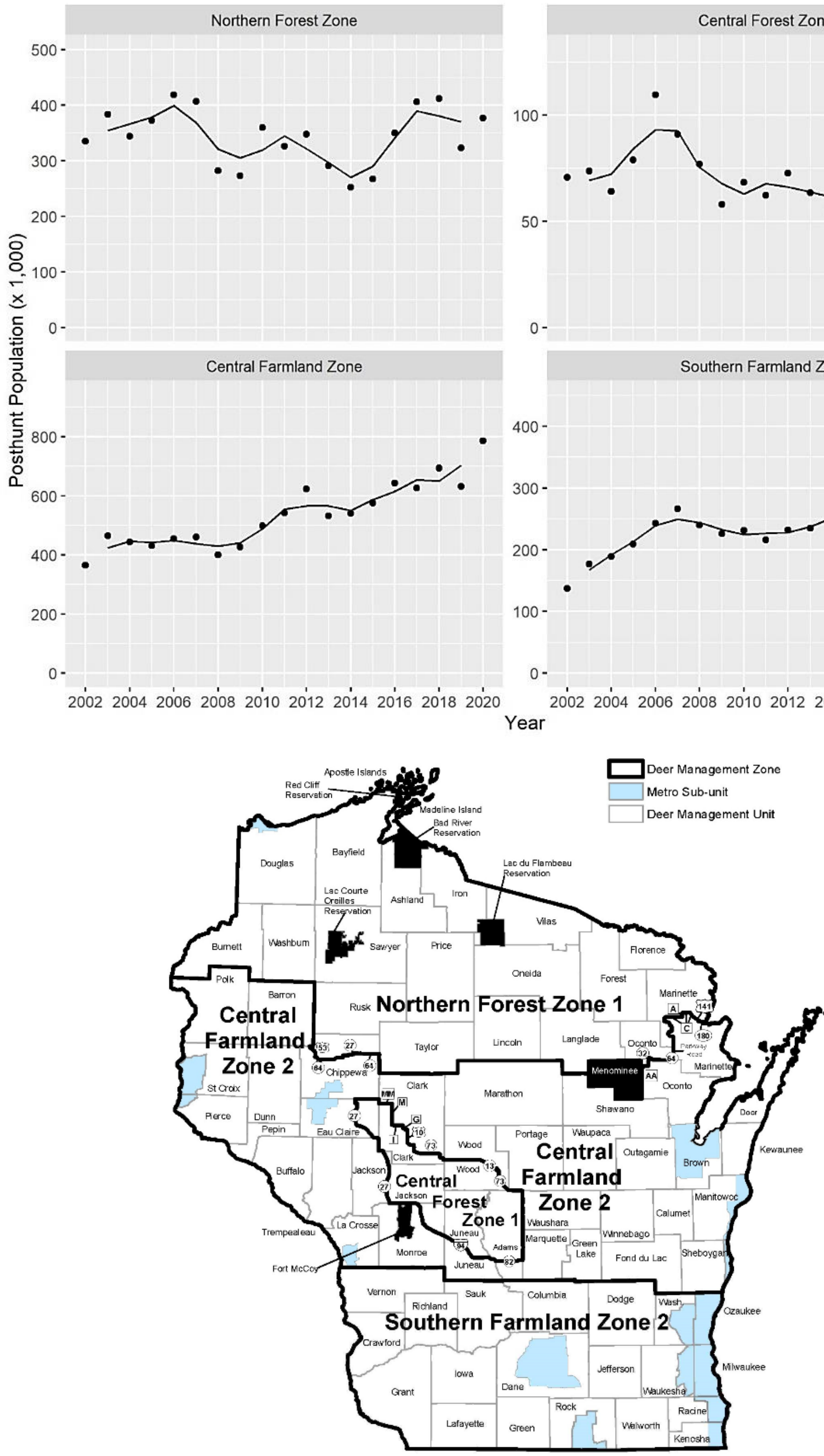


Figure 11. White-tailed deer post-hunt population estimate trends in deer management units (see map for zone boundaries) from 2002 through 2020. Figures from WDNR White-tailed Deer Population Status 2020 report by Beth Wojcik and Jennifer Stenglein.

