Conservation Strategy for the Eastern Loggerhead Shrike (*Lanius ludovicianus migrans*)

and

Species Conservation Planning Workshop Report

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January 2024 workshop facilitation team:

	Toronto, ON, Canada	**Nashville, TN, U.S.**
Workshop facilitators	Jessica Steiner (lead facilitator)	Stephanie Winton
PVA modelers	Phil Miller	Amy Chabot
Technical support and recorders	Katie Zajac Drew Sauve	Hana Thompson Alisa Solecki

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A list of participants for the full Species Conservation Planning process is provided in Appendix A of this document and all are thanked for their time and contributions.

Eastern Loggerhead Shrike Conservation Planning Workshop participants at the Toronto Zoo (top) and Nashville Zoo/online (bottom), January 2024.

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Acronyms

BMP	Beneficial Management Practices
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPSG	Conservation Planning Specialist Group
CSI	Canadian Species Initiative
FAC	Full Annual Cycle
IUCN	International Union for Conservation of Nature
LOSH WG	Loggerhead Shrike Working Group
PVA	Population Viability Analysis
SCP	Species Conservation Planning
SDM	Species Distribution Model
SSC	Species Survival Commission
U.S.	United States
USGS	United States Geological Survey

Executive Summary

The loggerhead shrike (*Lanius ludovicianus*) is a medium-sized, raptorial passerine endemic to North America. This species has faced precipitous and range-wide population declines of 76% since the 1960s (Sauer et al. 2020), with migratory populations experiencing the most drastic declines. Due to global population declines of over 50% in the last 40 years, Partners in Flight lists the species as a Common Bird in Steep Decline. The loggerhead shrike is a priority species in 15 of 22 Joint Ventures, and in 16 of the 35 Bird Conservation Regions. In the United States, 34 states currently list the taxon as a Species of Greatest Conservation Need in their State Wildlife Action Plans. In Canada, the migratory eastern subspecies known as the eastern loggerhead shrike (*L. l. migrans*) is listed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2014). Breeding populations of this subspecies persist primarily in Ontario, overwintering in the eastern United States. Loggerhead shrike subspecies are indistinguishable in the field, use similar habitat, and can co-occur in the same areas, especially during migration and wintering when migratory birds fly south into regions with resident populations.

Recovery efforts for the *migrans* subspecies in Ontario, Canada have been ongoing since the 1990s when the wild population experienced a precipitous drop in numbers. These efforts include both *in situ* (with wild populations in their natural habitats) and *ex situ* (in human care outside of a species natural habitat) conservation actions. An ongoing conservation breeding and release program has reduced the negative trend in wild population abundance in Ontario by ~50% since 2005 (Tischendorf 2015). Colour banding of both released captive-bred and wild birds, combined with intensive annual population monitoring, has amassed considerable data on habitat use and population demographics of *L. l. migrans* on the breeding grounds in Ontario. In recent years, additional data have been collected through coordination of an expanded broadscale colour

banding program of wild loggerhead shrike across the species' eastern North American range. There is a need to update recovery plans with this new knowledge to increase the effectiveness of conservation efforts. For migratory *L. l. migrans*, a One Plan Approach inclusive of the full annual cycle (FAC) is necessary to ensure actions and resources are effectively targeted

To address this need and to inform long-term conservation planning for *L. l. migrans*, the Conservation Planning Specialist Group (CPSG), part of the Species Survival Commission (SSC) of the International Union for Conservation of Nature (IUCN), facilitated a Species Conservation Planning (SCP) process informed by a population viability analysis (PVA). Forty participants from Canada and the United States, including representatives from government agencies, non-governmental organizations, academia, industry, and other groups with vested interests in the species and its habitat, contributed to the development of the Conservation Strategy for the Eastern Loggerhead Shrike through a series of online and in-person workshops beginning in July 2021 and culminating in a final 3-day workshop January 23 – 25, 2024. The results of this process form the basis of the Conservation Strategy for Eastern Loggerhead Shrike, presented in Part I of this report. Every attempt was made through the design and facilitation of these workshops to generate appropriate and useful material for an effective plan that lays out broad guidance for recovering loggerhead shrike populations across the *migrans* subspecies historic range; the planning process is summarized in Part II of this report.

