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Structured decision-making workshop: Chronic wasting disease management of cervids in Massachusetts

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Structured decision-making workshop: Chronic wasting disease management of cervids in Massachusetts

Workshop dates: 13 – 15 February 2024

Workshop location: Massachusetts Division of Fisheries and Wildlife
1 Rabbit Hill Rd
Westborough, MA

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Data Availability Statement:

At the time of publication, data were not available from the Massachusetts Division of Fisheries and Wildlife. Questions about the data may be directed to Martin Feehan (martin.feehan@mass.gov).

EXECUTIVE SUMMARY

This document describes the results of a 2.5-day rapid decision prototype workshop that evaluated management activities for chronic wasting disease (CWD) in Massachusetts (MA) that were either proactive (i.e., actions taken prior to CWD arrival/detection) or reactive (i.e., actions taken after CWD arrival/detection). The workshop was led by members of the Wildlife Section of the MA Division of Fisheries and Wildlife (hereafter referred to as MassWildlife) and included a group of agency communications specialists and district managers. U. S. Geological Survey staff and a volunteer acted as decision facilitators and led the analysis of the decision.

Chronic wasting disease is an always fatal neurological disease that has spread across much of North America and threatens the health of deer populations in locations where it occurs (reviewed by Escobar et al. 2020). CWD can spread into new areas via two general mechanisms: (1) natural spread (e.g., dispersal of CWD-infected male white-tailed deer [*Odocoileus virginianus*]), and (2) anthropogenic spread (e.g., CWD spread facilitated by human intervention; Leiss et al. 2017, Escobar et al. 2020). Once CWD arrives in a state, natural resources agencies spend eight times more on CWD than agencies with no known cases; to cover these new CWD-related management activities, the natural resources agencies are typically forced to reallocate money from existing conservation priorities (Chiavacci, 2022).
As of May 2024, there were 34 U.S. states and five Canadian provinces that had detected CWD positive free-ranging and/or captive animals in the family Cervidae (collectively referred to as 'cervid' hereafter), and the number of new states/provinces that are detecting CWD for the first time continues to grow (U. S. Geological Survey, May 2024). As of February 2024, the closest CWD positive state to MA with CWD detected in free-ranging white-tailed deer is Pennsylvania. To date, there have been no detections of CWD in MA, but testing has been limited in MA since 2012. The growing number of CWD positive states suggests that there may be increasing risk of CWD entering and establishing in MA as the number of CWD cases increases across North America.

According to a 2023 survey of hunters in MA conducted by MassWildlife, 68% of hunters were concerned about CWD entering MA, and 88% of respondents said that it was at least moderately important to keep CWD out of MA; these survey results indicate that most hunters may support CWD risk reduction actions (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024). In addition, 23.1% of responding deer hunters in MA have hunted for cervids in CWD-positive states/provinces in the last five years (not including states/provinces that have been able to successfully eradicate CWD following a positive detection). Participants of the survey were also asked, "how many deer have you harvested that tested positive for CWD?". A total of three respondents said that they had one deer test positive for CWD, which, when extended to the whole population of MA deer hunters, results in an estimated 32 CWD positive deer harvested in CWD-positive states and imported into MA in the last five years. When asked about how they transport harvested deer from out of state into MA, the three participants indicated either "already processed & packaged" or "not applicable." Note, that in MA, it is a violation of regulation to import whole carcasses or high-risk parts (e.g., head, brain, spinal tissues, bones) of any member of the Cervidae family (wild or captive) from a state/province that has detected CWD; it is legal to bring in deboned meat, cleaned skull caps, hides without the head, or a fixed taxidermy mount (Massachusetts Division of Fisheries and Wildlife, 2024*a*).

To date, testing for CWD has been limited in MA since 2012. However, the data collected from the 2023 MA hunter survey suggests that there is a real risk of CWD being imported by a MA resident who has hunted in a CWD positive state. Therefore, given the higher costs of CWD management post arrival, the

potential natural spread of CWD from nearby states, and the risk of CWD introduction via human-mediated cervid movement, MassWildlife is motivated to take actions that minimize the risk of CWD introduction and spread in MA with the ultimate goal of managing thriving wildlife populations and maximizing hunter and general public satisfaction, which are both parts of the MassWildlife mission.

A 2.5-day rapid prototyping structured decision making workshop was held with MassWildlife staff to develop a decision framework for CWD management in MA. During the workshop, we defined the context and extent of CWD management activities in MA. Next, we identified four fundamental objectives that help achieve the mission of MassWildlife and that address stakeholder concerns. The fundamental objectives included: (1) maximizing hunter satisfaction and participation, (2) maximizing public satisfaction (non-consumptive), (3) maximizing health and sustainability of cervids, and (4) maximizing the efficiency of CWD management. Then, we generated a list of five alternatives (i.e., strategies) that varied the intensity of proactive and reactive actions. The five strategies were: (1) minimal proactive and minimal reactive actions, (2) intermediate proactive and intermediate reactive actions, (3) intensive proactive and intermediate reactive actions, (4) minimal proactive and intensive reactive actions, and (5) intensive proactive and intensive reactive actions. Lastly, we estimated the performance of each strategy on the fundamental objectives and assessed the overall performance of strategies relative to one another. We did so by first estimating the consequences of each alternative strategy on fundamental objectives using expert elicitation, and then, we elicited objective weights from MassWildlife staff to incorporate the relative importance of different fundamental objectives.

Given that it is unknown when CWD will arrive in MA, we evaluated the performance of alternative strategies against fundamental objectives given three distinct scenarios for time to arrival of CWD: introduction in 2.5, 7.5, or 10+ years. The preliminary results of the rapid prototype indicate that the performance of the CWD management strategies that we evaluated depends on when CWD first arrives in MA. If CWD were to arrive in 2.5 or 7.5 years from now (February, 2024), then the 'minimal proactive and minimal reactive' strategy performs the best on both the deer population and cost fundamental objectives (fundamental objectives 3 & 4), but the 'intensive proactive and intensive reactive' strategy performs best on both of the human dimensions fundamental objectives (fundamental objectives 1 & 2) as well as the minimize CWD prevalence objective (also related to fundamental objective 3). We also found that public trust is likely to remain high across all five alternative strategies if CWD arrives after year 10, but public trust decreases if CWD arrives in year 2.5 or 7.5. After incorporating objective weights, we found that in scenarios where CWD arrives in the near-term (in years 2.5 or 7.5), an intermediate strategy (e.g., 'intermediate proactive and intermediate reactive' or 'intensive proactive and intermediate reactive') performed best, and the 'minimal proactive and intensive reactive' strategy performed worst. Conversely, if CWD were to arrive after 10 years, then the 'minimal proactive and minimal reactive' and 'minimal proactive and intensive reactive' strategies performed best. Collectively, these results suggest that the decision on which alternative strategy to employ is sensitive to when CWD arrives in MA.

Following the discussion of the preliminary results, we identified the following four next steps. First, we discussed how a more detailed communications plan is needed and would likely alter the performance estimates of the alternative strategies on fundamental objectives 1 & 2, which were hunter and public satisfaction, respectively. The development of the communication plan would likely be easier once the alternative actions have been identified along with the audience and message. Second, a surveillance plan could be a useful tool to inform CWD management. Surveillance for CWD was performed in MA annually from 2002 to 2012 (n = 4,356 wild white-tailed deer and moose [*Alces alces*] samples). Limited surveillance was conducted from 2013 to 2022; and in 2023, 242 wild samples were collected. It is not

clear whether MA needs a robust or minimal surveillance plan (e.g., is a minimal surveillance plan enough to detect the pathogen at the threshold that would trigger action?), or what type of invasion event the surveillance plan should target (e.g., natural vs anthropogenic spread events). The use of decision trees and a formal risk assessment may help answer these questions. Third, some of the elicited estimates from experts during this rapid prototype could be replaced with empirical data. Lastly, given that the decision was sensitive to when CWD arrived in MA and a surveillance plan would rely on the mode of introduction, forecasting and predicting the CWD invasion front and/or the likelihood of different incursion events across MA would provide valuable insights.

INTRODUCTION

The mission of the Massachusetts Division of Fisheries and Wildlife (MassWildlife) is to conserve freshwater fish and wildlife and to manage lands and species for public enjoyment, in the Commonwealth of Massachusetts (MA), including the protection of endangered plants and animals (Massachusetts Division of Fisheries and Wildlife, 2024*b*). Specifically, MassWildlife restores, protects, and manages land for wildlife to thrive and for people to enjoy (Massachusetts Division of Fisheries and Wildlife, 2024*b*). Within MassWildlife, the Wildlife Section manages all game species, including waterfowl, wild turkeys (*Meleagris gallopavo*), small game, black bears (*Ursus americanus*), furbearers, moose (*Alces alces*), and deer (e.g., *Odocoileus virginianus*) for population health, public enjoyment and utilization, and to minimize human-wildlife conflicts.

One of the primary biological resources in MA is white-tailed deer (*Odocoileus virginianus;* herein, deer). Deer are an important cultural resource for wildlife viewers, a nutritional resource for those that consume venison (e.g., Hunters Share the Harvest Program; Massachusetts Division of Fisheries and Wildlife, 2024*c*), and a recreational resource for hunters and the general public. In conserving and protecting deer and the value that they provide to residents of MA and elsewhere, MassWildlife strives to limit disease and other stressors on deer populations. One increasingly apparent threat to deer is chronic wasting disease (CWD). Chronic wasting disease is an always fatal neurological disease that has spread in the family Cervidae (collectively referred to as 'cervid' hereafter) across large parts of North America and threatens the health of deer populations in locations where it occurs. It is part of a group of diseases called transmissible spongiform encephalopathies (TSEs) or prion diseases and affects members of the deer family including free-ranging and captive white-tailed deer, moose, mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), sika deer (*Cervus nippon*), red deer (*Cervus elaphus*), reindeer (caribou; *Rangifer tarandus*), and black-tailed deer (*Odocoileus hemionus hemionus*).

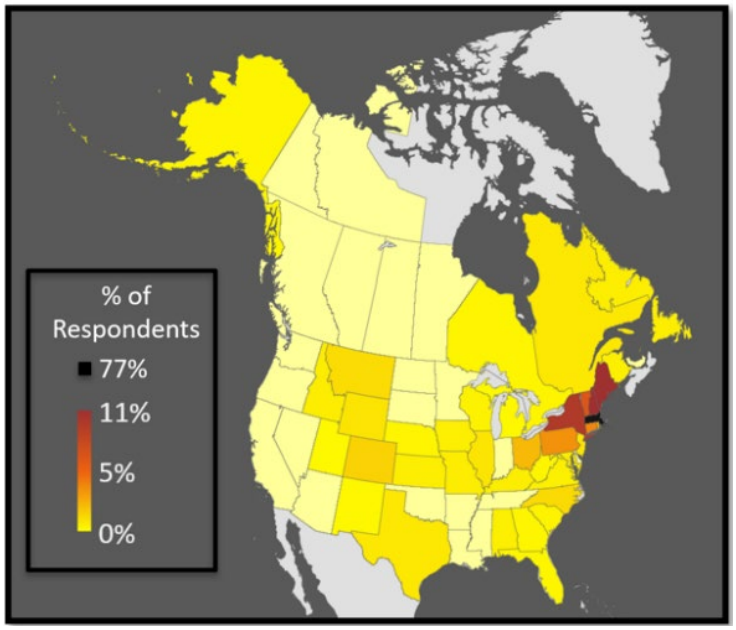

Figure 1. Percent (%) of Massachusetts hunter survey respondents that have hunted in each of the following states or provinces in the United States or Canada, respectively, in North America over the last five years. Source of data: DiRenzo et al. 2024.

