# 2024
# Moose Harvest Recommendation

to the
Vermont Fish and Wildlife Board

Vermont Fish and Wildlife Department
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This recommendation aims to achieve moose population objectives established in the *2020-2030 Big Game Management Plan* and to improve the health of moose in WMUs E1 and E2 by reducing the impact of winter ticks. The Department recommends issuing 180 moose hunting permits between WMUs E1 and E2 to reduce the moose population and thereby reduce winter tick abundance. No permits are recommended for the other 19 WMUs, because moose densities remain below established objectives and hunting thresholds. The recommended permit allocation is the same as approved by the Board in 2023.

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.

# Summary of Key Points

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

- Moose density in WMU E remains above the objective of 1 moose per square mile established in the *2020-2030 Big Game Management Plan*.
    - Moose densities greater than 1 moose per square mile are uncommon in North America, occurring in less than 10% of moose range.
    - In Vermont, no WMU outside 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 and ongoing monitoring 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 94 moose, or about 10% of the current estimated population in WMU E.

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

## 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.

Moose density objectives throughout most of moose range in Vermont have been set at 0.5 moose/mi$^2$ (**Figure 1**). This objective is a carryover from earlier moose management plans, and 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 most of these WMUs have never reached 0.5 moose/mi$^2$.

In WMUs D2, E1, and E2, density objectives reflect higher historical densities and the impact of winter ticks on the size and health of the region's moose population. Research has found reduced frequency of winter tick epizootics (where more than 50% of calves die from winter tick infestations) at moose densities near 1/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.

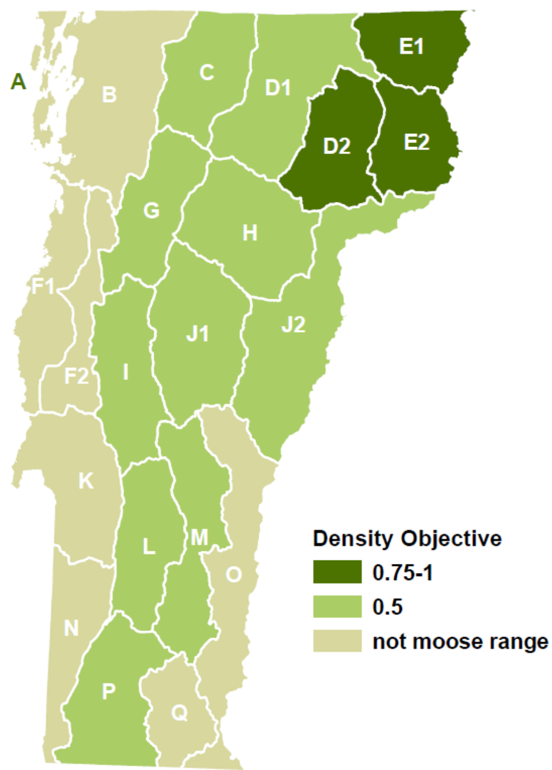


**Figure 1. Moose density objectives (moose per square mile of moose habitat) established in Vermont's *2020-2030 Big Game Management Plan*.**

Hunting thresholds have also been established for each WMU at 75% of the density objective (**Table 1**). 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

## 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 2023 (2021–2023 rolling average) density estimates for WMUs E1 and E2 are 1.29 and 1.56 moose/mi$^2$, respectively, which are well above the density objectives established in the *2020-2030 Big Game Management Plan*. Moose population densities in all other WMUs remain below established hunting thresholds (**Table 1**).

