2023
Moose Harvest Recommendation

to the
Vermont Fish and Wildlife Board

Vermont Fish and Wildlife Department
Agency of Natural Resources
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The Department's goal is to improve the health of moose in northeastern Vermont by reducing winter tick abundance and their impacts on moose health, survival, and birth rate. The Department recommends issuing 180 moose hunting permits between WMUs E1 and E2 to reduce the moose population and thereby reduce winter tick abundance. See the table below for specific permit allocations.

The current number of moose in WMU E has been sufficient to sustain winter ticks at high levels that are negatively affecting moose health and survival. Winter ticks are a host-dependent parasite with moose being the primary host responsible for major fluctuations in winter tick densities. Therefore, reduction in moose population density decreases the number of available hosts which in turn decreases the number of winter ticks on the landscape. Moose population reduction will be necessary to break the winter tick cycle and improve the health of moose in this region.

Reducing winter tick numbers directly, either by treating moose or the landscape with some form of acaricide or fungal pathogen, is not currently a viable option. Research in this area is ongoing, but the realities of treating an entire landscape or a sufficient portion of the moose population make it unlikely that this will be a practical option soon.

Failure to reduce moose population density will perpetuate the current, unhealthy state of moose in WMU E for decades and would be inconsistent with the Department's established objective of managing for a healthy moose population. Importantly, 65% of Vermont residents support maintaining a smaller moose population through hunting if it reduces the number of moose that die each year from winter ticks. Only 15% oppose this approach (Responsive Management 2019).

Although winter ticks can be found on moose throughout the northeast, they do not significantly impact moose populations across the more-peripheral parts of their range, including the rest of Vermont, due to lower moose population densities that limit tick abundance.

Recommended 2023 moose hunting permit allocations by season, permit type, and WMU.

	E1	E2	Total
Archery Season			
Either-sex	11	9	20
Regular Season[1]			
Either-sex	29	25	54
Antlerless-only	55	45	100
Auction[2]	choice		3
Special Opportunity[2]	choice		3
TOTAL			**180**

[1] *Veteran permits are a priority draw for the first 5 regular season permits.*

[2] *Auction and Special Opportunity Permits are either sex and allow choice of season and WMU.*

Summary of Key Points

- The moose population is stable in most of Vermont, including WMU E (E1 & E2).

- Moose density in WMU E remains above the objective of 1 moose/square mile established in the *2020-2030 Big Game Management Plan*.
    - No WMU outside of the Northeast Kingdom ever had a moose density of $1/mi^2$.
    - Moose densities greater than $1/mi^2$ support high numbers of winter ticks that negatively impact the health of moose.
    - Moose densities below $0.75/mi^2$ support relatively few winter ticks that do not impact moose populations. This is the case in most of Vermont – winter ticks are present, but do not cause population level impacts.

- Results of moose research in WMU E indicate health of moose is poor in that region.
    - Adult survival remains relatively good, but detrimental health impacts of winter ticks have caused birth rates to be very low.
    - Heavy winter tick loads can cause more than half of moose calves to die in late winter.

- The Department recommends 180 moose hunting permits (80 either sex and 100 antlerless only) be allocated in WMU E to reduce moose numbers and thereby reduce the impacts of winter ticks on the health of moose and help maintain a sustainable moose population.
    - This would result in the harvest of approximately 100 moose, or about 10% of the current estimated population in WMU E.
    - Recent harvests have been insufficient to effectively reduce moose numbers to achieve management objectives and promote a healthy moose population.

- No permits are recommended for the other 19 WMUs, which cover 93% of Vermont, because moose densities remain below objectives and hunting thresholds established in the *2020-2030 Big Game Management Plan*.

Goals

This recommendation aims to improve the health of moose in WMUs E1 and E2 by reducing the impact of winter ticks and to achieve moose population objectives established in the *2020-2030 Big Game Management Plan*.

Management Objectives

Moose population objectives for each WMU were established in Vermont's *2020-2030 Big Game Management Plan*. These objectives aim to maintain healthy regional moose populations at levels that are socially acceptable and ecologically sustainable.

In WMUs D2, E1, and E2, density objectives reflect the impact of winter ticks on the size and health of the region's moose population. Research has found reduced frequency of tick epizootics (where more than 50% of calves die from winter tick infestations) at moose densities below 1.06/mi^2 and no tick epizootics at densities below 0.75/mi^2 (Samuel 2007, Jones 2016). The Department will initially try to maintain moose densities at or below 1/mi^2 to reduce winter tick abundance and the frequency of epizootics and improve the health of the moose population. However, if tick impacts are not reduced, the moose density may need to be reduced to 0.75/mi^2. Ultimately, the goal is to have healthy moose, with fewer calves dying each year from heavy winter tick loads and healthier cows with higher birth rates.