Massachusetts constituents are also concerned about CWD arrival in MA, where there have been no known CWD detections as of June 2023. According to a 2023 survey of hunters in MA conducted by MassWildlife (*n* = 8,065 total hunter respondents*;* of which *n* = 7,419 deer hunter respondents), 68% of deer hunters were concerned about CWD entering MA and 88% of deer hunters said that it was at least moderately important to keep CWD out of MA, indicating a majority of deer hunters in MA may support CWD risk reduction actions in MA (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024). In addition, according to the 2023 survey of MA hunters, 23.1% of respondent deer hunters have hunted for cervids in the last five years within states or provinces where CWD has been detected (Figure 1) and 21.2% of respondent deer hunters transported deer back into MA. MassWildlife also found that only 8% of deer hunters had either stopped or reduced their time hunting in areas with positive CWD detections.

In the survey, MassWildlife also asked participants, "how many deer have you harvested that tested positive for CWD?" A total of six respondents said that they had at least one deer test positive for CWD of which three respondents said that they imported the CWD-positive deer into MA, resulting in a minimum estimate of 32 CWD positive deer (= (3 deer positive deer / 8,065 total hunter respondents) * 84,580 total license holders) being imported into MA in the last five years. However, testing harvested deer for CWD is not a strict requirement in most places, and only 11% of hunters who reported harvesting deer outside of MA also reported having those deer tested for CWD. Therefore, our estimate of 32 CWD positive deer entering MA in the last five years is likely an underestimate. When asked about how they transported harvested deer from out of state into MA, the three respondents that reported having a CWD positive harvested deer either indicated "already processed & packaged" or "not applicable." In MA, it is a violation of regulation to import whole carcasses or high-risk parts (e.g., head, brain, spinal tissues, bones) of any member of the Cervidae family (wild or captive) from a state or province that has detected CWD; it is legal to bring in deboned meat, cleaned skull caps, hides without the head, or a fixed taxidermy mount (Massachusetts Division of Fisheries and Wildlife, 2024*a*). This regulation accounts for why only 6.2% of deer hunting respondents reported transporting whole deer into MA compared to 21.2% of hunters having imported deer into MA in any condition including deboned and processed. However, there remains a significant risk of hunters illegally importing cervid parts or inadvertently consuming CWD prions in legally harvested, processed, and imported venison. The rapid rate of states detecting their first CWD cases, including nine new states in the last three years (Chronic Wasting Disease Alliance, n.d.*a*), particularly highlights the risk as deer reported from CWD negative states may very well be positive. As a result, there is likely a measurable risk of CWD being imported into MA by MA residents who hunt out of state.

To date, there have been no detections of CWD in MA, but testing has been limited in the state since 2012 (Figure 2; MA CWD response plan 2012; also see section below *RISK OF CWD ENTERING MASSACHUSETTS AND SURVEILLANCE*). As of May 2024, the closest known detections of CWD infected deer to the state of MA were in New York (which has not detected CWD subsequently since 2005; New York State Department of Environmental Conservation, n.d.) and Quebec (which also has not detected CWD infected deer since 2018; Gouvernement du Québec, 2024). Outside of those two locations, the next closest state/province that has detected CWD is Pennsylvania, where CWD is actively spreading in free-ranging and captive deer (Figures 2, 3).

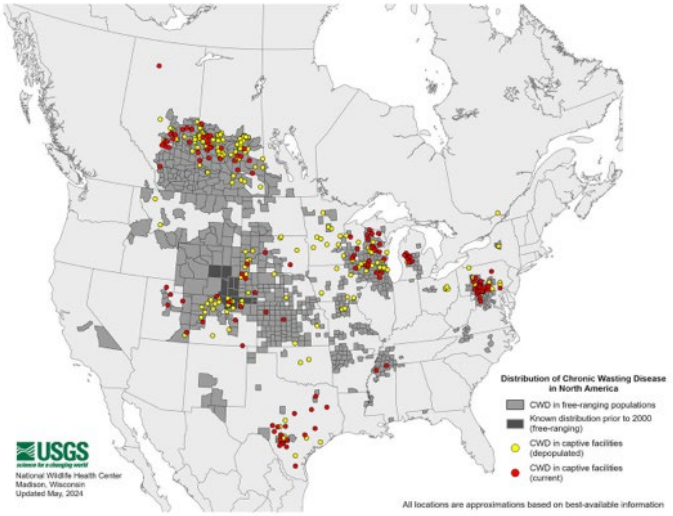

Figure 2. From U. S. Geological Survey (2024). Distribution of chronic wasting disease (CWD) in North America, as of May, 2024.

With each passing year, the number of states and provinces in North America where CWD is detected is growing (Chronic Wasting Disease Alliance, n.d.*a*); as of May 2024, there were 34 U.S. states and 5 Canadian provinces that had detected CWD positive free-ranging and/or captive cervids (Figure 2; U. S. Geological Survey, May 2024). This suggests that there may be an increasing risk of CWD entering and establishing in MA as the number of CWD cases increases across North America.

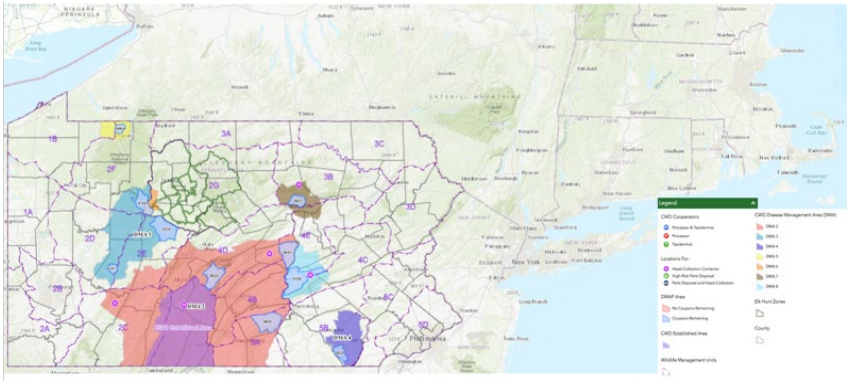

Figure 3. From Pennsylvania Game Commission (n.d.). Chronic wasting disease management areas in Pennsylvania between 2023 - 2024, map accessed in April, 2024.

In addition to risks posed to wildlife health by CWD, there are associated economic costs of CWD. Chiavacci (2022) showed that natural resources agencies that have detected CWD spent eight times more on CWD-related costs than natural resource agencies in states with no known CWD cases (Figure 4). These results highlight the financial burden that states face once CWD arrives and illustrates how money might be reallocated from conservation priorities to CWD disease management post arrival.

MassWildlife operates under state-specific legislation to address specific wildlife threats and achieve their agency's mission. MassWildlife's regulatory authority is granted by the Massachusetts General Law Chapter 131 (Regulatory Authority: M.G.L. c. 131, § 5). Massachusetts operates under the following statutes related to cervid management: damage by moose or deer (Regulatory Authority: M.G.L. c. 131, § 1I), disposition of deer, rules and regulations, permits, fees (Regulatory Authority: M.G.L. c. 131, §

22A), and deer tags (Regulatory Authority: M.G.L. c. 131, § 72). Statutes can only be changed by the legislature, and MassWildlife can make recommendations to the Massachusetts Division of Fisheries and Wildlife Board to change regulations. Massachusetts also has regulations related to deer hunting and tagging (Regulation 321 CMR 3.00; Massachusetts Division of Fisheries and Wildlife 2023*a*) and miscellaneous regulations related to the possession and propagation of captive cervids (Regulation 321 CMR 2.00; Massachusetts Division of Fisheries and Wildlife 2023*b*).

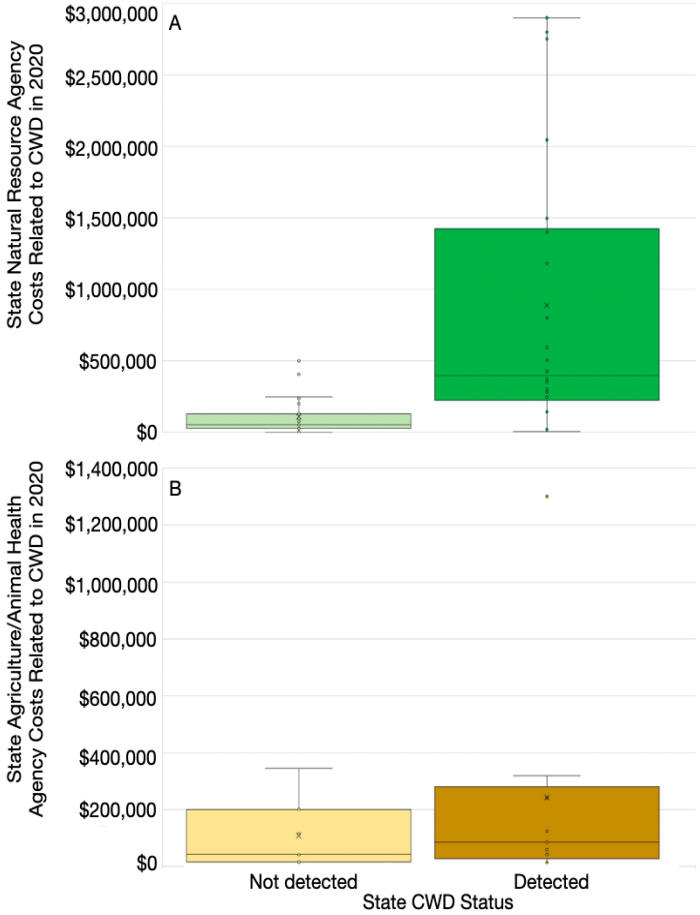

Figure 4. From Chiavacci (2022). Distribution of reported chronic wasting disease (CWD) costs in states in 2020 that have and have not had CWD detections. Panel (A) relates to state natural resource agencies, and (B) relates to state agriculture/animal health agencies. Box plots show the middle 50% of values (from the 25th to 75th percentiles) with a line for the median, whiskers extending to the minimum and maximum non-outlier values, and dots outside of the box or whiskers for any outliers.

Deer management decisions, including regulation-setting, are under the direct authority of the Massachusetts Division of Fisheries and Wildlife Board (herein referred to as 'the Board'; Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 19 Dec 2023). Determining appropriate regulations occurs by thorough evaluation of alternatives by MassWildlife internally, presentations by MassWildlife staff to the Board, and then, a public comment period (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 19 Dec 2023). During the public comment period, anyone from the public is invited to attend public hearings and provide comments. Following the public hearings, the Board approves or rejects the recommendations for regulatory changes. Following the Board approval process, the package then goes to the Executive Office of Energy

and Environmental Affairs for approval, followed by the Executive Office of Administration and Finance, and the Governor's Office. Obtaining the final signatures from the various levels of state government for the regulations to be promulgated may take two to six months, and the entire process can take more than a year (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024).