While conservation goals and strategies have been established separately for Canada and the United States, there are strong parallels for addressing priority threats across the subspecies' range. Short-term (10-year) goals for both countries prioritize:

- protecting and conserving existing shrike habitat,
- restoring and enhancing degraded habitat,
- reducing knowledge gaps,
- mitigating direct threats, and
- improving wild population demographics through integrated *in situ* and *ex situ* strategies

Continued and improved coordination and integration of conservation research, planning, and action implementation across the United States and Canada is needed. Further, a high priority need for loggerhead shrike conservation in the United States is to improve the sustainability of the Loggerhead Shrike Working Group by securing a dedicated coordinator to help finalize action plans for the United States, support and track progress of plan implementation, and maintain communication between working group members.

The Conservation Strategy reflects the need to establish healthy, viable populations of loggerhead shrike across the geographic range of *L. l. migrans* throughout its FAC in order to recover the focal subspecies. Conservation efforts benefitting the species in these regions will ultimately benefit *L. l. migrans* and vice versa. Recovery actions will significantly contribute to the ultimate long-term vision of achieving viable, self-sustaining populations of loggerhead shrike across eastern North America, including *L. l. migrans*, supported by local communities and industries.


H. Hess/WPC

Part I: Conservation Strategy for the Eastern Loggerhead Shrike

Part I: Conservation Strategy

The following presents the Conservation Strategy for Eastern Loggerhead Shrike (*Lanus ludovicianus migrans*) that resulted from a series of online and in-person Species Conservation Planning (SCP) workshops that took place July 2021 - January 2024, designed and facilitated by the International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) Conservation Planning Specialist Group (CPSG), and organized by representatives of the Canadian Species Initiative, Wildlife Preservation Canada, African Lion Safari, Queen's University, and the American Bird Conservancy. Full details of the planning process can be found in Part II of this report.

Species Background and Status Review

Species Overview

The loggerhead shrike (*Lanius ludovicianus*) is a medium-sized, predatory songbird found only in North America. Loggerhead shrikes prefer large areas of open short grasslands with scattered shrubs that provide key habitat elements (nest sites, perches, hunting areas, and impaling sites). They are often associated with active pasturelands and undeveloped areas of limestone bedrock. Loggerhead shrike benefit from cattle grazing and mixed "heritage" farming but are also found in rural residential areas, and even open urban areas such as golf courses and sports fields. There is evidence that loggerhead shrike aggregate their breeding territories, relying on the existing presence of breeding conspecifics to cue in on suitable habitat (Etterson 2003).

Loggerhead shrikes exhibit a variety of migratory behaviours from obligate migrants (populations in the northern part of the species range), facultative (central populations), and resident (southern populations); these populations are usually segregated geographically during the breeding season. Northeastern populations of loggerhead shrike are migratory and considered a unique subspecies: eastern loggerhead shrike, *L. l. migrans* (Chabot and Lougheed 2021). Prior to European colonization, breeding *L. l. migrans* were found across the provinces and states around the Great Lakes, occupying a range of native prairie, savannah, shrub-steppe and alvar habitat (Pruitt 2000). Agricultural grasslands now comprise most of the suitable habitat for shrikes. Data from tracking, banding, and genetic studies reveal that *L. l. migrans* originating from breeding populations in Ontario migrate and spend their non-breeding season east in the Atlantic coastal states and west within the Mississippi Alluvial Valley, including states south of the Great Lakes such as Pennsylvania (A. Chabot, pers comm; Wildlife Preservation Canada, unpublished data).

Conservation Status

The species has experienced drastic, range-wide declines in the past 50 years, with the current population less than a quarter of what it was in 1966 (Sauer et al. 2020). As a result, it is considered a species at risk across Canada and is a priority for conservation in 34 U.S. states. Migratory populations are especially at risk. Many potential reasons for the decline of the loggerhead shrike have been suggested, including habitat loss, pesticides, collisions with vehicles, diseases such as West Nile Virus, and competition between migratory and non-migratory individuals on the wintering grounds.

The *migrans* subspecies has disappeared from much of its former range and is in danger of becoming extinct (COSEWIC 2014). Only Ontario still has a confirmed breeding population of more than a few pairs, in two core breeding areas (the Carden Alvar [Carden] and the Napanee Limestone Plain [Napanee]; see Figure 2). Although individuals from the *migrans* subspecies can be found as breeders in the north central United States (U.S.), these populations appear to be comprised of multiple subspecies (A. Chabot, pers comm).