Moose density objectives throughout the rest of moose range in Vermont have been set at 0.5 moose/mi^2 (**Figure 1**). This lower objective reflects ecological limitations on moose densities in these regions due to limited young forest habitat, higher deer densities, and a warming climate. Moose densities in these WMUs have never reached 1/mi^2.

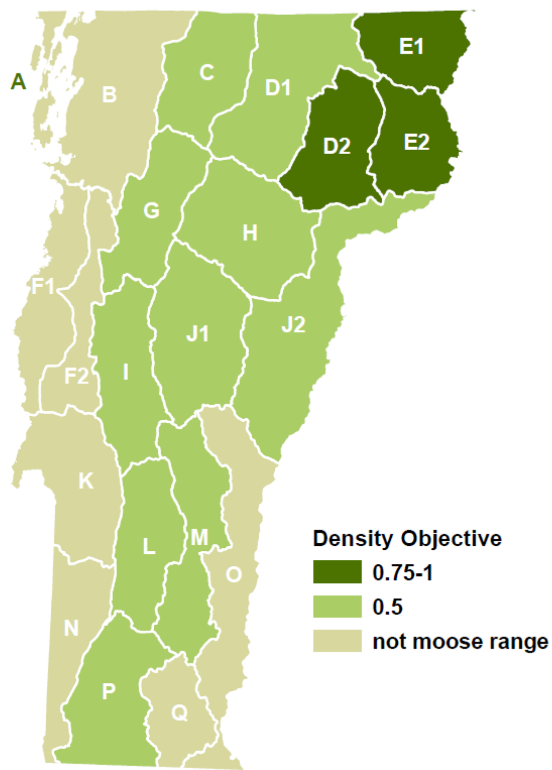

Figure 1. Moose density objectives (moose per square mile of moose habitat) established in Vermont's *2020-2030 Big Game Management Plan*.

Hunting thresholds have also been established for each WMU at 75% of the density objective. The Department will only consider hunting moose when densities exceed this threshold for two consecutive years. This ensures the other values of moose are maximized at these lower densities.

Population Status

Moose and Winter Ticks

Studies in Vermont, New Hampshire, and Maine have concluded that winter ticks are the primary cause of moose mortality across their core range in New England (Musante et al. 2007, 2010, Bergeron et al. 2013, Dunfey-Ball 2017, Jones et al. 2017, Ellingwood et al. 2019, Jones et al. 2019, DeBow et al. 2021), with some moose hosting an astonishingly high number of ticks (>50,000/individual; Jones et al. 2019).

Core moose range (continuous red/brown area in **Figure 2**) in New England extends from northeastern Vermont through northern New Hampshire and western and northern Maine. This part of the region has a colder climate with longer winters, low deer densities, large blocks of forest, and an abundance of young forest created by commercial timber management which allows it to sustain higher densities of moose than more peripheral parts of their range. Importantly, population-level effects of winter ticks have only been observed in the region's core moose range, where moose densities have been high enough to support large numbers of winter ticks.

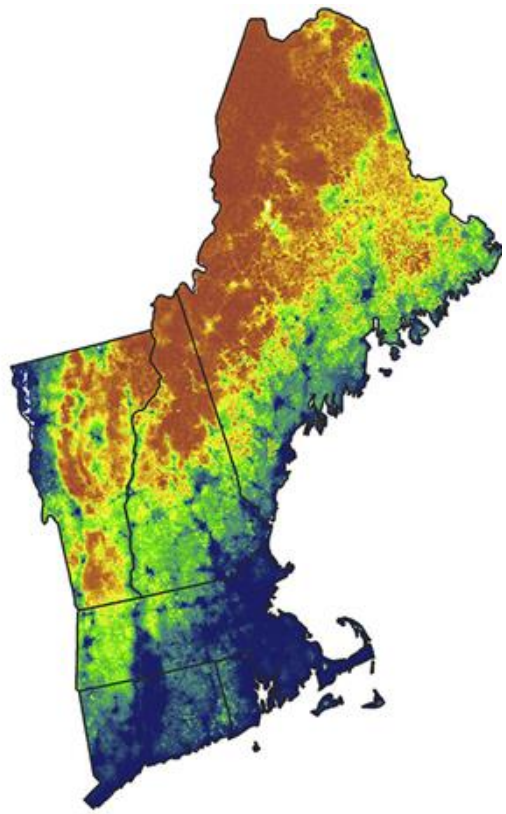

Figure 2. Estimated probability of occurrence of moose in the New England region from Pearman-Gilman et al. 2020.