MassWildlife drafted their first CWD response plan in 2005, and it was updated roughly annually until 2012, when federal funding for CWD-specific positions at the state level were discontinued, and the CWD Program Coordinator contract position ended at MassWildlife (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024). In 2012, there were only 22 CWD positive U.S. states and 2 Canadian provinces. Figure 5 shows the distribution of CWD across North America in 2014 for reference. Today, as of May 2024, there are 34 CWD positive states and five provinces across North America (Figure 2). As a result, there is a need to update the MA CWD management plan and consider the latest CWD distributions and science. This effort is aided by renewed interest in CWD management and research at the federal level. For example, the U.S. Department of Agriculture has provided funds to assist states and territories in managing CWD spread and establishment (U.S. Department of Agriculture, Animal and Plant Health Inspection Services n.d.). Some of these resources have been available to MA to aid in the prevention and surveillance of CWD.

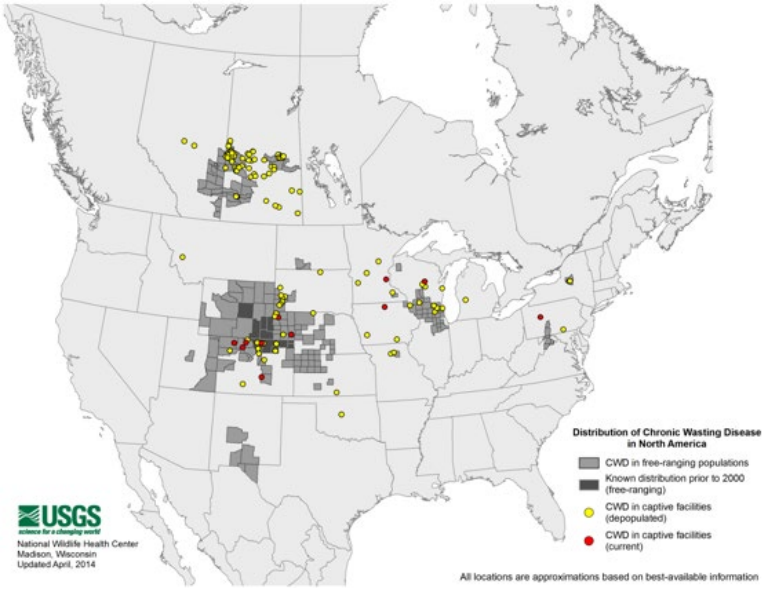

Figure 5. From U. S. Geological Survey (2014). Distribution of chronic wasting disease (CWD) in North America, as of April, 2014.

Developing an updated CWD management plan for MA will require that MassWildlife evaluate whether and how to minimize the risk of CWD introduction and spread while considering the satisfaction of both hunters and the general public. The MA CWD management plan will include both free-ranging and captive cervid management activities and will be applicable to the entire state of MA (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024). However, care will be taken to identify actions that are appropriate in all locations where deer occur; this includes rural and suburban landscapes (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024). Because MA has no documented cases of CWD, the plan will encompass both preventative (proactive) as well as reactive actions in the event CWD is detected across a 10-year

time horizon (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024).

CWD Background

In 1967, CWD was first recognized as a disease in captive mule deer at the Colorado Division of Wildlife Foothills Wildlife Research Facility in Fort Collins, Colorado. In 1978, CWD was determined to be a transmissible spongiform encephalopathy. Several species in the family Cervidae (collectively referred to as 'cervid' hereafter) are susceptible to CWD, and the disease is always fatal with no known cure (reviewed by Escobar et al., 2020). Chronic wasting disease is spread both directly via contact with infectious live animals and indirectly through contaminated bodily fluids, tissues, and environmental components (Almberg et al., 2011). In 1979, the disease was diagnosed in captive mule deer and black-tailed deer (*Odocoileus hemionus columbianus*) at the Wyoming Fish and Game Department's Sybille Wildlife Research Facility (Chronic Wasting Disease Alliance, n.d.*a*). Then, in 1981, the first documented occurrence of CWD in a wild cervid was detected by the Colorado Division of Wildlife in a free-ranging elk (*Cervus canadensis*; Chronic Wasting Disease Alliance, n.d.*a*). Later, in 1985, the same agency documented the first case of CWD in a wild mule deer (Chronic Wasting Disease Alliance, n.d.*a*). Also in 1985, the Wyoming Fish and Game Department documented the state's first case of CWD in a wild mule deer (Chronic Wasting Disease Alliance, n.d.*a*). The first confirmed case of CWD outside the Colorado/Wyoming endemic zone was at a captive elk facility in Saskatchewan in 1996 (Chronic Wasting Disease Alliance, n.d.*a*). Years later in 2001, CWD was confirmed in wild and captive white-tailed deer (*Odocoileus virginianus*) in South Dakota and Nebraska, respectively (Chronic Wasting Disease Alliance n.d.*a*). The first diagnosis of CWD in free-ranging moose (*Alces alces*) was made in Colorado in 2005 (Baeten et al. 2007). Since these early CWD detections, it has spread across North America (Figure 2 & 5), as well as spread to Asia (Sohn et al. 2002) and Europe (Tranulis et al. 2021). This broad geographic distribution highlights the disease's ability to spread across landscapes, continents, and borders, affecting different cervid species globally. The continued spread of CWD is a major concern for hunters, farmed deer producers, and wildlife managers because it is always fatal, has no known cure, and persists in the environment for many years (Miller & Vaske, 2023).

Risk of CWD entering Massachusetts and surveillance

Aside from closer detections of CWD to MA, other risk factors to CWD *entering* MA include (reviewed by Leiss et al. 2017): interstate transportation of (live or dead) cervids by hunters or the captive cervid industry, natural migration of wild cervid populations, and the use of cervid products that may contain prions (Gough & Maddison 2010).

If CWD entered MA, several risk factors influence CWD's ability to *establish and spread* in MA. First, CWD prions can persist in the environment for years, making them difficult to eliminate (Johnson et al. 2006; Almberg et al. 2011). Second, hunting and wildlife feeding practices could cause animals to aggregate and facilitate CWD spread (Sorensen et al. 2014). Third, some white-tailed deer genotypes are more susceptible to infection than others, which influences disease spread and selection (reviewed by Ketz et al. 2022). Similarly, some cervid species are more or less susceptible to CWD infection, and species composition across the landscape could facilitate or hamper disease spread (reviewed by Escobar et al. 2020).

MassWildlife received funding to sample between 200 and 500 animals annually from 2002 to 2012 (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024).

Between 2002 and 2012, a total of 4,356 CWD samples were collected from wild white-tailed deer and moose (both hunter harvested and "suspect" animals). An additional 92 samples were collected during that same timeframe from captive cervids including fallow deer (*Dama dama*), sika deer, red deer, elk, reindeer, and white-tailed deer. During this time, CWD sampling effort varied by wildlife management zone (WMZ) and was based on the deer population size, number of captive cervid facilities in each WMZ, and the proximity to New York state (which had tested positive in 2005; Chronic Wasting Disease Alliance *n.d.*a); where areas to the west that border New York (where a positive was detected in 2005) and counties with captive cervid facilities were prioritized for sampling. In 2012, the federal funding source was discontinued, ending MassWildlife's surveillance efforts (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024).

In 2023, MassWildlife received U.S. Department of Agriculture (USDA) funds for CWD sampling, and 242 samples were collected (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024). MassWildlife used the SOP4CWD software (Cornell Wildlife Health Lab, 2023), which uses an economic efficiency model to determine surveillance sample size, and they identified that a minimum of 150 samples annually need to be collected (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 12 Feb 2024).

Managing wildlife diseases in the northeast can be challenging because states are small, inter-state travel is easy, and while some regulations are shared across states, they may also differ. For example, bans on natural urine-based scent lures (Connecticut (CT), Rhode Island (RI), Vermont (VT); Deer and Deer Hunting, 2021) and the transport of high-risk carcass parts (e.g., neurological tissues; all of Northeast United States; Theodore Roosevelt Conservation Partnership, 2019) are common; however, there are other actions that are not as broadly implemented, such as those related to hunting regulations (e.g., feeding [CT, MA, New Hampshire (NH) allowed; Maine (ME) conditionally banned; whereas NY, RI, VT not allowed] or baiting [NH allowed; CT, MA, ME conditionally banned; whereas NY, RI, VT not allowed]; Chronic Wasting Disease Alliance n.d.*b*). There remains a high degree of uncertainty surrounding the efficacy of proactive and reactive measures to the management of CWD.

Given the threat of CWD invasion to MA, proactively developing a framework for decision makers to plan for management is warranted. Here, we describe the structured decision making process used by MassWildlife during a 2.5-day workshop to address CWD management in MA.

STRUCTURED DECISION MAKING OVERVIEW

A 2.5-day rapid prototyping structured decision making workshop was held with MassWildlife staff to develop a decision framework for CWD management in MA. Decision analysis is the formal application of common sense for situations too complex for the informal use of common sense (Kenney, 2004). It is a logical, deliberate process based on agency and stakeholder values, and values are explicitly incorporated via objectives into the decision. Structured decision making is also a transparent, reproducible decision-making process; and in this report, we outline the structured decision making process for CWD management in MA.

First, we provide an overview of structured decision making. Note that although we worked through each of the steps (Problem, Objectives, Alternatives, Consequences, Tradeoffs; Figure 6), they are iterative and can be revised. Also note that this was a rapid prototype that spanned 2.5-days, where other structured decision making processes may take longer.

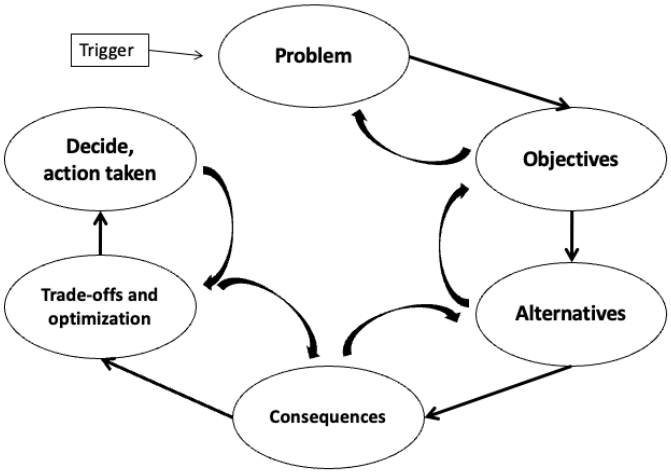

Figure 6. A visual diagram of the steps during a structured decision making process. Note the linear and re-iterative visiting of the steps.

Problem – The structured decision making process starts by defining the problem. During this step, we defined who the decision maker is, what triggered the decision, why the decision matters, and list any known legal, financial, and political constraints. We also discussed the frequency and timing of the decision, and the scope (temporal, spatial, taxonomic, etc.). The problem statement related to CWD management in MA can be located under the *Introduction* section above.