**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 2021–2023.**

| 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 | 21 | (14–29) |
| C | 351 | 0.5 | 0.38 | 0.36 | 126 | (105–146) |
| D1 | 449 | 0.5 | 0.38 | 0.13 | 57 | (41–72) |
| D2 | 346 | 0.75-1 | 0.56 | 0.46 | 160 | (129–190) |
| E1 | 306 | 0.75-1 | 0.56 | 1.29 | 393 | (343–444) |
| E2 | 326 | 0.75-1 | 0.56 | 1.56 | 508 | (428–588) |
| F1 | 108 | n/a | n/a | 0.02 | 2 | (2–2) |
| F2 | 158 | n/a | n/a | 0.03 | 4 | (3–5) |
| G | 363 | 0.5 | 0.38 | 0.06 | 22 | (14–29) |
| H | 466 | 0.5 | 0.38 | 0.19 | 87 | (70–105) |
| I | 407 | 0.5 | 0.38 | 0.11 | 46 | (34–59) |
| J1 | 464 | 0.5 | 0.38 | 0.04 | 19 | (14–23) |
| J2 | 633 | 0.5 | 0.38 | 0.22 | 137 | (108–166) |
| K | 359 | n/a | n/a | 0.04 | 15 | (8–21) |
| L | 346 | 0.5 | 0.38 | 0.13 | 44 | (31–57) |
| M | 424 | 0.5 | 0.38 | 0.22 | 93 | (69–117) |
| N | 275 | n/a | n/a | 0.02 | 6 | (6–6) |
| O | 478 | n/a | n/a | 0.02 | 12 | (10–14) |
| P | 447 | 0.5 | 0.38 | 0.15 | 68 | (49–88) |
| Q | 219 | n/a | n/a | 0.08 | 17 | (10–23) |
| **STATE** | **7380** | | | | **1837** | **(1489–2185)** |

The Department continues to receive interest in moose hunting in areas outside WMU E, and some local areas could likely sustain a limited moose harvest. However, the uneven distribution of functional moose habitat (and therefore moose) in much 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 setting more appropriate and achievable population objectives and calculating more meaningful estimates of moose density in WMUs with less homogeneous moose habitat.

In WMU E, moose were overabundant in the early 2000s and the Department intentionally worked to reduce moose numbers. Since population reduction efforts ended in 2010, moose density has remained relatively stable in WMU E near 1.5 moose/mi$^2$ (**Figure 2**). Importantly, the density of moose over that time has been high enough to support problematic numbers of winter ticks.

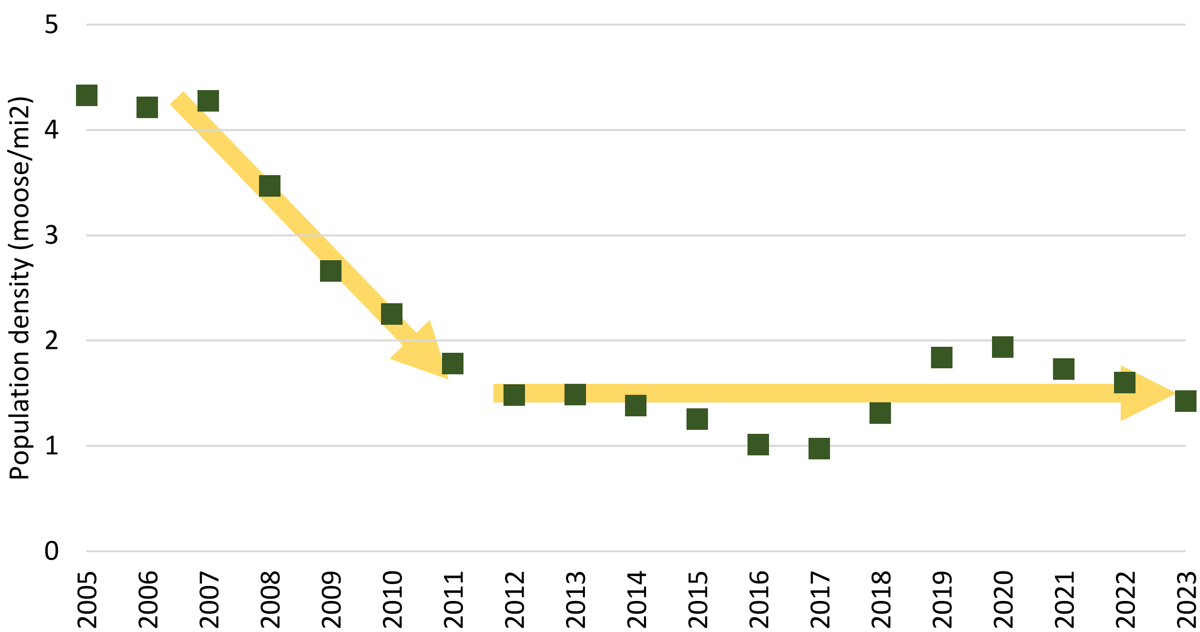


**Figure 2. Moose density estimates (green squares) and major trends (yellow arrows) in WMU E during 2005–2023. Density estimates are based on moose sighting rates reported by deer hunters.**

## 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 3**) 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. 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.