Although winter ticks can be found on moose throughout the region, they are not impacting moose populations across the more-peripheral parts of their range in the northeast, including the rest of Vermont, due to lower moose densities which limit tick abundance. Moose numbers outside of the Northeast Kingdom have declined, but the main cause of that decline was not winter ticks. It was likely due to a combination of declining quantity of young forest, increased parasite loads (particularly brainworm linked to increasing deer densities), and fewer moose in core moose range to migrate out to these other regions.

Vermont Research

During 2017–2019, 126 moose (36 adult cows and 90 calves) were fitted with GPS radio collars in WMU E to monitor survival and birth rates. Results of this research clearly showed that chronic, high winter tick loads caused the health of moose in WMU E to be poor. Birth rates were low and overwinter calf survival was poor (49%; DeBow et al. 2021). Although adult female survival remained relatively good, it was lower than expected for a population without major predators. Survival of breeding age females has significant influence on population trends in long-lived species like moose.

Ongoing and Future Research

Fieldwork associated with the survival study concluded in 2019; however, the Department continues to monitor survival and calf recruitment in the remaining collared cows. Additionally, the large amounts of data collected during this study allowed University of Vermont researchers to analyze other aspects of moose and winter tick ecology. This related research focused on understanding 1) How winter tick impacts on moose relate to habitat use and quality (*see* Blouin et al. 2021*a* and Blouin et al. 2021*b*), 2) How winter ticks affect moose nutritional condition and stress levels (*see* Rosenblatt et al. 2021), and 3) Moose genetic diversity and connectivity (*see* Rosenblatt et al. 2023).

Other ongoing research at UVM is assessing the effect of various fungal pathogens on survival of winter tick larvae (*see* Sullivan et al. 2021 and Sullivan et al. 2022). While some of these fungi have resulted in high mortality of winter tick larvae in the lab, an important next step is to determine the effectiveness and feasibility of using these pathogens to control winter ticks in the field.

The Department is currently partnering with UVM, the University of Massachusetts, New Hampshire Fish and Game, Maine Department of Inland Fisheries and Wildlife, Massachusetts Division of Fisheries and Wildlife, New York Department of Environmental Conservation, the US Forest Service, and several other partners on a large, regional research effort focused on non-invasive monitoring of moose and winter ticks. A major focus of this project involves deployment of more than 500 long-term camera monitoring stations across the five states. The current project also involves collection and analysis of urine and feces, winter tick surveys, and development of an integrated population model that can incorporate all these data.

For more information about moose research in Vermont and New England, visit vtfishandwildlife.com/conserve/conservation-planning/animal-inventory/mammals/moose-research

Population Health

Many factors affect the health of individual moose and the overall population. These include diseases and parasites (e.g., winter ticks and brainworm), habitat quality, and environmental conditions. Ultimately, how fast a population grows and how resilient it is to additional sources of mortality is determined by how long individuals can be expected to live (i.e., the survival rate) and how many new individuals are added to the population each year (i.e., the birth rate).

In the early 2000s, moose were overabundant in WMU E. They were causing significant damage to forest regeneration and their physical condition was declining as habitat quality declined. The Department actively reduced the moose population in this area to bring it into balance with the habitat and to improve the health of moose. By 2011, the population had been reduced to a level the habitat could support; however, health measures did not improve (**Figures 3** and **4**).

Moose health and reproductive rates have remained poor since 2011 due to the impacts of chronic high winter tick loads. Moose are not currently limited by habitat in the core part of their range, including WMU E (Dunfey-Ball 2017). There is enough available habitat and adequate forage to support the current population. However, habitat quality can influence the distribution of moose on the landscape (i.e., higher densities of moose in areas with the highest quality habitat), which can influence local winter tick abundance and impacts on moose health (Healy et al. 2019, Blouin et al. 2021*a* and *b*).