Objectives – Fundamental objectives describe the set of complete and independent concerns that a decision maker has when making a decision. As a result, they are used as the criteria to evaluate how well the alternative strategies (defined in the *Alternatives* section next) perform and are measured by measurable attributes. Measurable attributes include a description of what will be measured (i.e., the attribute), the type of attribute (e.g., natural, proxy, or constructed), the units of the attribute, the aspiration of the decision maker (e.g., maximize, minimize, etc.), and a baseline value (if applicable).

Alternatives – Alternatives describe management actions that can change or influence the outcomes of the fundamental objectives (and their measurable attributes). Alternatives also define the set of options from which the decision will originate (i.e., we cannot select an action that is not identified for consideration). Alternatives must be financially, legally, and politically reasonable. We can bundle a number of distinct alternative actions that might influence different parts of the system into "alternative strategies".

Consequences – To evaluate the performance of each alternative strategy, the outcome of each measurable attribute (i.e., fundamental objective) is predicted under each alternative strategy. Because data and predictive models were not available on the timeline of this rapid prototype, the expertise of MassWildlife staff was used to elicit specific parameters during the consequence assessment (expert elicitation methods: Morgan, 2014; Sutherland and Burgman, 2015). Experts hold privileged information that is acquired through their experience and training.

Tradeoffs – When making complex wildlife management decisions, managers are often tasked with balancing multiple objectives (Runge et al. 2013). When these objectives are in competition with one another, such that no alternatives can simultaneously maximize the performance of all objectives, there are tradeoffs that must be navigated. To evaluate tradeoffs in this management decision, decision makers might be asked to indicate the relative importance of each fundamental objective using a

weighting procedure. Weights provide the general importance or relative values that a decision maker places on each fundamental objective, and weights are context dependent, meaning that they should only be interpreted for the decision at hand (Hemming et al. 2022). Fundamental objective weights should align among planning documents, legislation, and the decision. In our case, the weights should represent the values of MassWildlife on each fundamental objective.

In the following section (*Workshop structure*), we provide details on who attended the workshop from which agency and the materials covered each day.

WORKSHOP STRUCTURE

A 2.5-day rapid prototyping structured decision making workshop was planned with MassWildlife staff from 13 – 15 February 2024 at the Massachusetts Division of Fisheries and Wildlife Headquarters (1 Rabbit Hill Rd, Westborough, MA).

Before the 2.5-day rapid prototyping workshop, on Dec 19, 2023, we held a virtual pre-workshop meeting to provide an overview of the structured decision making process to the participants, as well as to start defining the problem. At this meeting, the following participants attended: Martin Feehan (MassWildlife, Deer and Moose Biologist), David Wattles (MassWildlife, Black bear and Furbearer biologist), Alyssa Grayson (MassWildlife, CWD Contractor), Susan McCarthy (MassWildlife, Wildlife biologist), Michael Huguenin (MassWildlife, Assistant Director of Wildlife Research), and Margaret McEachran (University of Massachusetts, and volunteer at the U. S. Geological Survey). The two U. S. Geological Survey biologists (DiRenzo and Cook) facilitated and led the meeting. Following the meeting, DiRenzo and Cook drafted the initial problem statement and circulated it to the group.

On Day 1 (Feb 13, 2024) of the workshop, we held the workshop virtually from 9 am – 4:30 pm due to a predicted snowstorm in the area. DiRenzo and Cook facilitated the conversations around revisiting the problem statement, defining objectives, and listing alternatives. All of the same participants from the virtual pre-workshop meeting were present during the duration of the workshop (Feehan, Wattles, Grayson, McCarthy, McEachran), except for Huguenin. We also had the addition of Meghan Crawford (MassWildlife, Community Engagement Biologist) for the remainder of the workshop. This group of participants (Feehan, Wattles, Grayson, McCarthy, McEachran, Crawford) will be referred to as the "core team."

On Day 2 (Feb 14, 2024) of the workshop, we met in person at the MassWildlife Headquarters in Westborough, MA from 9 am – 4:30 pm. DiRenzo, Cook, and McEachran facilitated the conversations around revisiting the problem statement, revisiting the objectives, bundling the alternatives into strategies, and eliciting the consequences of alternative strategies on fundamental objectives. The core team was present during the 2nd day plus the addition of the following individuals: Jody Simoes (MassWildlife, Human Dimensions Project Leader), Nicole McSweeney (MassWildlife, Assistant Director of Outreach & Education), Emily Stolarski (MassWildlife, Communication Coordinator), Michelle Collins (MassWildlife, Outreach and Marketing Coordinator), Astrid Huseby (MassWildlife, R3 Coordinator), Joseph Rogers (MassWildlife, District Supervisor), Andrew Madden (MassWildlife, District Supervisor), and Jason Zimmer (MassWildlife, District Supervisor).

On Day 3 (Feb 15, 2024) of the workshop, we met in person at the MassWildlife Headquarters in Westborough, MA from 9 am – 2:30 pm. DiRenzo and Cook facilitated the conversations around revisiting the problem statement, revisiting the objectives, revisiting the alternative strategies,

visualizing and discussing the consequences of alternative strategies on objectives, and eliciting the weights on objectives. The core team was present during the 3rd day minus McEachran and plus Huguenin.

In the remaining sections of the document (*Objectives*, *Alternatives*, *Consequences*, *Tradeoffs*, *Discussion*, *Next steps*), we document the application of structured decision making to CWD management in MA.

OBJECTIVES

During the rapid prototype, MassWildlife identified four fundamental objectives that are described in detail below (Figure 7). The group also assigned at least one measurable attribute per fundamental objective. In one case (fundamental objective 3), we used two attributes to describe different aspects of the fundamental objective.

In support of the four fundamental objectives, participants of the workshop also identified **means objectives** that influence the achievement of the fundamental objectives and describe the "how-to" (Figure 7).

They also identified three **process objectives** that describe the manner in which the decision is made. Here, the emphasis was on the quality of the process (e.g., efficient, fair, adherences to certain standards, etc.) and included a desire to:

- Use the best available science to inform management;
- Maintain public trust in MassWildlife;
- Develop a well-thought-out CWD management plan that achieves the mission of the agency and addresses concerns of relevant stakeholders.

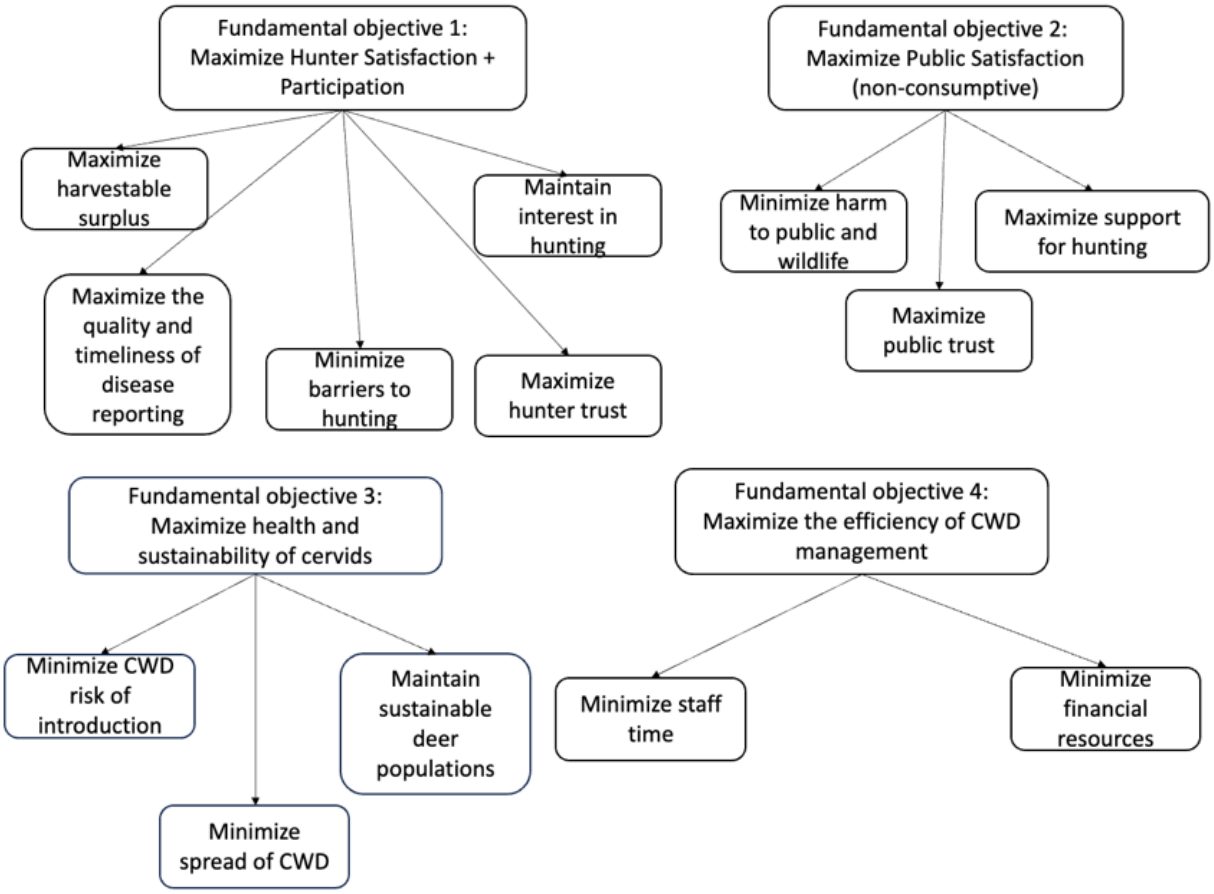

Figure 7. The objectives hierarchy with four fundamental objectives and between two to five means (or sub-objectives) per fundamental objective.

Fundamental objective 1: To maximize deer hunter satisfaction and participation in hunting in Massachusetts. MassWildlife is mandated to restore, protect, and manage land for wildlife to thrive and for people to enjoy (Massachusetts Division of Fisheries and Wildlife, 2024*b*). When discussing cervid management, the term "people" in the previous statement can be broken down into two populations: consumptive and non-consumptive. We defined the consumptive population as hunters. For hunters to enjoy wildlife, the Wildlife Section feels that it is their responsibility to maintain the hunting public's confidence in deer management and the safety of consuming hunter-harvested deer. The revenues from hunting sales are also primarily used for conservation programs at MassWildlife. Under fundamental objective 1, the following five means objectives were identified: maximize harvestable surplus, maximize the quality and timeliness of disease reporting, minimize barriers to hunting, maximize hunter trust, and maximize interest in hunting.

Measurable attribute 1: Number of hunters who report hunting deer on MassWildlife's annual hunter survey in year 10

- Type = natural
- Units = number of hunters
- Aspiration = maximize
- Baseline values = ~43,000 deer hunters as of 2024

The baseline value is a rough estimate based on the number of deer hunting licenses sold, the proportion of respondents of the MassWildlife annual hunter survey who said they hunted in the previous year, and the proportion of respondents of the MassWildlife annual hunter survey who said they hunted deer. This information was shared by MassWildlife workshop participants during the workshop discussions.