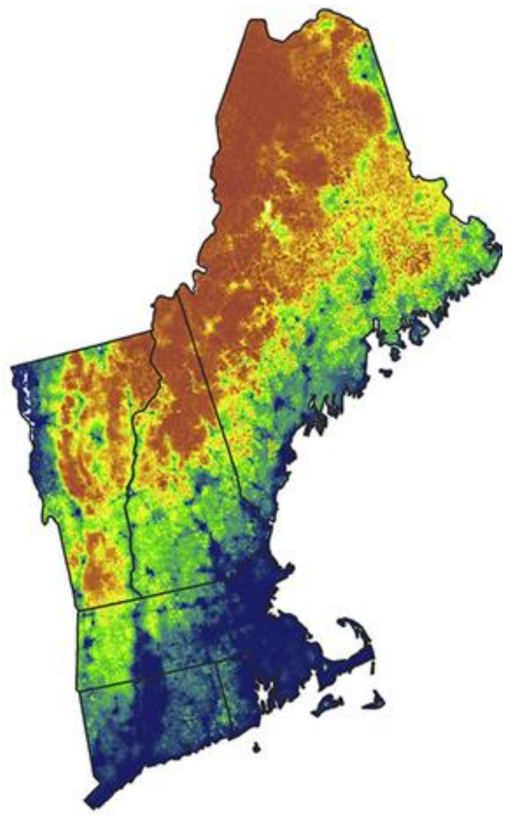

**Figure 3. Estimated probability of occurrence of moose in the New England region from Pearman-Gilman et al. 2020.**

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 related research at UVM assessed 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 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 multiple northeastern universities and state and federal agencies on regional research efforts focused on non-invasive monitoring of moose and winter ticks. A component of this involves deployment of hundreds of long-term camera monitoring stations that will hopefully allow for better monitoring of moose health and population trends, particularly in parts of the region with little or no moose harvest.

## Recent Winter Tick Impacts in WMU E

The severity of annual tick infestations is dependent not only 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 2020-2023 than during 2017-2019 (**Figure 4**). Additionally, small improvements in health measures for all age classes (***see* Population Health**), and anecdotal evidence (e.g., reports of dead moose, bloody beds, engorged ticks in snowmobile trails) suggest that tick impacts have been lower during at least 3 of the past 4 years.

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.

Winter tick counts on bull moose harvested in October 2023 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.

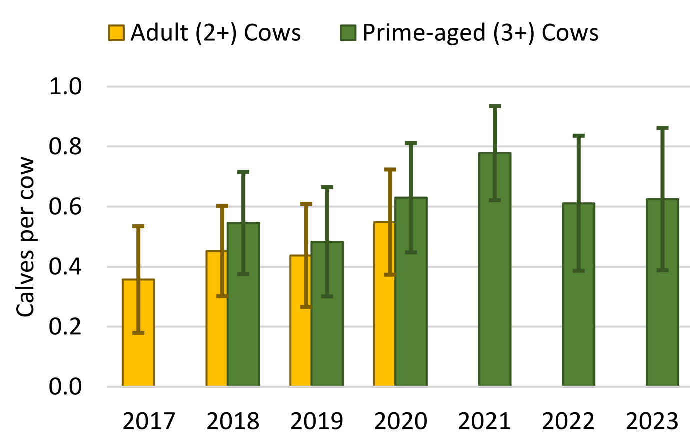


**Figure 5. Summer calf recruitment of collared cow moose in Wildlife Management Unit E, 2017–2023.**

This measure provides an indication of tick abundance on the landscape, but final tick loads on moose are 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 arrived in late October, 2023 in much of WMU E, which may result in reduced winter tick impacts again in 2024.