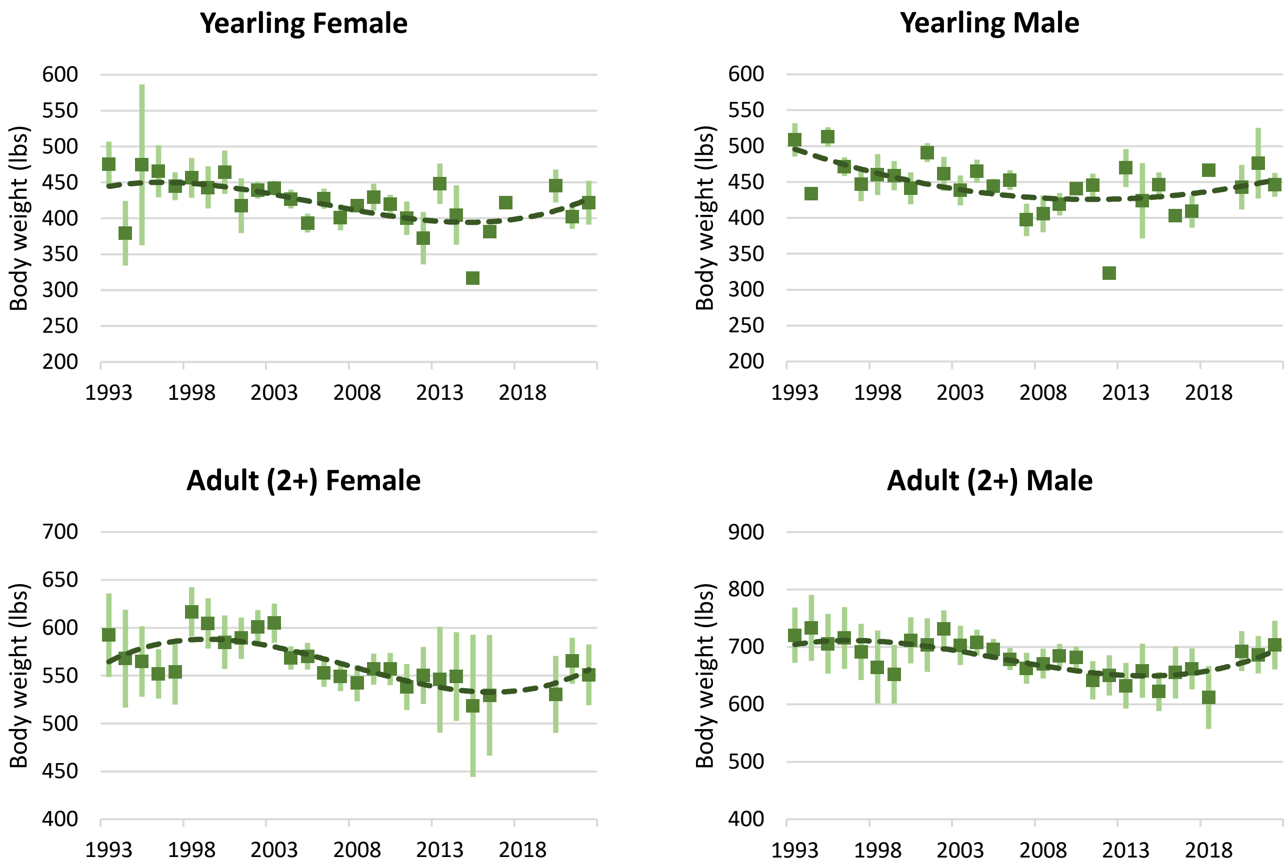

Figure 3. Field-dressed body weights of harvested moose in Wildlife Management Unit E, 1993–2022.