Note that MassWildlife's annual hunter survey is distinct from the previously mentioned CWD survey effort. The MassWildlife annual hunter survey is conducted annually and sent to 20,000 license holders to primarily measure effort and participation across game species and has a typical response rate of approximately 30%. This information was shared by MassWildlife workshop participants during the workshop discussions

Fundamental objective 2: To maximize public satisfaction (non-consumptive) with deer and CWD management in Massachusetts. Similar to fundamental objective 1, MassWildlife aims to maximize public satisfaction (non-consumptive stakeholders) as part of their mandate, responsibly manage cervids, as well as maximize public trust and credibility in the agency. Under fundamental objective 2, the following three means objectives were identified: to minimize harm to public and wildlife, maximize public trust, and maximize support for hunting.

Measurable attribute 2: The average trust on a scale from 1 to 5 that a nonhunting member of the public has in MassWildlife to appropriately manage CWD in year 10

- Type = constructed
- Units =
  - 1 = little to no trust in MassWildlife
  - 5 = a lot of trust in MassWildlife
- Aspiration = maximize

Fundamental objective 3: To maximize health and sustainability of cervids. MassWildlife has an ethical responsibility and land ethic mandate to reduce the risk of CWD introduction and spread in MA. Under fundamental objective 3, the following three means objectives were identified: minimize risk of CWD introduction, minimize spread of CWD, and maximize sustainable deer populations. We identified the following two measurable attributes to characterize this fundamental objective.

Measurable attribute 3a: The average prevalence of CWD across the state of MA in year 20 (Two notes [1] this is true CWD prevalence, not apparent prevalence calculated from a sample of the population; and [2] we use year 20 here instead of year 10 to include an estimate of the enzootic equilibrium)

- Type = natural
- Units = prevalence
- Aspiration = minimize

Measurable attribute 3b: The deer population size in year 10 measured by the percent deviation from the current deer population within a CWD affected area that can be attributed to CWD management only (i.e., this metric does not include natural or background fluctuations of deer populations)

- Type = constructed
- Units =
  - < 100% = deer population decline (e.g., 95% means 5% less deer than MA currently has in 2024)

- 100% = stable deer population (e.g., 100% means that the deer population has not increased or decreased, and it is identical to the current 2024 MA deer population size)
- > 100% = deer population increase (e.g., 105% means 5% more deer than MA currently has in 2024)

- Aspiration = maximize
- Baseline = 100%

Fundamental objective 4: To maximize the efficiency of chronic wasting disease management. CWD management can be costly in terms of staff time and financial resources to execute management actions. In other states, it has been observed that CWD management takes away from other conservation priorities (Chiavacci 2022). Under fundamental objective 4, the following two means objectives were identified: minimize staff time, and minimize financial resources.

Measurable attribute 4: The cumulative staff hours dedicated to CWD over the next 10 years (2024 – 2034)

- Type = natural
- Units = cumulative number of hours
- Aspiration = minimize

ALTERNATIVES

We first brainstormed a list of potential management actions intended to influence the fundamental objectives listed above. We specified if the actions would be implemented proactively (i.e., before CWD introduction), reactively (i.e., after CWD introduction), or as either proactively or reactively. If an action can be taken either proactively or reactively, in most cases, it is the same action unless otherwise specified.

Then, for each proactive and reactive list of management actions, we identified which management actions could be used under three scenarios varying in effort and intensity of actions: minimal, intermediate, and intensive. Note that not all management actions were assigned to a scenario. This process generated a list of three proactive scenarios and three reactive scenarios as follows:

Minimal proactive:

- Maintain existing captive cervid permitting, allowing for the continued permitted possession of captive deer for propagation or education
- Make no directives or regulations for cervid carcass disposal
- Minimal communications to inform public/hunters on CWD-related issues
- Maintain existing interagency coordination on CWD or cervid-related issues
- Continue allowance of deer-based lures for hunting
- Maintain existing enforcement of CWD or cervid-related issues
- Maintain existing importation rules of cervid carcasses
- Maintain existing deer harvest regulations and management practices

Intermediate proactive:

- Pass regulations for zoos that clearly define exemptions for Association of Zoos & Aquariums (AZA) accredited facilities, while banning captive cervids at other facilities

- Sunset current captive cervid permits allowing for the possession of only existing individual deer and ceasing issuance of new permits for new captive cervid facilities
- Require CWD testing of all deceased captive cervids
- Contract for lined landfills for cervid carcass disposal
- Increase coordination with Tribes for CWD testing of harvested deer
- Request assistance from state partners to enhance enforcement, implementation, and coordination of proactive CWD management strategies
- Pass regulations banning baiting/feeding of deer
- Pass regulations banning deer-based lures while promoting low-risk products (e.g., synthetic lures)
- Pass regulations banning importation of high-risk deer parts (e.g., brain, head, spinal cord) except from New England states
- Increase issuance of deer damage permits
- Actively encourage and incentivize private landowners to increase access for deer hunting
- Increase antlerless deer permit issuance
- Increase deer hunting season lengths

Intensive proactive:

- Pass regulations banning captive deer at all zoo facilities
- Sunset current captive cervid permits allowing for the possession of only existing individual deer and ceasing issuance of new permits for new captive cervid facilities
- Require CWD testing of all captive cervids
- Make cervid carcass disposal recommendations and provide dumpsters
- Contract for lined landfill disposal for cervid carcass disposal
- Increase coordination with Tribes for CWD sample collection
- Coordinate with other agencies and partners for communications and implementation of proactive CWD management strategies
- Pass regulations banning all deer baiting, feeding, and salt licks
- Pass regulations banning deer-based lures while promoting low-risk products (e.g., synthetic lures)
- Increase enforcement on rehabilitators for deer possession violations
- Actively work with legislators and hunting organizations to remove archery discharge setbacks statutes and municipal discharge ordinances
- Pass regulations requiring the deboning of deer carcasses for importation from all states
- Pass regulations restricting the selling of cervid hides, hooves, and bones
- Increase overall deer harvest by increasing antlerless deer permit allocations, increasing the issuance of deer damage permits, creating other antlerless harvest opportunities, increasing buck bag limits, and by lengthening seasons

Minimal reactive:

- Maintain existing captive cervid permitting
- Make no deer carcass disposal recommendations
- Maintain current interagency coordination on deer-related topics
- Maintain current enforcement of CWD-related regulations
- Maintain existing importation of deer carcasses regulations
- Maintain existing deer harvest regulations and management practices

Intermediate reactive:

- Close all captive facilities once CWD is detected in a cervid facility
- Pass regulations for zoos that clearly define exemptions for AZA accredited facilities, while banning captive cervids at other facilities
- Pass cervid carcass disposal regulations and provide dumpsters
- Increase coordination with Tribes for CWD sample collection
- Coordinate with other agencies and partners for communications and implementation of reactive CWD management strategies
- Pass regulations banning all deer-based lures (e.g., scent glands, urine) for deer hunting
- Promote use of low-risk cervid attractant products (e.g., grunt tubes, etc.)
- Actively work with legislators and hunting organizations to remove archery discharge setbacks and municipal discharge ordinances
- Pass regulations banning the importation of high-risk cervid parts except for New England states
- Pass regulations banning the selling of cervid hides, hooves, and bones
- Actively encourage per license, antlerless permits, season lengths
- Implement regular CWD testing of remaining captive cervids including IHC or ELISA testing of retro-pharyngeal lymph nodes for deceased captive deer and RT-QulC for live captive deer
- Depopulate captive cervid herds within facilities where CWD occurs
- Contract for lined landfill for cervid carcass disposal
- Purchase an incinerator for cervid carcass disposal
- Conduct low intensity culling of deer in areas after CWD detection
- Conduct some targeted deer removal by hunters in areas after CWD detection
- Increase staff capacity to work on CWD-related issues
- Work with MA Department of Transportation and Department of Public Words to reduce movement of cervid roadkill
- Coordinate with private landowners to increase access to private properties for hunting opportunities
- Replace hunter tags if harvested deer is CWD-positive

Intensive reactive:

- Close all captive cervid facilities within MA once CWD is detected in either a cervid facility or wild animal
- Require all captive deer removed as part of closure to be tested for CWD
- Include zoos in permitting, change permits for propagators, educators
- Pass cervid carcass disposal regulations and provide dumpsters
- Increase coordination with Tribes for CWD sample collection
- Coordinate with other agencies and partners for communications and implementation of reactive CWD management strategies
- Pass regulations that ban all deer-based lures (e.g., scent glands, urine) for cervid hunting
- Promote use of low-risk cervid attractant products (e.g., grunt tubes, etc.)
- Actively work with legislators and hunting organizations to remove archery discharge setbacks statutes and municipal discharge ordinances

- Pass regulations requiring deboned cervid parts from all states (regardless of CWD status)
- Increase issuance of deer damage permits
- Actively encourage and incentivize private landowners to increase access for deer hunting
- Pass regulations to increase buck bag limits, buck tags per license, antlerless permits, and season lengths
- Purchase a digester, lined landfill contract, or incinerator (whichever is most effective) for cervid carcass disposal
- Conduct targeted deer removal by hunters/other groups in an area after CWD detection
- Conduct high intensity culling of cervids in an area following hunting opportunity after the CWD detection
- Increase staff capacity to work on CWD-related issues through financial and hiring actions
- Pay landowners for hunter and sharpshooter access for lethally removing cervids
- Incentivize hunting within the CWD positive zones and adjacent containment areas to reduce deer densities and slow the spread
- Replace hunter tags if harvested deer is CWD-positive

Note that none of these alternatives include any type of communication plan because an audience, a message, and a goal (e.g., to inform an audience or change behavior) were not identified. When this rapid prototype is revisited in the future, the identified management actions can help facilitate and aid those conversations.

Also note that surveillance/monitoring plans were not included because those are not management tools in and of themselves; rather they are tools used to inform management actions. A surveillance plan that appropriately informs the preferred management alternative can be developed at a later stage.

Lastly, we paired proactive and reactive scenarios to generate a list of five alternative strategies:

(1) minimal proactive + minimal reactive
(2) intermediate proactive + intermediate reactive
(3) intensive proactive + intermediate reactive
(4) minimal proactive + intensive reactive*
(5) intensive proactive + intensive reactive

*Note, this strategy is the closest to how MassWildlife is currently poised to manage CWD, where there are currently no proactive actions being taken and they may need to aggressively target any positive CWD detections (Martin Feehan, Massachusetts Division of Fisheries and Wildlife, oral communication, 13 Feb 2024).

CONSEQUENCES

During the consequence step, we used the five alternative strategies generated above, and we measured their performance in terms of our fundamental objectives using the following two-step approach: (1) expert elicitation and (2) predicting consequences.

Expert elicitation

Because data and predictive models were not available on the timeline of this rapid assessment, we used the expertise of the MassWildlife staff to elicit specific parameters during our consequences assessment. MassWildlife staff were asked to self-select as experts, and different staff participated to estimate different parameter values. Specifically, the following MassWildlife staff participated for the human dimension's measurable attributes (e.g., hunter and public satisfaction): Jody Simoes, Nicole McSweeney, Emily Stolarski, Michelle Collins, and Astrid Huseby. We also had the following district managers participate in the expert elicitation for parameters related to human dimensions, CWD introduction, CWD spread, and staff time: Jason Zimmer, Andrew Madden, and Joseph Rogers. A list of participants and their job titles are included in the *Workshop structure* section above for more information on expertise.