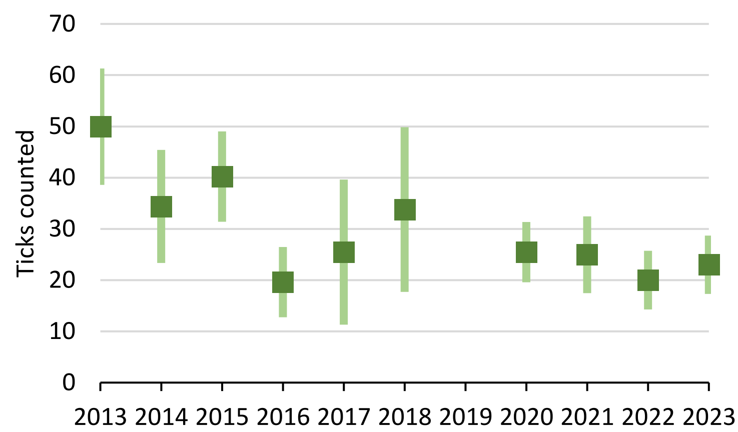


**Figure 6. Winter tick counts on bull moose harvested in Wildlife Management Unit E, 2013–2023.**

## Population Health in WMU E

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 7** and **8**).

Moose body condition 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). 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*). Broader distribution and increased volume of timber harvests in WMU E over the past decade has resulted in a better distribution of optimal habitat. As a result, it appears moose are less concentrated around a limited number of hot spots.

It is unlikely that recent moose harvests (prior to 2023) were sufficient to cause a population reduction that would affect winter tick abundance. However, they have at least limited or prevented population growth, which in combination with a better distribution of optimal habitat, has likely limited local concentrations of moose that benefit winter ticks. In this way, moose density, as it affects winter tick abundance, may have functionally been reduced despite little or no change in overall average density across the WMU.

Body condition and reproductive rates have shown signs of improvement in recent years. This has likely been driven by reduced winter tick impacts in recent years due primarily to unfavorable climate conditions for ticks. While this is encouraging, we still need to see additional and sustained improvement. Even with a better distribution of optimal habitat, moose population reduction will be necessary to maintain these improvements when future climate conditions become more favorable for winter ticks.