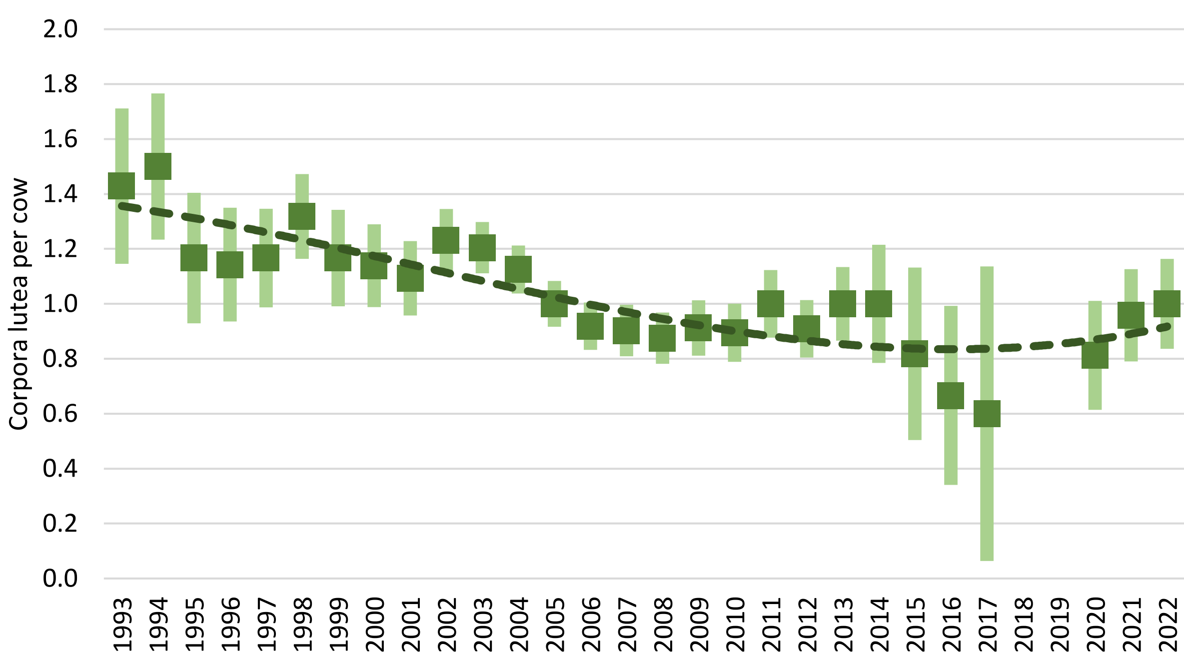

Figure 4. Ovulation rate of prime-aged (≥3 years old) cow moose in WMU E, 1993-2022. Data are 3-year rolling averages from counts of corpora lutea in ovaries collected from hunter-harvested moose.

Recent Winter Tick Impacts

The severity of annual tick infestations is not only dependent on moose density, but also on climate, including temperature, humidity, wind, and snow. Annual variation in climate conditions results in variation in winter tick loads on moose. As long as climate conditions periodically result in reduced winter tick infestations, moose densities can remain at levels that perpetuate heavy tick loads and unhealthy moose for the foreseeable future.

Vermont has not collared moose calves since 2019. As a result, the Department relies on other sources of information to estimate winter tick impacts since that time. Summer calf recruitment of collared cow moose was better during 2020-2022 than during 2017-2019 (**Figure 5**). Additionally, small improvements in health measures for all age classes (**Figures 3 and 4**), the proportion of yearlings in the moose harvest, and anecdotal evidence (e.g., reports of dead moose, bloody beds, engorged ticks in snowmobile trails) suggest that tick impacts were lower during the past 3 years, and particularly during 2020 and 2021.

While reduced winter tick impacts are encouraging, they are likely the result of unfavorable climate conditions for winter ticks in recent years. Fluctuations in winter tick impacts are expected, and current moose densities in WMU E will allow winter tick abundance and impacts on moose to increase again when climate conditions are more favorable for ticks.

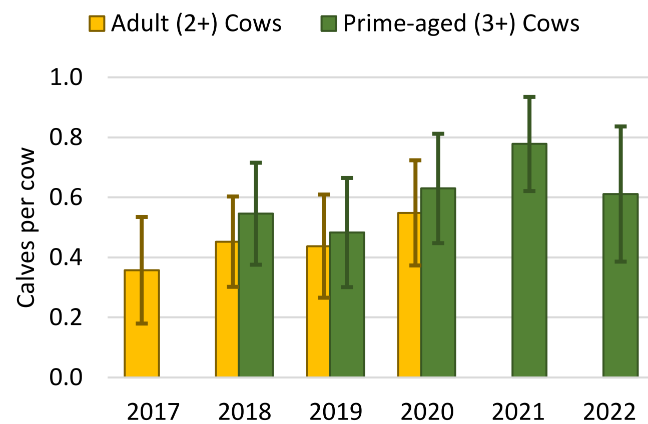

Figure 5. Summer calf recruitment of collared cow moose in Wildlife Management Unit E, 2017–2022.

Winter tick counts on bull moose harvested in October 2022 were comparable to those observed in recent years (**Figure 6**). The long-term trend in this index is encouraging, but there has been no change since 2016.

This measure provides an indication of tick abundance on the landscape, but final tick loads on moose will be largely determined by the length of the questing period. The questing period is typically ended by weather conditions (e.g., persistent snow or freezing conditions) that kill questing winter tick larvae. Persistent snow did not arrive in WMU E until mid-November 2022, which may result in more severe winter tick impacts in 2023 than harvest tick counts would suggest.