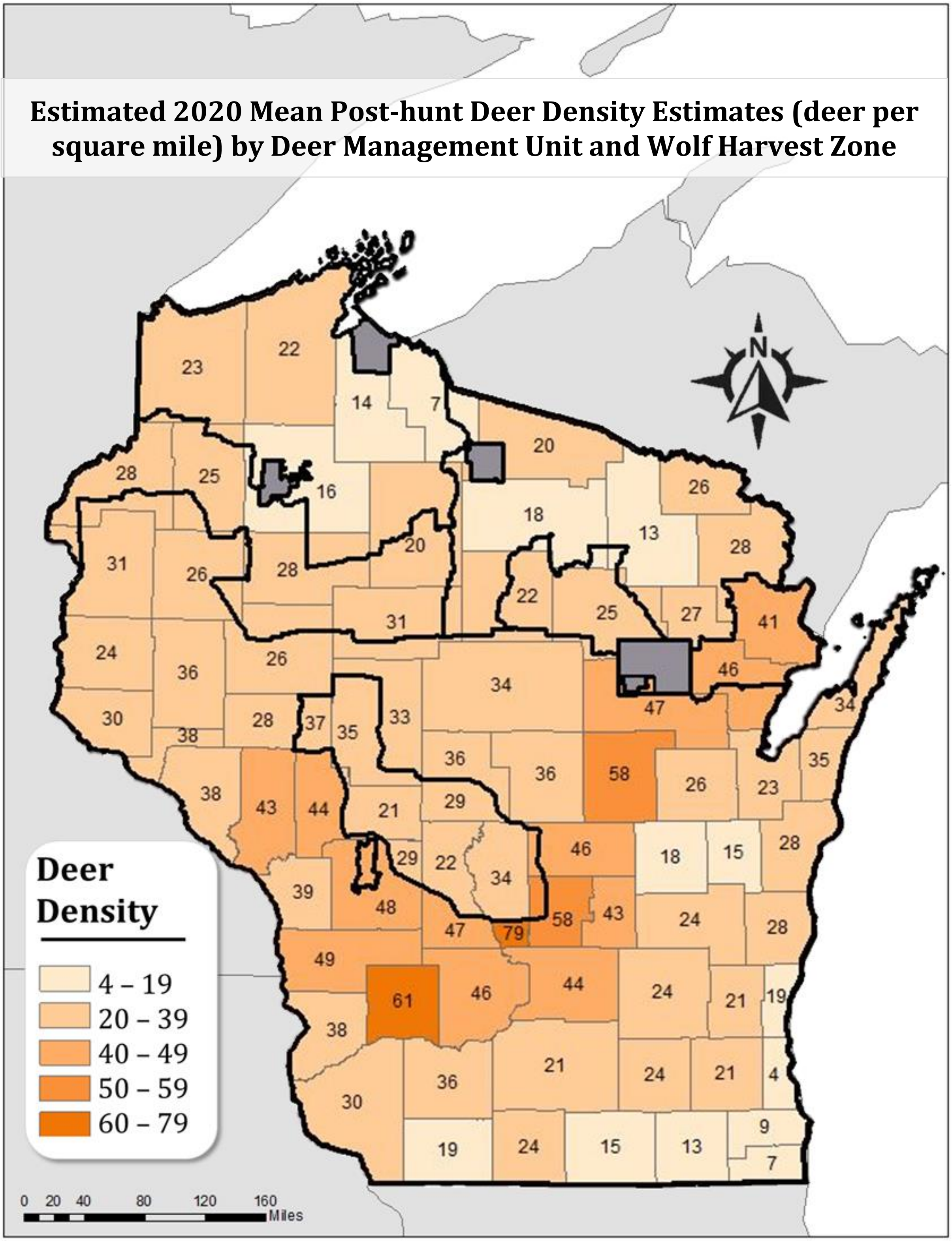


Figure 12: Estimated 2020 mean post-hunt white-tailed deer density estimates for each deer management unit shown as deer per square mile (total area) with Wolf Harvest Zones overlaid. Gray polygons represent tribal reservations.