Conservation Efforts


J. Giocomo

Due to concerns that the subspecies was facing imminent extinction in eastern Canada, an assurance population was established with ~50 wild fledgling founders obtained from nests in Ontario in 1997 and 1998. Several partners in Canada and the U.S. now participate in the ongoing conservation breeding program coordinated by Wildlife Preservation Canada. Since 2003, the majority of the hatch-year birds produced have been released in suitable habitat in Ontario to augment the wild population. The remainder are retained to maintain optimum *ex situ* population size, age structure, and founder representation. The federal and Ontario Recovery Strategies for the Loggerhead Shrike, *migrans* subspecies in Canada (Environment Canada 2015; Ontario Ministry of Natural Resources and Forestry 2016) include conservation breeding as a priority recovery activity. Results to date indicate that the breeding and release program is having a stabilizing effect in Ontario (Tischendorf 2015; Miller 2023, Appendix C), and suggest that where suitable habitat remains or can be restored, the subspecies could be reintroduced back into its former range.

The breeding program is highly integrated with ongoing field-based recovery efforts including wild population monitoring, habitat stewardship, and public education. Radio-tracking captive-bred and released juveniles in recent years has also contributed to the dataset of migratory movements for birds from Ontario, supplementing existing genetic and colour-band resight data.

All of these efforts have benefitted from range-wide collaboration through the Loggerhead Shrike Working Group (LOSH WG), which was formed in 2013 to facilitate international cooperation. To date, working group members have established a multi-state/province colour banding program that is helping to amass data on habitat use and population dynamics, and has developed predictive occupancy/distribution models. The group is also working toward developing standardized protocols for shrike surveys and monitoring that can be implemented across the species range and creating Beneficial Management Practices (BMPs) documents for land managers in areas of loggerhead shrike occupancy.

In view of continued declines of loggerhead shrike across their range, particularly the migratory *migrans* subspecies, and recent collaborative conservation and research accomplishments, an updated bi-national conservation strategy for loggerhead shrike was deemed necessary to ensure the long-term viability of *L. l. migrans*. Given similarities in the ecology of different loggerhead shrike subspecies, and evidence of intergradation (subspecies crosses), conservation efforts for loggerhead shrike populations across the northeastern species range, regardless of subspecies, are expected to benefit *L. l. migrans* and vice versa.

Full Annual Cycle One Plan Approach Population Viability Analysis

Population viability analysis (PVA) modeling is a valuable tool for quantitative risk analysis of declining and small populations, both free ranging (*in situ*) and those managed in human care (*ex situ*). Computer simulations can be used to project probability distributions of possible fates under varying scenarios. Ranges of plausible values for uncertain parameters can be used in ‘sensitivity testing’ to determine what effects these uncertainties might have on the various aspects of population demography. This can be useful not only in assessing the impact of uncertainty in model results but also for estimating which threats or management actions may have the greatest effect on population viability. Results can also help prioritize research to address knowledge gaps and identify key parameters that should be monitored during management to assess the success of conservation efforts.

Previous PVAs for *L. l. migrans*, which focused solely on the Ontario breeding population and effects of releases from the *ex situ* breeding program, identified migration and overwinter survival of both adults and juveniles as significant limiting factors (Tischendorf 2009, 2015). Taking a full annual cycle (FAC) approach is considered best practice for migratory populations, like *L. l. migrans*, that face seasonal or age-specific threats or limitations (Figure 1; Wallace et al. 2024, Ng et al. 2018, Hostetler et al. 2015, Marra et al. 2015). An updated and expanded demographic analysis was undertaken, which included *L. l. migrans* breeding and non-breeding seasons, migration (the seasonal movement to and from a breeding ground) and dispersal (movements among breeding grounds), and more fully integrated *ex situ* population management and release activities (Miller 2023, Appendix C). The recent model therefore improved understanding of the effects of events in both the breeding and the nonbreeding season on population dynamics and ensured that this strategy was developed in adherence to CPSG's One Plan Approach to species conservation, where all responsible parties jointly develop one integrated conservation plan for all populations of a species, including *ex situ* populations (Byers et al. 2013).