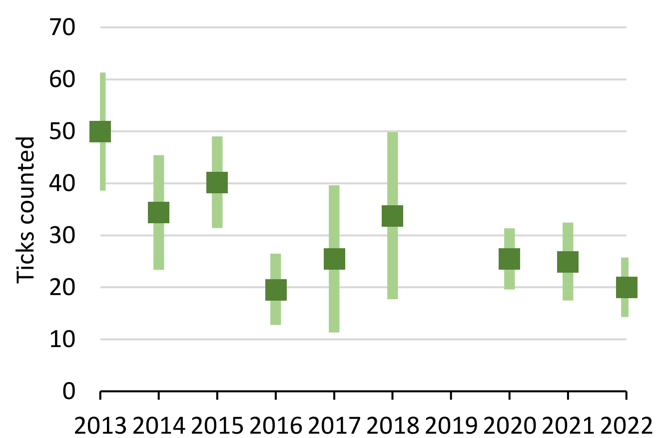

Figure 6. Winter tick counts on bull moose harvested in Wildlife Management Unit E, 2013–2022.

Population Estimates

Regional moose densities in Vermont are estimated from moose sighting rates reported by deer hunters during the November rifle season. This approach, originally developed by the New Hampshire Fish and Game Department, relates sighting rates to moose densities determined by aerial surveys (Bontaites et al. 2000). Aerial surveys conducted in Vermont allowed the Department to modify this model to better fit Vermont sighting data. Sighting rates often vary from year to year due to factors other than the number of moose (e.g., weather conditions), so a 3-year rolling average is used to smooth out some of this variation.

Using this approach, the 2022 (2020–2022 rolling average) density estimates for WMUs E1 and E2 are 1.68 and 1.54 moose/mi^2, respectively, which are well above the upper density objectives established in the *2020-2030 Big Game Management Plan* (1 moose/mi^2; **Table 1**). Importantly, following the intentional population reduction that ended in 2010, it appears that moose numbers have been relatively stable at this level in WMU E over the past 10 years (**Figure 7**).

The Department continues to receive interest in moose hunting in areas outside WMU E. While some of these local areas could sustain a limited moose harvest, the moose population density in all WMUs except E1 and E2 remains below established hunting thresholds (**Table 1**).

The uneven distribution of functional moose habitat (and therefore moose) in parts of Vermont is a challenge for management. The Department will be reevaluating moose habitat mapping, taking advantage of recent research efforts (e.g., Pearman-Gilman et al. 2020, Blouin et al. 2021*a*) to better reflect the area of functional habitat in each WMU. This should allow for more meaningful estimates of moose density in WMUs with less homogeneous moose habitat.

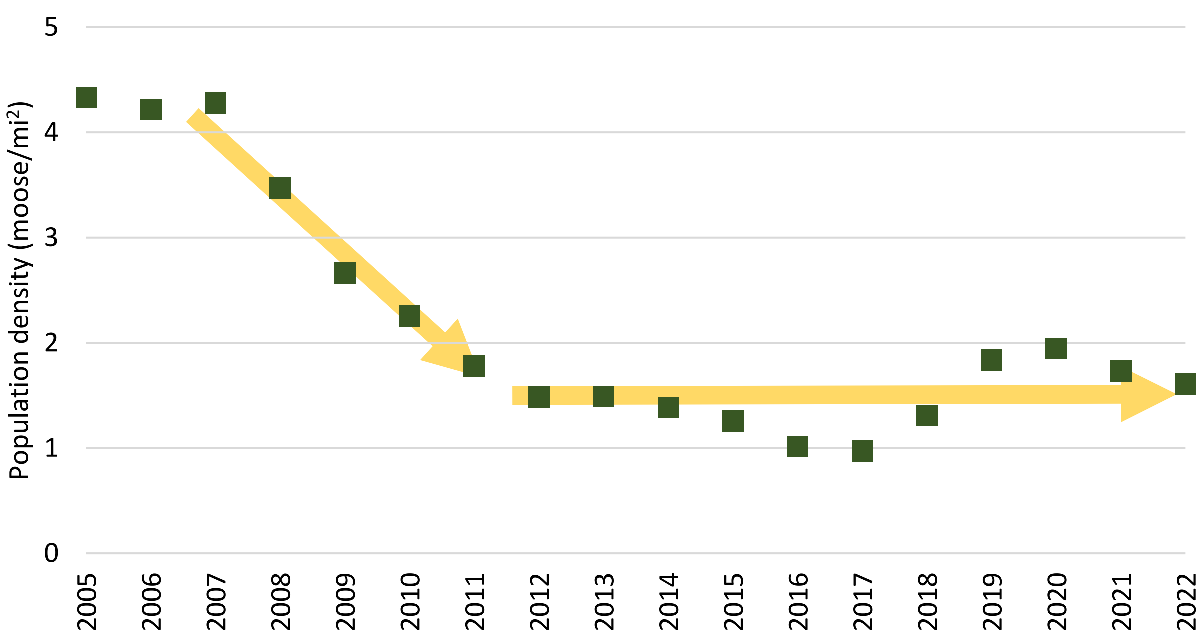

Figure 7. Moose density estimates (green squares) and major trends (yellow arrows) in WMU E during 2005–2022. Density estimates are based on moose sighting rates reported by deer hunters.