Across all alternative strategies and time periods of CWD introduction (i.e., introduction in year 2.5, 7.5, and 10+), we asked MassWildlife staff to assume that their communication plan is the same as status quo (i.e., what they are already doing).

In terms of surveillance, we asked MassWildlife to assume an intensive surveillance plan that detects CWD shortly after arrival. Aspects of a surveillance program and its power to detect CWD may be evaluated separately.

The general structure of the elicitation was as follows: the following questions were presented to experts in the order in which they appear here. Each question was presented one at a time, and in some instances, experts discussed the baseline value and then made predictions on the consequences of the alternative strategies on the fundamental objectives. After all self-identified experts were done answering each question, responses were collected, and the next question was asked. For each question, we only asked experts for their best guess. No measure of uncertainty or confidence was elicited during the rapid prototype. We also did not include any group discussion of values following elicitation because of the time constraint of the workshop.

Because there was uncertainty in when CWD would arrive in MA, we first asked the experts to estimate the probability that CWD would be introduced within three different time periods:

- **CWD introduction:** What is the probability (or percent chance) that CWD will be introduced in MA in each of the following three time periods?
    1. Between 1 – 5 years from now (February 14, 2024)
    2. Between years 6 – 10 from now (February 14, 2024)
    3. Greater than 10 years from now (February 14, 2024)

We then asked experts to provide their best estimate using their expert knowledge for the following parameters under each of the five alternative strategies and assuming three different CWD arrival timelines: CWD arrives in 2.5 years (i.e., arrives in 2027), arrives in 7.5 years (2031), and arrives after 10 years (after 2034).

- **CWD prevalence:** We used a simple logistic regression model constructed by Margaret McEachran that projects CWD prevalence as a function of time since introduction, where experts were asked to estimate the growth rate of the disease (Samuel, 2023; Supplementary Information S1).
- **Hunter satisfaction**: What would be the number of hunters who report hunting deer on the annual hunter survey if CWD was introduced in MA in each of the three time periods under each of the five alternative strategies?

* Estimates for hunter satisfaction included the background expected decline in hunter participation over time.

- **Public trust:** What is the level of public trust in the management of CWD by MassWildlife if CWD was introduced in MA in each of the three time periods?
- **Deer population:** What is the percent deviation of a deer population within a CWD affected area as a result of CWD management only if CWD was introduced in MA in each of the three time periods?
    * Estimates for deer population did not include any type of natural changes to deer population growth or decline.
- **Staff time:** What is the average number of annual hours of staff time under each of the following alternative strategies?
    1. Proactive minimal
    2. Proactive intermediate
    3. Proactive intensive
    4. Reactive minimal
    5. Reactive intermediate
    6. Reactive intensive

Following expert elicitation, for all parameters except staff time, we calculated the average value under each CWD introduction time period under each of the five alternative strategies. To determine CWD prevalence in year 20, we extracted the CWD prevalence from the logistic regression under each of the five alternative strategies at years 18 (if CWD was introduced in year 2.5) and 13 (if CWD was introduced in year 7.5). To estimate cumulative staff time, we summed up the number of staff hours over a 10-year period under each of the five alternative strategies.

Predicting consequences

We used Simple Multi-Attribute Rating Technique (SMART) tables to visualize the consequences (i.e., performance) of each alternative by fundamental objective in each of the three time periods (i.e., introduction of CWD in 2.5, 7.5, and +10 years; Risawandi et al. 2016). The values displayed in the SMART tables below (Tables 1 – 3) represent raw, unweighted average values across all experts that responded to the questions.

Table 1. Raw, unweighted consequence assessment using expert judgement if chronic wasting disease (CWD) were introduced in year 2.5 (i.e., arrives in 2027). Blue colors indicate better performance on that particular attribute (row), white colors are intermediate, while red colors indicate worse performance on that particular attribute. Objective (obj) number (#) along with fundamental objective are listed in the first two left-most columns along with the means objective most related to the measurable attribute and the desired direction of the scale. The five alternative actions are listed in the following five columns. This data was collected as part of the expert elicitation process during the workshop and generated by MassWildlife participants.

Obj #	Fundamental objective	Means objective	Direction of scale	Minimal proactive and minimal reactive	Intermediate proactive and intermediate reactive	Intensive proactive and intermediate reactive	Minimal proactive and intensive reactive	Intensive proactive and intensive reactive
1	Maximize hunter Satisfaction + Participation	Maintain interest in hunting	Maximize	27500	30667	29611	29222	30850
2	Maximize public satisfaction (non-consumptive)	Maximize public trust	Maximize	2.82	3.41	2.97	2.68	2.91
3a	Maximize health and sustainability of cervids	Minimize spread of CWD	Minimize	0.37	0.19	0.16	0.23	0.04
3b	Maximize health and sustainability of cervids	Maintain sustainable deer populations	Maximize	101	81	74	78	69
4	Maximize the efficiency of CWD management	Minimize staff time	Minimize	5966	15231	8116	23056	25206

Table 2. Raw, unweighted consequence assessment using expert judgement if chronic wasting disease (CWD) were introduced in year 7.5 (i.e., arrives in 2031). Blue colors indicate better performance on that particular attribute (row), white colors are intermediate, while red colors indicate worse performance on that particular attribute. Objective (obj) number (#) along with fundamental objective are listed in the first two left-most columns along with the means objective most related to the measurable attribute and the desired direction of the scale. The five alternative actions are listed in the following five columns. This data was collected as part of the expert elicitation process during the workshop and generated by MassWildlife participants.

Obj #	Fundamental objective	Means objective	Direction of scale	Minimal proactive and minimal reactive	Intermediate proactive and intermediate reactive	Intensive proactive and intermediate reactive	Minimal proactive and intensive reactive	Intensive proactive and intensive reactive
1	Maximize hunter satisfaction + participation	Maintain interest in hunting	Maximize	29100	31056	31444	31000	31550
2	Maximize public satisfaction (non-consumptive)	Maximize public trust	Maximize	2.91	3.59	3.32	3.09	3.15
3a	Maximize health and sustainability of cervids	Minimize spread of CWD	Minimize	0.28	0.07	0.06	0.16	0.01
3b	Maximize health and sustainability of cervids	Maintain sustainable deer populations	Maximize	101	82	81	76	71
4	Maximize the efficiency of CWD management	Minimize staff time	Minimize	2947	10219	9397	8644	15094

Table 3. Raw, unweighted consequence assessment using expert judgement if chronic wasting disease (CWD) were introduced after 10 years (i.e., arrives after 2034). Blue colors indicate better performance on that particular attribute (row), white colors are intermediate, while red colors indicate worse performance on that particular attribute. Objective (obj) number (#) along with fundamental objective are listed in the first two left-most columns along with the means objective most related to the measurable attribute and the desired direction of the scale. The five alternative actions are listed in the following five columns. This data was collected as part of the expert elicitation process during the workshop and generated by MassWildlife participants.

Obj #	Fundamental objective	Means objective	Direction of scale	Minimal proactive and minimal reactive	Intermediate proactive and intermediate reactive	Intensive proactive and intermediate reactive	Minimal proactive and intensive reactive	Intensive proactive and intensive reactive
1	Maximize hunter satisfaction + Participation	Maintain interest in hunting	Maximize	32430	31500	32050	32030	31650
2	Maximize public satisfaction (non-consumptive)	Maximize public trust	Maximize	4.27	4.39	4.11	4.36	4.05
3a	Maximize health and sustainability of cervids	Minimize spread of CWD	Minimize	0	0	0	0	0
3b	Maximize health and sustainability of cervids	Maintain sustainable deer populations	Maximize	101	94	89	98	89
4	Maximize the efficiency of CWD management	Minimize staff time	Minimize	1437	7712	10037	1437	10037

TRADEOFFS

We used a swing weighting approach to determine the relative importance of different fundamental objectives for this decision-making process (von Winterfeldt & Edwards, 1986). Swing weighting uses the range of possible outcomes, from the worst to the best, for each fundamental objective to elicit context-specific preferences via ranking and scoring. Before eliciting the ranks and scores, we set up five hypothetical alternatives using the best and worst outcomes per fundamental objective, where one fundamental objective was assigned its best outcome, and all other fundamental objectives were assigned their worst outcome (Table 4).

Table 4. List of five hypothetical alternatives MassWildlife staff were asked to consider during the swing weighting. Baseline refers to the worst possible outcome across all alternative strategies. The five distinct hypothetical alternatives are labeled #1 – 5 across the top in the last five columns of the table. In each hypothetical alternative, one fundamental objective was assigned its best outcome (across diagonal of hypothetical alternatives) and all other fundamental objectives were assigned their worst outcome.

Obj #	Fundamental objective	Measurable attribute	Direction	Baseline	1	2	3	4	5
1	Hunter satisfaction	Number of hunters	Maximize	27,500	32,430	27,500	27,500	27,500	27,500
2	Public satisfaction	Categorical 1 = No trust 5 = Max trust	Maximize	1	1	5	1	1	1
3a	Chronic wasting disease (CWD)	CWD prevalence	Minimize	37%	37%	37%	1%	37%	37%
3b	Deer population size	Percent change from current size	Maximize	69% of current	69%	69%	69%	101%	69%
4	Costs – staff time	Total hours	Minimize	25,206	25,206	25,206	25,206	25,206	1,437

Ranking refers to ordering the fundamental objectives from one to five (because fundamental objective 3 had two measurable attributes). Following ranking, each fundamental objective is then provided a score, where the first ranked fundamental objective receives a score of 100, and each lesser ranked fundamental objective receives a lower score depending on the relative importance of that objective to the first objective. After ranks and scores were received from each MassWildlife staff, we standardized the values to sum to one, and we averaged the weights across staff to obtain a single weight per fundamental objective.

A summary of objective weights per MassWildlife staff that participated in the swing weighting is shown in Figure 8.