The goal for the recent PVA was to provide information that would assist in the development of this Conservation Strategy. Major results of the PVA and sensitivity testing are summarized below:

- All populations within the geographic scope of the project are likely to experience continued declines in abundance in the absence of new or increased conservation action.
- Releases of fledglings from the *ex situ* population can serve as a means of reversing population declines if conducted with appropriate intensity.
- All Ontario wild populations would benefit substantially from targeted releases of captive-bred young; however, when releases are terminated, the recipient population(s) would experience renewed declines in abundance as underlying reproductive rates are not sufficient to overcome loss of individuals through mortality both within seasonal habitats and during migration/dispersal events.
- Restricting the Ontario releases to Carden puts the Napanee population in significant risk of extinction.
- Increases in migration survival rates appear to significantly improve demographic performance in the Ontario populations and may yield sustained population growth after releases are terminated; this is in contrast to improvements in reproductive output and adult mortality which did not result in a successful outcome when modeled.
- Female hatch year mortality, adult female mortality, the percentage of females reproducing, and clutch size are the parameters to which the model is most sensitive, and thus likely where management actions would be most effective.
- Populations of 50 or more individuals will demonstrate greater resilience from environmental and demographic stochasticity.
- Management actions focused on improving carrying capacity will increase the likelihood of viability for populations.

Results from this recent analysis greatly informed and facilitated FAC strategy development in a One Plan Approach. Full details on model structure, demographic rates, and results can be found in Appendix C *A Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States* and Appendix D *A Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States: Addendum*.

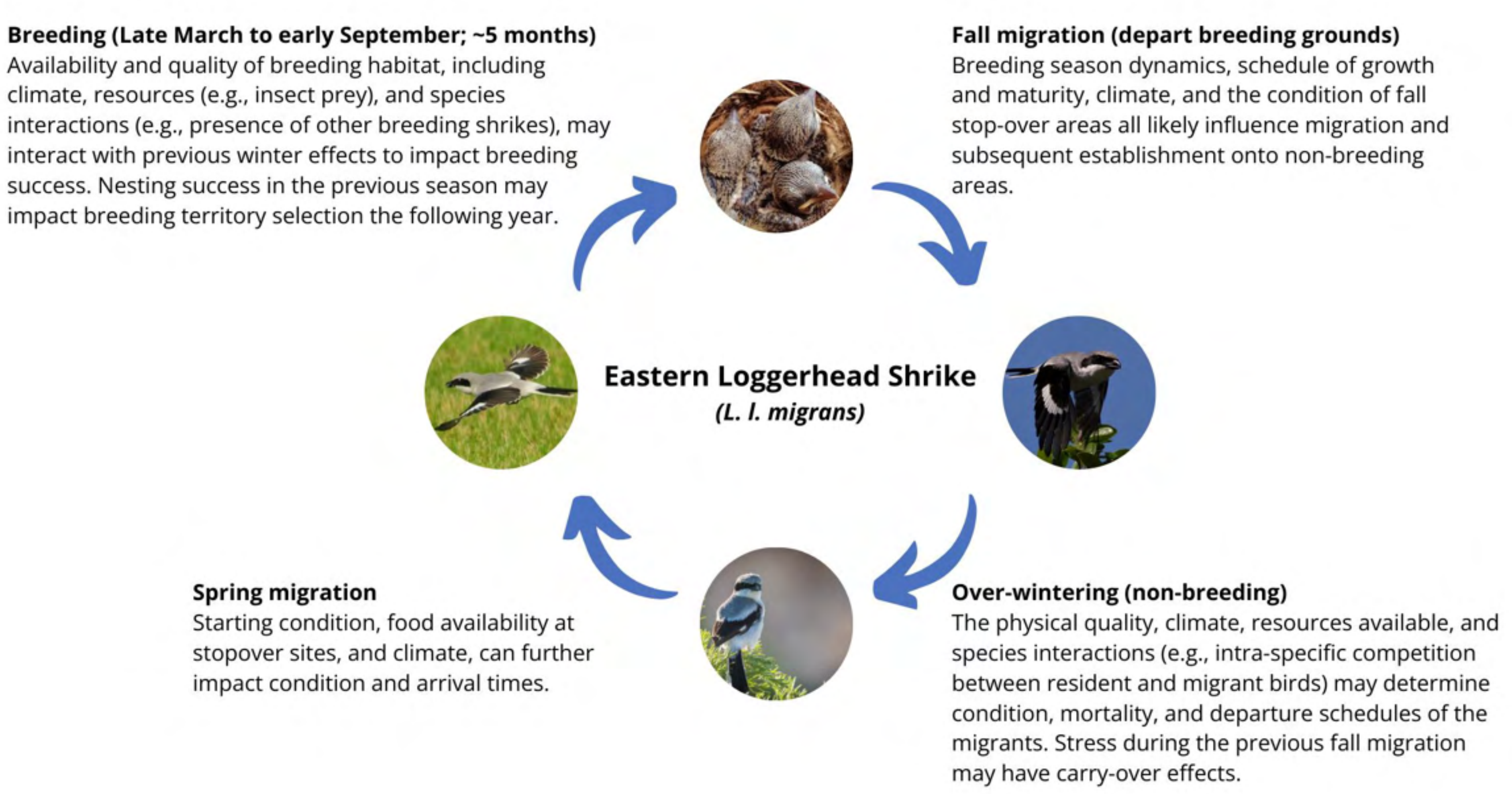

Figure 1. A conceptualization of the full annual cycle of migratory eastern loggerhead shrike (*Lanus ludovicianus migrans*) in North America (adapted from Agrawal et al. 2019), *for illustrative purposes only*. Photo credits in clockwise order: WPC, P. Rathner, B. Matsubara, K. Hennige.