Table 1. Moose density estimates based on sighting rates by deer hunters and density objectives and hunting thresholds established in the *2020-2030 Big Game Management Plan*, by WMU. Density estimates are based on average sighting rates during 2020–2022.

WMU	Habitat (mi^2)	Density ($moose/mi^2$)			Population Estimate	
		Objective	Hunting Threshold	Current Estimate	N	(80% CI)
A	35	n/a	n/a	0.02	1	(1–1)
B	420	n/a	n/a	0.05	23	(16–29)
C	351	0.5	0.38	0.30	104	(85–124)
D1	449	0.5	0.38	0.21	94	(75–114)
D2	346	0.75-1	0.56	0.41	141	(115–168)
E1	306	0.75-1	0.56	1.68	514	(455–574)
E2	326	0.75-1	0.56	1.54	501	(426–577)
F1	108	n/a	n/a	0.03	3	(2–5)
F2	158	n/a	n/a	0.02	4	(3–5)
G	363	0.5	0.38	0.08	29	(20–38)
H	466	0.5	0.38	0.23	105	(86–125)
I	407	0.5	0.38	0.08	32	(23–40)
J1	464	0.5	0.38	0.07	32	(21–43)
J2	633	0.5	0.38	0.31	198	(166–230)
K	359	n/a	n/a	0.05	16	(11–22)
L	346	0.5	0.38	0.17	57	(42–72)
M	424	0.5	0.38	0.22	92	(71–113)
N	275	n/a	n/a	0.04	12	(6–18)
O	478	n/a	n/a	0.03	13	(10–15)
P	447	0.5	0.38	0.15	66	(48–84)
Q	219	n/a	n/a	0.06	14	(7–20)
STATE	**7380**				**2051**	**(1689–2417)**

Population Projections

Based on survival rates and calf recruitment observed from collared moose during 2018–2022, the moose population in WMU E is expected to remain stable with a harvest of 25 adult cows annually. This is a change from projections provided in recent harvest recommendations that suggested this cow harvest would result in a population reduction. Those projections were based on lower survival and reproductive rates observed during 2017-2019, which were relatively severe tick impact years, and may have underrepresented potential population growth. The current projection is consistent with the observed stable population over the past 11 years (**Figure 7**), when the average annual moose harvest in WMU E has been 41 moose (range: 0-75).

Harvest Recommendation

The Department recommends harvesting approximately 50 adult cow moose (~10% of the cow population) in WMU E during the 2023 moose hunting seasons. The Department further recommends that this be accomplished through the issuance of 80 either-sex hunting permits and 100 antlerless-only hunting permits. Given historical success rates and sex-age composition of the harvest for each permit type, this allocation is expected to result in the harvest of approximately 103 moose (range: 86–118) with an expected breakdown of 42 bulls (range: 34–47), 53 cows (45–63), and 8 calves (6–10).

Approximately 55% of permits are recommended to be allocated to WMU E1 due to higher moose densities in that WMU. Approximately 25% of either-sex permits are allocated to the archery season, based on the percentage of total applications that were for this season in recent years and the need to obtain sufficient biological data during the regular season. Allocations to the auction, special opportunity, and veterans are set by statute. Permit breakdown by season, type, WMU, and special allocation is provided below in **Table 2**.

Table 2. Recommended 2023 moose hunting permit allocations by season, permit type, and WMU.

	E1	E2	Total
Archery Season			
Either-sex	11	9	20
Regular Season[1]			
Either-sex	29	25	54
Antlerless-only	55	45	100
Auction[2]	choice		3
Special Opportunity[2]	choice		3
TOTAL			**180**

[1] *Veteran permits are a priority draw for the first 5 regular season permits.*

[2] *Auction and Special Opportunity Permits are either sex and allow choice of season and WMU.*

The results of the moose study and continued monitoring of moose clearly show that the current density of moose in WMU E has been sufficient to sustain winter ticks at high levels that are negatively affecting moose health and survival. Research has shown that winter tick abundance is directly related to moose population density. Reducing the density of moose decreases the number of available hosts which in turn decreases the number of winter ticks on the landscape. Moose population reduction will be necessary to break the winter tick cycle and improve the health of moose in this region.