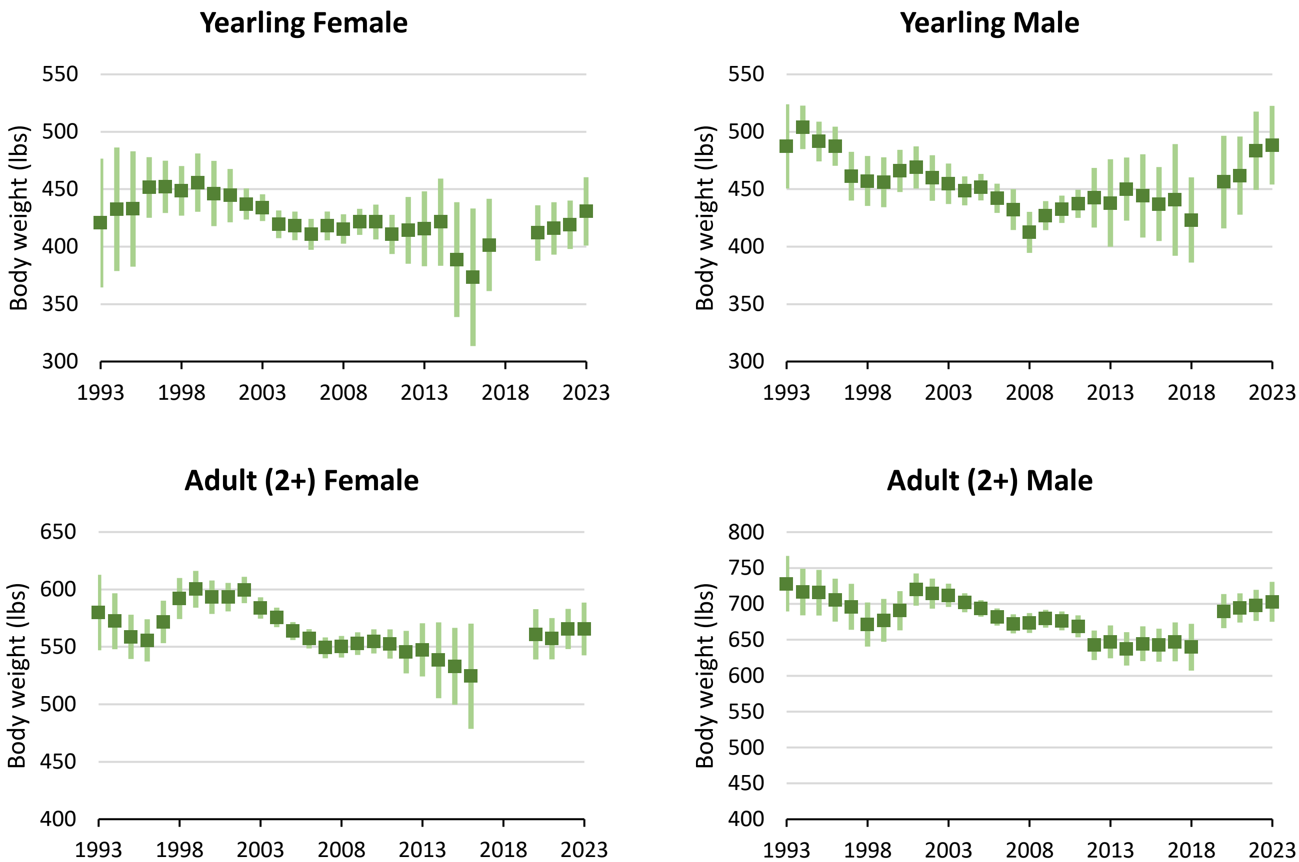


**Figure 7. Field-dressed body weights of moose harvest during the regular season in Wildlife Management Unit E, 1993–2023. Data are 3-year rolling averages with 95% confidence intervals.**

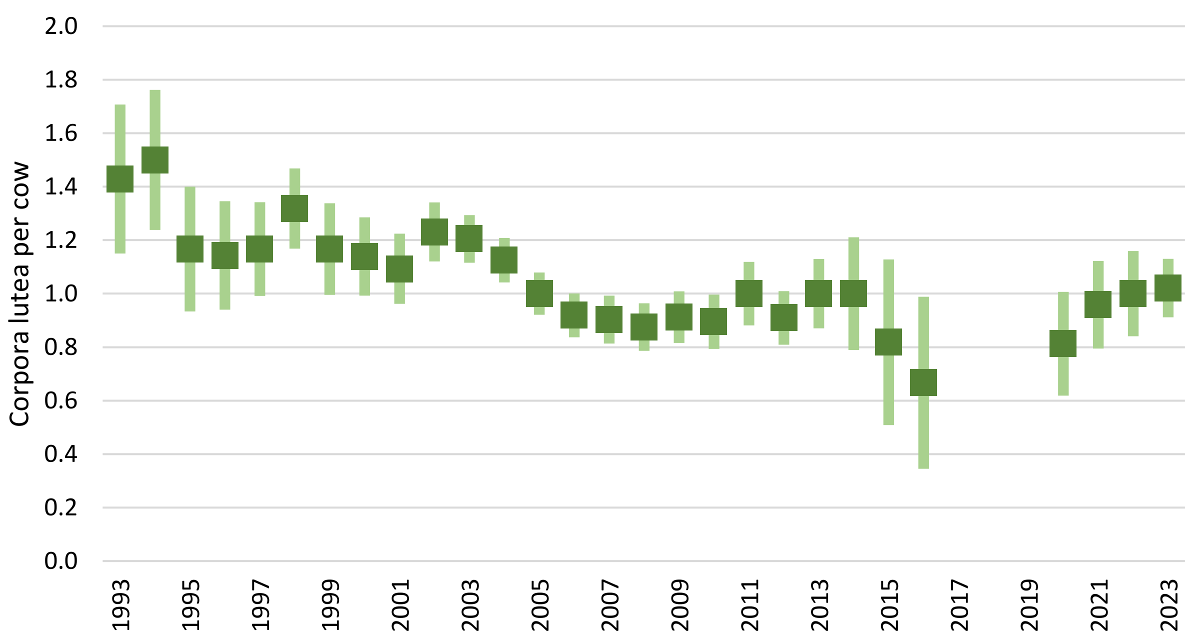


**Figure 8. Ovulation rate of prime-aged (≥3 years old) cow moose in WMU E, 1993-2023. Data are 3-year rolling averages from counts of corpora lutea in ovaries collected from hunter-harvested moose.**

## Harvest Recommendation

The Department recommends harvesting approximately 47 adult cow moose (~10% of the cow population) in WMU E during the 2024 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 94 moose with an expected breakdown of 41 bulls, 47 cows, and 6 calves.