Geographic Scope

The geographic scope of this strategy encompasses the FAC of *L. l. migrans*, and therefore covers the needs of current and historic breeding populations of *L. l. migrans* in Ontario; historic populations in Michigan, Ohio, Pennsylvania, and New York; and all loggerhead shrike occupying suitable habitat areas in the central and southeastern U.S. that are or were historically used by *L. l. migrans* for breeding and/or overwintering (Figure 2). Migratory behaviour differs among the populations: the four Ontario populations are obligate migrants, while populations across the U.S. portion of the range include obligate migrant, partially migratory, and non-migratory birds, depending on latitude. Accordingly, the population model includes both extant populations of *L. l. migrans* and populations of *L. l. centralis* in areas where migratory *L. l. migrans* overwinter and is inclusive of populations of obligate migrants, partially migratory populations and non-migratory populations. Only regions currently supporting suitable habitat were included; as a result, some historic areas e.g. Grey-Bruce in Ontario, were excluded at this time based on recent species distribution modeling (see Part II, Box 1). See Appendix C for full details on model structure and methodology used to define the geographic scope.

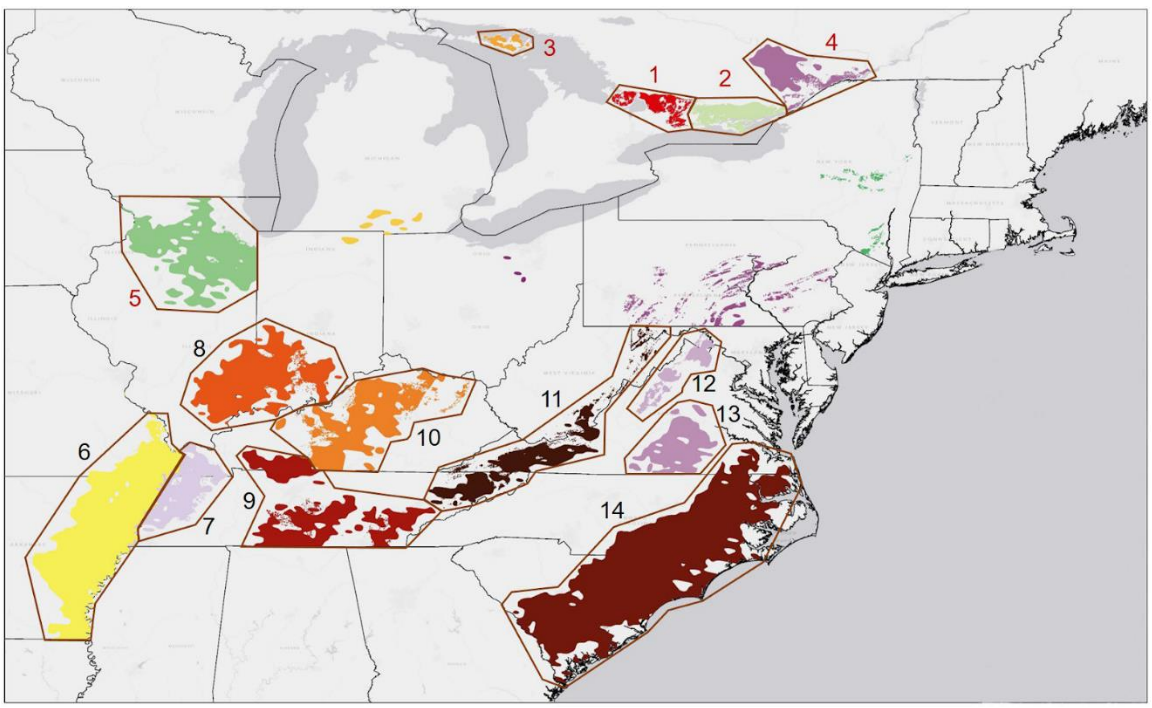

Figure 2. Geographic scope of the eastern loggerhead shrike (*Lanius ludovicianus migrans*) Conservation Strategy. Population labels: 1. Carden; 2. Napanee; 3. Manitoulin; 4. Smiths Falls; 5. Northern Illinois; 6. Missouri-Arkansas; 7. West Kentucky-Tennessee; 8. Illinois-Indiana; 9. Eastern Tennessee; 10. Kentucky; 11. Appalachian Plateau; 12. Virginia Valleys; 13. Virginia Piedmont; 14. Coastal. Suitable habitat in Michigan, Ohio, Pennsylvania and New York is additionally covered. Numerical identifiers in red text denote obligate migratory populations.

Conservation Vision

The conservation vision presents the ultimate goal for *L. l. migrans* recovery within the next 25 years. This vision guides the recommended conservation strategies.

25-year Conservation Vision

"We envision ***self-sustaining*** *populations of loggerhead shrike (*Lanius ludovicianus*) that ensure the long-term* ***viability*** *of* L. l. migrans *in suitable and restored habitat* ***across the subspecies' historic range*** *including breeding, migration, and wintering habitats. Local communities and industries celebrate and understand the birds as an important component of thriving, diverse grassland ecosystems that span public and private lands."*


A. Solecki/WPC


N. Cairns


H. Hess/WPC


K. Hennige


J. Spero/WPC


. Spero/WPC

The vision reflects that healthy, viable populations of loggerhead shrike across the geographic range of *L. l. migrans* throughout its FAC are necessary to ensure recovery of the focal subspecies. As well, given the indistinguishable behaviour, habitat, and ecology between subspecies of loggerhead shrike in eastern North America, efforts benefitting the species in the defined geographic range of the plan will also benefit *L. l. migrans* and vice versa.