Addendum – Detailed Methodology

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 km2 hexagonal cells placed over the union of all sampled tracking blocks, which was the optimal size identified by a simulation analysis. 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. We truncated the tracking data to exclude any surveys conducted after February 21 to 1) reduce potential of confounding the abundance estimate by including data during and following the harvest, and 2) produce a robust pre-harvest estimate. This resulted in 14 survey occasions. 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 the data.

Defining pack-occupied range

The 2020 – 2021 pack-occupied range is shown in Figure 13 below. DNR uses data from previous tracking seasons and other confirmed reports of pack activity to define pack-occupied range. The defined pack-occupied range represents the area of inference for the population estimate produced from the tracking data. While there may be additional wolves outside the range, those wolves are not included in the pack-occupied range model estimate. However, the DNR will present information of packs outside of pack-occupied range to the wolf committees, as needed.

The pack-occupied 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 pack-occupied range during the 2021 – 2022 tracking season, then that tracking block will be added to the pack-occupied range for the 2022 – 2023 tracking season. The criteria for inclusion in pack-occupied range is based on data during the previous 4 tracking seasons. Four years was identified as the number of years which allowed the pack-occupied range to respond to possible expansions and contractions of wolf range, while minimizing inclusion or exclusion based on spurious changes in wolf range. The criteria for inclusion are as follows (with any criteria being met resulting in inclusion):

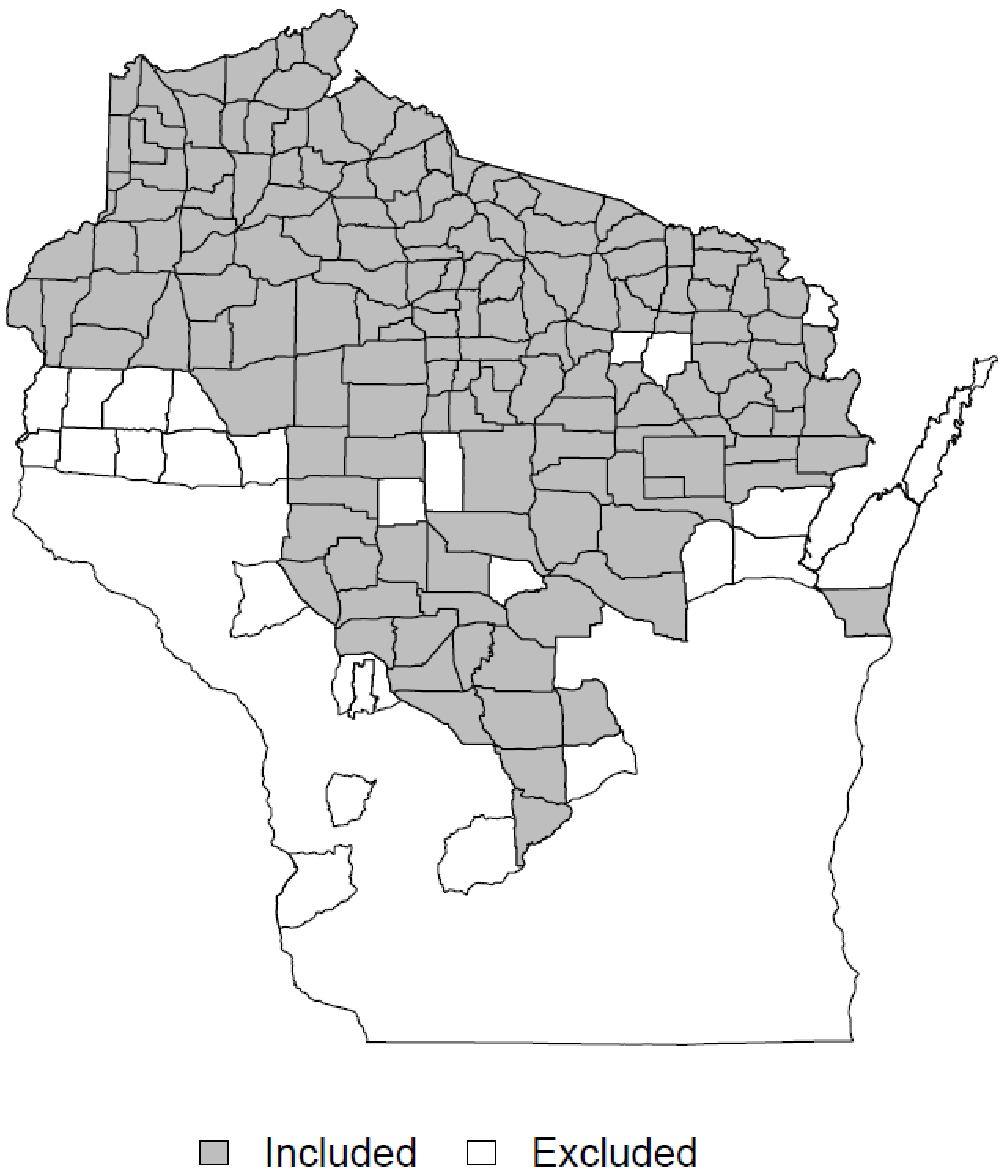
- Tracks from at least two wolves were observed within a block during a single tracking event
- Single wolf tracks were observed in a grid during separate surveys within a tracking season