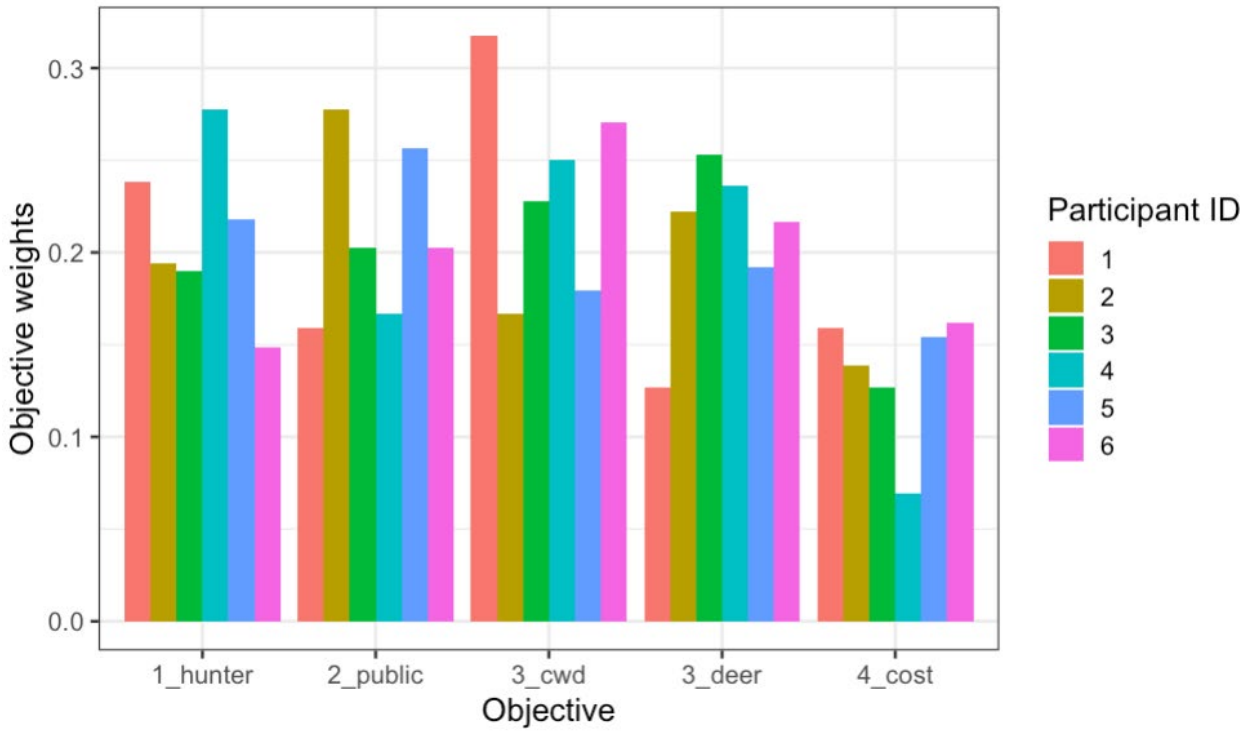

Figure 8. Elicited swing weights using the hypothetical alternatives (Table 4) across six MassWildlife staff. Colors denote the weights provided by each participant across each fundamental objective (listed across the x-axis). 1_hunter = Fundamental objective 1; 2_public = Fundamental objective 2; 3_cwd = Fundamental Objective 3a; 3_deer = Fundamental Objective 3b; 4_cost = Fundamental Objective 4.

To identify which alternative strategy performed the best across our fundamental objectives, we normalized and weighted the values in the SMART tables under each of the three CWD introduction scenarios. After values were weighted, we summed the scores under each alternative strategy to calculate an overall score. The alternative strategy with the highest overall score indicates that it is the best performing strategy across our fundamental objectives (Figures 9 – 11).

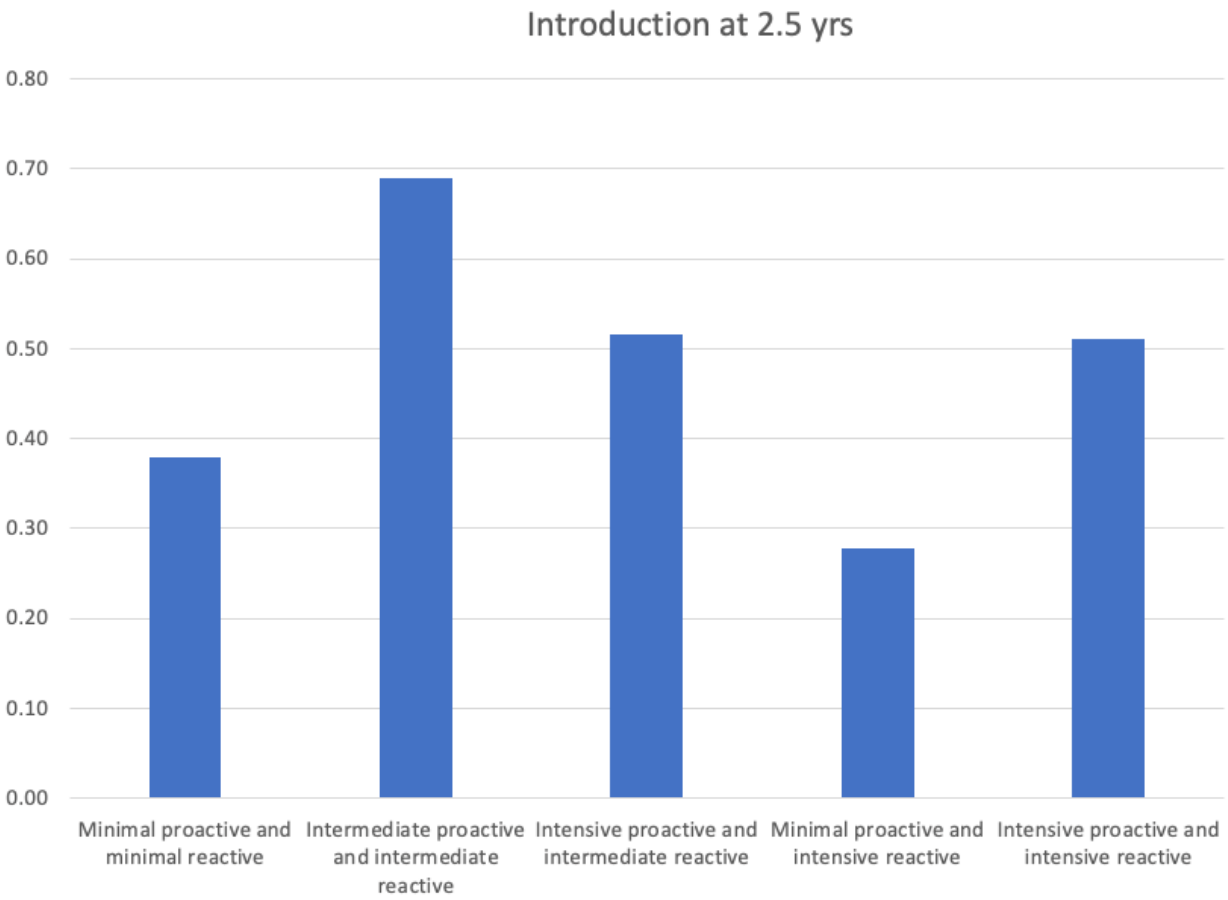

Figure 9. Overall scores (y-axis) by alternative strategies (x-axis) if chronic wasting disease (CWD) were to arrive in year 2.5. Higher overall scores indicate higher performance across fundamental objectives.

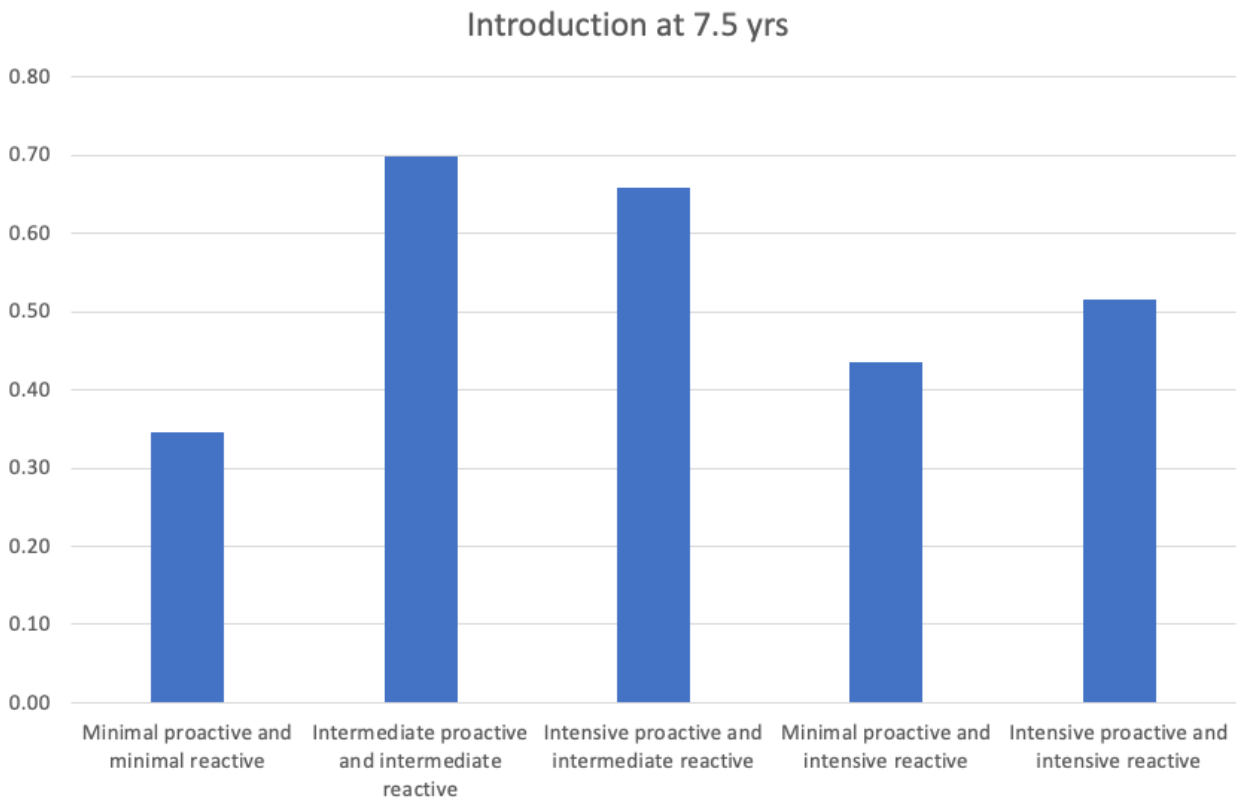

Figure 10. Overall scores (y-axis) by alternative strategies (x-axis) if chronic wasting disease (CWD) were to arrive in year 7.5. Higher overall scores indicate higher performance across fundamental objectives.