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 the same as prior years and are limited by statute and regulation. Permit breakdown by season, type, WMU, and special allocation is provided below in **Table 2**. This is the same permit allocation approved by the Fish and Wildlife Board in 2023.

**Table 2. Recommended 2024 moose hunting permit allocations and expected harvest by season, permit type, and WMU.**

| | Permits | | | Expected Harvest | |
|---|---|---|---|---|---|
| | E1 | E2 | Total | | |
| **Archery Season** | | | | | |
| Either-sex | 11 | 9 | 20 | 10 | *(7–13)* |
| **Regular Season**[1] | | | | | |
| Either-sex | 29 | 25 | 54 | 36 | *(29–42)* |
| Antlerless-only | 55 | 45 | 100 | 44 | *(37–56)* |
| **Auction**[2] | choice | | 3 | 2 | *(0–3)* |
| **Special Opportunity**[2] | choice | | 3 | 2 | *(0–3)* |
| **TOTAL** | | | **180** | **94** | *(73–117)* |

[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 negatively affect 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.

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 about 4% per year and reach the objective of 1 moose/mi$^2$ (632 moose in WMU E) in 2031 (**Figure 9**).

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. If tick impacts are reduced each year, as in the past 4 years, this harvest may not be enough to prevent population growth.

Each of these projections assumes 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.

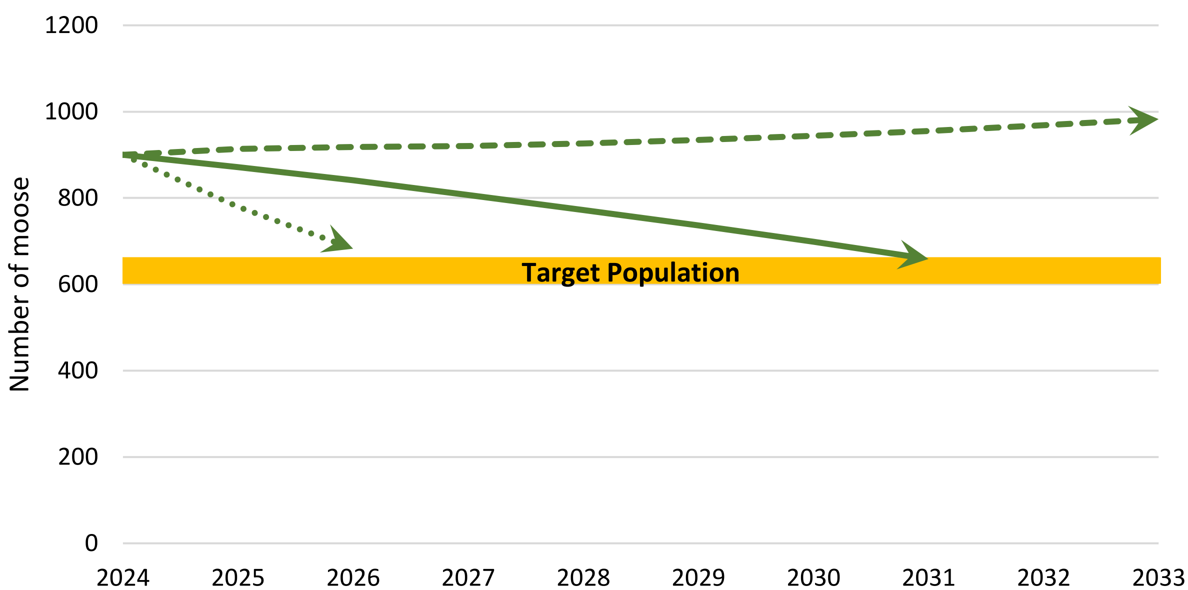


**Figure 9. Moose population projections in WMU E at the proposed cow harvest given expected (solid line), worst-case (dotted line), and improved (dashed line) winter tick impacts. Projections assume consistent harvest each year and no change in survival or birth rates.**

Maintaining a healthy, stable, and sustainable moose population requires action to improve moose health. 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. 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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