Beyond track observations, only confirmed evidence of pack activity in a block will trigger its addition to the pack-occupied 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

Snapshot data resulted in the inclusion of 2 tracking blocks. Depredation events did not result in the inclusion of blocks. Further, one confirmed wolf pack depredation in Wood County warrants the delineation of a new tracking block for the 2021 – 2022 season.

Figure 13. Depiction of tracking blocks used to define 2020-21 pack-occupied range as defined in the criteria above.



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: $z_i \sim Bernoulli(\psi_i)$ $logit(\psi_i) = b_0 + b_1 \times forest_i + b_2 \times ag_i + b_3 \times road\_density_i$ $y_{it} \sim Bernoulle(z_i p_{it})$ $logit(p_{it}) = a_0 + a_1 \times \log(effort_{it})$ 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 $road\_density_i$ is the density of primary, secondary, and forest roads in sample grid i, in km/km2. 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. The occupancy results are consistent with previous years. Occupancy probabilities vary across pack-occupied range and were highest in zone 1 and lowest in zone 6 (Figure 1). Similarly, detection probability was positively related to effort (a_1 = 1.01; 95% CrI = 0.82 – 1.21). Occupancy probability was positively related to forest cover (b_1 = 0.54; 95% CrI = -0.32 – 1.25) and negatively related to ag and developed land (b_2 = -1.88; 95% CrI = -1.53 – -0.35) and road density (b_3 = -0.84; 95% CrI = -1.72 – 0.01).

Mean pack size

We calculate 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 (165 km2).
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 2020 – 2021 tracking data (Table 3).

Mean home range size

Mean home range size was estimated from GPS locations from 01 December 2019 – 15 April 2020 and 01 December 2020 – 21 February 2021, for 40 and 23 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 adehabitat 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 $h = href \times p$, 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 was implausibly large (>400 km2, or about 2.5X the previous year's mean HR size). There were 4 such cases among the 2020 – 2021 data, resulting from obvious over-smoothing of the KDE, where a wolf periodically moved back-and-forth between two adjacent primary centers of activity. In each of these exceptional cases, 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 164.3 km2 (SE=12.85). 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, we are shifting the allocation of collaring effort among zones to produce home range estimates that are representative of the pack-occupied range.

Combining the intermediate estimates to produce the range-wide and zone-specific estimates

Abundance was estimated as $N = \Sigma \psi i A i K i \bar{x} i / \bar{h}$, where ψi was the probability of occupancy in sample unit i, Ai was the area of sample unit i, $\bar{h}$ is the mean two-year home range size, and $\bar{x}i$ is the 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.