Reducing winter tick numbers directly, either by treating moose or the landscape with some form of acaricide or fungal pathogen, is not currently a viable option. Research in this area is ongoing, but the realities of treating an entire landscape or a sufficient portion of the moose population make it unlikely that this will be a practical option soon.

The Department is committed to achieving a healthy moose population in WMU E by meeting the population objectives established in the [2020-2030 Big Game Management Plan](). The proposed permit allocation and resulting cow harvest would reduce the population by 5% per year and reach the objective of 1 moose/mi^2 (632 moose in WMU E) in 2030 or 2031 (**Figure 8**).

In a worst-case scenario, where tick impacts are relatively severe every year, it would still take several years for the population to reach the target level. Importantly, the Department is confident that such a steep decline could be detected and that reducing the cow harvest would halt that decline.

These projections assume constant harvest each year and no change in moose survival or reproductive rates. In practice, the moose population and winter tick impacts are dynamic, and management must remain adaptive. Actual permit allocations and harvest will be adjusted annually based on new information as it becomes available.

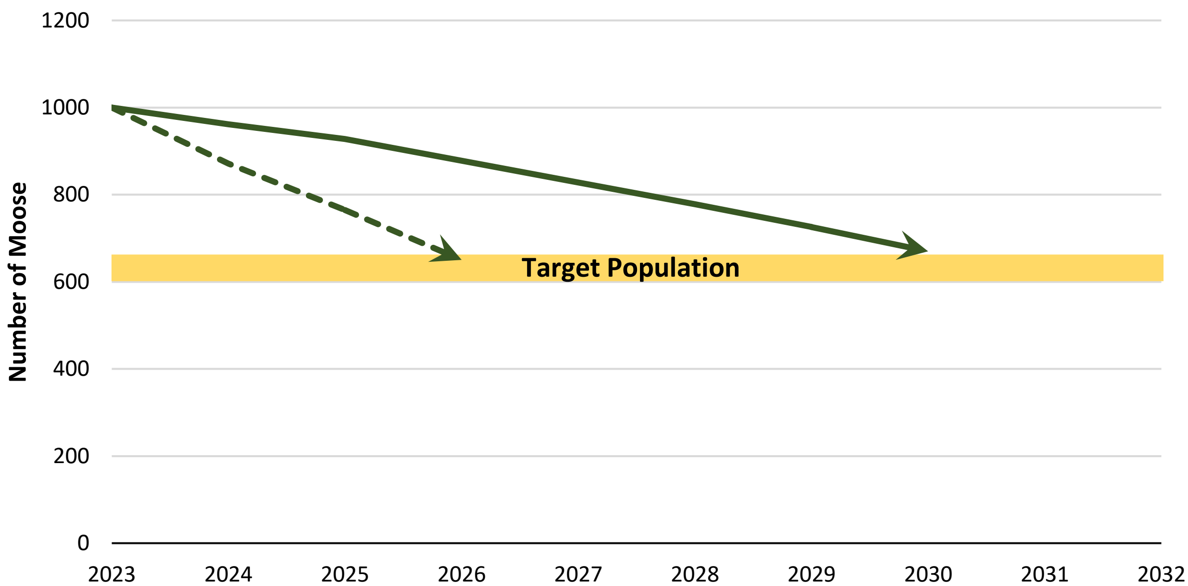

Figure 8. Moose population projections in WMU E at the proposed cow harvest given expected (solid line) and worst-case (dotted line) winter tick impacts. Projections assume consistent harvest each year and no change in survival or birth rates.

Maintaining the 2021 and 2022 harvest objective of 25 adult cows annually may not result in any population reduction, and certainly would not achieve population objectives within a reasonable timeframe. Without management action to reduce the moose population, high tick loads will continue to impact the health of moose in WMU E for the next decade and beyond. The resulting chronic stress, low birth rates, and high calf mortality will make the population less resilient to diseases, parasites, and environmental variation, which could cause the population to destabilize. Maintaining a healthy, stable, and sustainable moose population requires action to improve moose health. Importantly, 65% of Vermont residents support maintaining a smaller moose population through hunting if it reduces the number of moose that die each year from winter ticks. Only 15% oppose this approach (Responsive Management 2019).

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