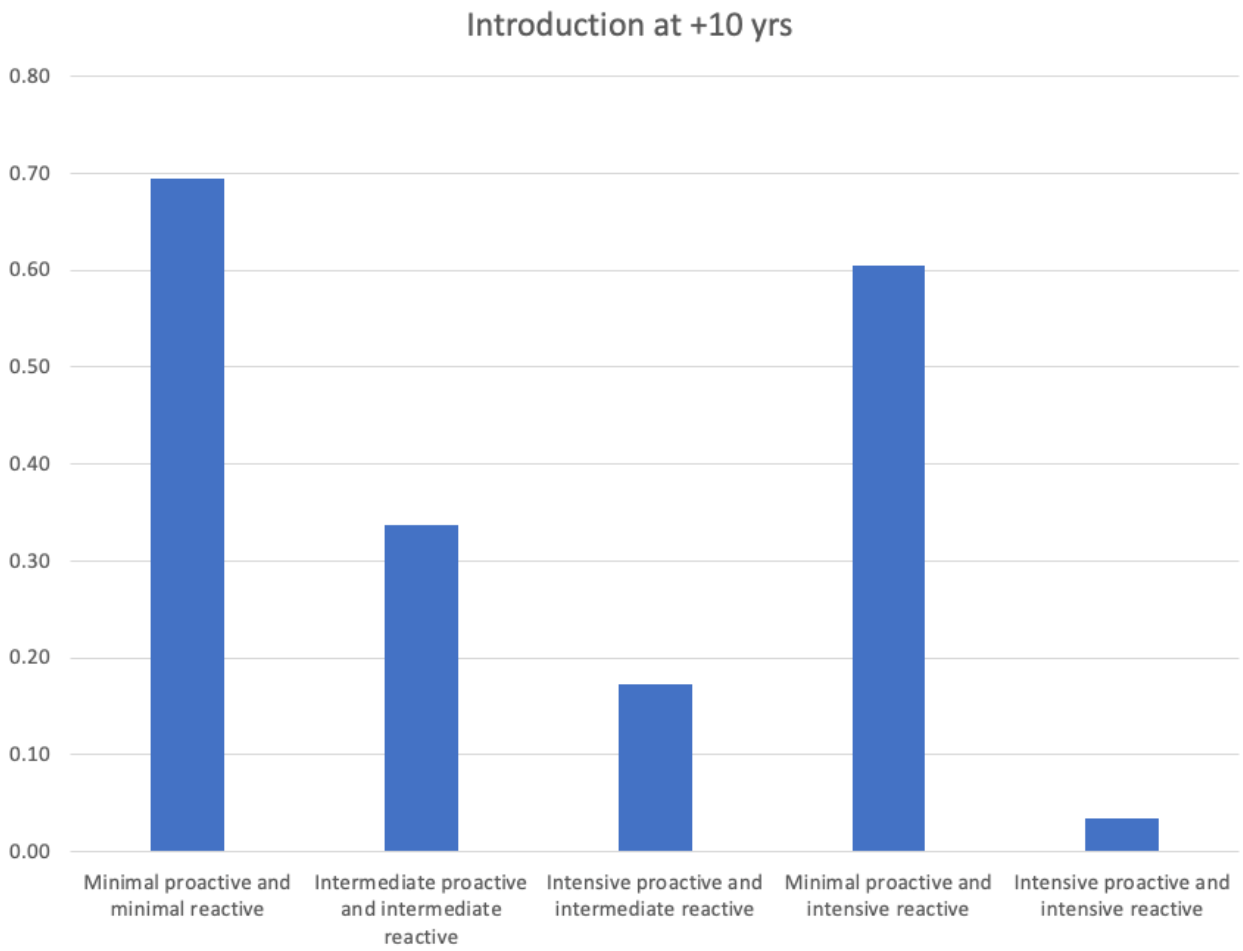

Figure 11. Overall scores (y-axis) by alternative strategies (x-axis) if chronic wasting disease (CWD) were to arrive after year 10. Higher overall scores indicate higher performance across fundamental objectives.

DISCUSSION

The decision on whether and how to minimize the CWD introduction into MA considered the tradeoffs in hunter and public satisfaction, CWD spread, and MassWildlife staff time. Navigating the tradeoffs in these decisions is difficult, and this rapid prototype serves as a first step in understanding and disentangling those considerations.

We found there were at least four main conclusions in terms of the performance of alternatives on the fundamental objectives:

1. If CWD were to arrive in years 2.5 or 7.5, then the 'minimal proactive and minimal reactive' strategy performs best on deer population and costs, but the 'intensive proactive and intensive reactive' strategy tended to perform better on human dimensions metrics (hunters and public) and CWD prevalence.

- The 'minimal proactive and minimal reactive' strategy performs well for the deer population because no adverse management actions are taken to reduce population size that would minimize CWD spread. Along those same lines, the minimal alternative performs well for staff time because little time will be spent on any CWD-related management actions.

- In contrast, the 'minimal proactive and minimal reactive' strategy performs poorly for the three remaining fundamental objectives (hunter and public satisfaction, as well as minimize CWD spread) because minimal actions are taken to prevent the spread of CWD, and constituents typically want wildlife agencies to do something to protect and manage wildlife.
- The 'intensive proactive and intensive reactive' strategy tended to perform better than the other strategies for human dimensions metrics (hunters and public) because constituents may want to see that MassWildlife is actively managing wildlife (i.e., protecting, restoring, conserving). In contrast, the 'minimal proactive and minimal reactive' strategy performs poorly for human dimensions metrics (hunters and public) because (as stated before) constituents want to see that MassWildlife is managing wildlife.

2. When looking at the consequence tables (Tables 1 – 3), intermediate strategies performed mostly in the middle [somewhere between the 'minimal proactive and minimal reactive' strategy and the 'intensive proactive and intensive reactive' strategy], except for 'minimal proactive and intensive reactive' strategy (which, as mentioned before, is close to how MassWildlife is poised to manage CWD now).

- This suggests that the strategy that MassWildlife is currently taking (i.e., 'minimal proactive and intensive reactive' strategy) may not work well to meet their fundamental objectives if CWD arrives within 10 years.
- Two of the three intermediate strategies ('intermediate proactive and intermediate reactive' and 'intensive proactive and intermediate reactive') under the 2.5 and 7.5 year CWD introduction horizon performed intermediately between the 'minimal proactive and minimal reactive' strategy and the 'intensive proactive and intensive reactive' strategy. The last intermediate strategy was the 'minimal proactive and intensive reactive' strategy, which performed relatively poorly for all fundamental objectives if CWD arrived in 2.5 or 7.5 years (mostly red or white boxes; Tables 1 & 2). However, the 'minimal proactive and intensive reactive' strategy performed almost as well as the minimal strategy if CWD arrives after 10 years.
- When looking at the overall performance of the different strategies (Figures 9 – 11), intermediate strategies were the best performing, except for the scenario where CWD arrives after year 10, then 'minimal proactive and minimal reactive' strategy is the best performing alternative strategy.

3. Public trust is expected to decline under any scenario where CWD arrives within 10 years.

- Public trust was expected to be consistently high across all alternative strategies under the arrival after 10-year scenario (range = 4.11 – 4.39; Table 3), whereas public trust varied more widely if CWD arrived in 2.5 years (range = 2.68 – 3.41; Table 1) and 7.5 years (range = 2.91 – 3.59; Table 3).
- This pattern (where public trust varied across CWD introduction scenarios with little variation in public trust if it arrived after 10 years) might indicate that some directed messaging on CWD is needed to communicate that there are broadscale patterns of disease spread that are not entirely under control of MassWildlife.

4. The decision on which alternative strategy to employ is sensitive to when CWD arrives.

- If CWD arrives in years 2.5 or 7.5, then an intermediate strategy (e.g., 'intermediate proactive and intermediate reactive' and 'intensive proactive and intermediate reactive') perform the best, and the 'minimal proactive and intensive reactive' strategy performs the worst. If CWD

were to arrive after 10 years, then either the 'minimal proactive and minimal reactive' strategy or 'minimal proactive and intensive reactive' strategy performs the best. Here, we are detecting the sensitivity of the decision in how to manage CWD relates to when CWD may be introduced or arrive.

NEXT STEPS

In terms of potential next steps, we have identified the following:

1. A more detailed communications plan could be considered and would likely alter estimates provided during the consequence assessment.
    - Once regulations have been proposed, a more tailored approach to audience, message, and purpose (i.e., informational vs behavior changing) can be created.
2. A surveillance plan could be created as a tool to inform management. It is not clear whether MA needs a robust or less intense surveillance plan, or what type of invasion event the surveillance plan should target (e.g., walking across the border vs incursion event).
    - A more in-depth understanding of the spatial spread of CWD in PA and forecasted estimates of when CWD may be expected to arrive in MA (or other Northeastern states) may be helpful to designing the surveillance plan.
3. More robust estimates of consequences could be obtained by leveraging existing data and developing new predictive models for some measurable attributes. The following data were identified that could replace the estimates in the expert elicitation:
    - Hunter satisfaction:
        - License sales over time in MA
        - Data from other states on the effect of CWD on license sales
    - Public satisfaction:
        - A new general public survey (non-hunters), similar to the hunter survey MassWildlife developed in 2023, could be conducted to better understand and estimate public satisfaction about CWD and deer management alternatives.
    - CWD probability of introduction and spread under the alternatives and in consideration of broad scale spread in other states.
        - See analytical tools and CWD spread projections mentioned in #2 above.
    - Staff time & cost
        - Data from published literature on the time and cost of CWD in states where it occurs (Chiavacci 2022).
4. Forecasting and predicting the CWD invasion front and/or the likelihood of different incursion events across MA would provide valuable insights given that the decision was sensitive to when CWD arrived in MA.
    - Again, see analytical tools and CWD spread projections mentioned in #2 above.

Collectively, this rapid prototype and next steps can help MassWildlife be better equipped to responding to CWD arrival in MA.

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trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Supplementary Information for: Structured decision making workshop: Chronic wasting disease management of cervids in Massachusetts

Workshop dates: 13 – 15 February 2024

Workshop location: Massachusetts Division of Wildlife & Fisheries
1 Rabbit Hill Rd
Westborough, MA

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SUPPLEMENTARY INFORMATION S1

Chronic wasting disease logistic regression model for prevalence

In wild deer populations, CWD typically follows a logistic growth curve, with a growth rate that is initially quite low, followed by a period of rapid increase as the number of infected animals increases, and a subsequent period of leveling off (enzootic equilibrium) as the number of susceptible animals is depleted (Samuel, 2023). The level of prevalence that can be maintained at equilibrium is dependent on the contact structure, productivity, and density of deer in the area. According to Samuel (2023), the logistic equation describing CWD prevalence is:

$$P = \beta U - (\frac{\beta U}{(1 + e^{\beta 0 + \beta \cdot t}})$$

where P is the observed CWD prevalence, βU estimates the upper asymptote (enzootic equilibrium) of prevalence, β0 is the estimated intercept that predicts P at time = 0, β is the transmission rate, which can be considered correlated with the constant disease transmission coefficient for a frequency-dependent disease among deer, and *t* is the time step (value between 0 and 20). We used a βU value of 0.40 and a β0 value of -6 to force the intercept to CWD prevalence = 0 at time 0.

The transmission rate, β, is a composite of two rates: (1) the contact rate between deer and (2) the probability that a contact results in successful transmission and is bounded between 0 and 1. Although β is a constant through time, its effect on transmission changes over time (years since introduction) to produce the logistic curve's three stages described in previous paragraph.

Usually, different demographic categories experience different transmission rates (e.g., β for males is higher than β for females), but for this exercise, we assumed a single β for the entire population.
In this exercise, the participants considered how CWD growth rate (β) will be affected by the management strategies being considered. Strategies could affect either dimension of β: contact rate or probability of transmission given contact.

Assume that the disease has been introduced and that targeted removal, if it was implemented, was not successful in stopping ongoing transmission in Massachusetts. Assume equilibrium white tailed deer population dynamics over the course of the 20 years following inception of the plan.

Participants answered the question, “What will the growth of CWD (β) be under each of the following management strategies? Your answer must be between 0 and 1. Use the prevalence graphs at right to help visualize your estimates.” Participants only provided their best guess for all five alternative strategies.

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