Indicators of Success

Operationalization of key terms in the vision describe the indicators for measuring its successful realization:

- **Self-sustaining:** Ontario populations have a mean population growth rate (λ) of ≥1.0 for a period of 25 years in the absence of releasing individuals from the *ex situ* population (based on criteria in McInerny et al. 2022)
- **Viable:** Sufficiently low risk (<10%) of a loggerhead shrike population (as identified in Figure 2) falling below a critical abundance threshold of 50 breeding pairs (based on PVA sensitivity analysis, Appendix D) or becoming extirpated/extinct within 100 years (following criteria of IUCN Red List [IUCN Standards and Petitions Committee 2024] and COSEWIC [2021])
  - At least 90% of founder gene diversity maintained in the *ex situ* population
  - Genetic diversity in wild population retained at ≥95% of baseline level (to be determined) over a period of 25 years (Target 4.5 in Global Species Action Plan [IUCN 2023])
- **Across the subspecies' historic range:** At least one (1) *L. l. migrans* breeding population is re-established within the identified historic range in Canada or the U.S. (aligned with Recovery Strategy targets [Environment Canada 2015]).

Priority Threats for Intervention

Priority threats to loggerhead shrike and their habitats within the defined geographic scope (Figure 2) represent the most urgent needs for action that can most feasibly be mitigated in the next ten years (Table 1). Threats were prioritized as described in Part II of this report (*Summary of Final SCP Workshop Process*), which took a *migrans*-centric approach.

High priority threats impact *L. l. migrans* across the FAC (Figure 3). Several threats, such as predation, food availability, and road mortality, can be driven or exacerbated by habitat loss and degradation. In the U.S. especially, these threats are considered best addressed through actions focused on improving the quality and quantity of suitable habitat.

Table 1. Overall priority of threats to *L. l. migrans* across its full annual cycle range in Canada and the United States, based on magnitude of impact and feasibility of mitigation in the next ten years.

	Overall Priority	
Threat	Canada Breeding Grounds	U.S. Populations/*migrans* Wintering Grounds
Knowledge gaps	High	High
Habitat degradation	High	High
Habitat loss	Medium	High
Allee effect / Small populations	High	Medium*
Depredation of nests / Nest interference / Nestling mortality	High	Medium*
Interactions with motor vehicles	Medium	Medium*
Predation of hatch year	Medium	Medium*
Fluctuating / declining prey abundance limiting food availability	n/a	Medium*
Catastrophic events	Medium	Low
Interactions with industrial chemicals	n/a	Low
Predation of adults / overwintering	n/a	Low*

* threat can be indirectly or more feasibly mitigated via improvements to habitat quality and availability.
n/a - threat not applicable or has negligible contribution to population decline.

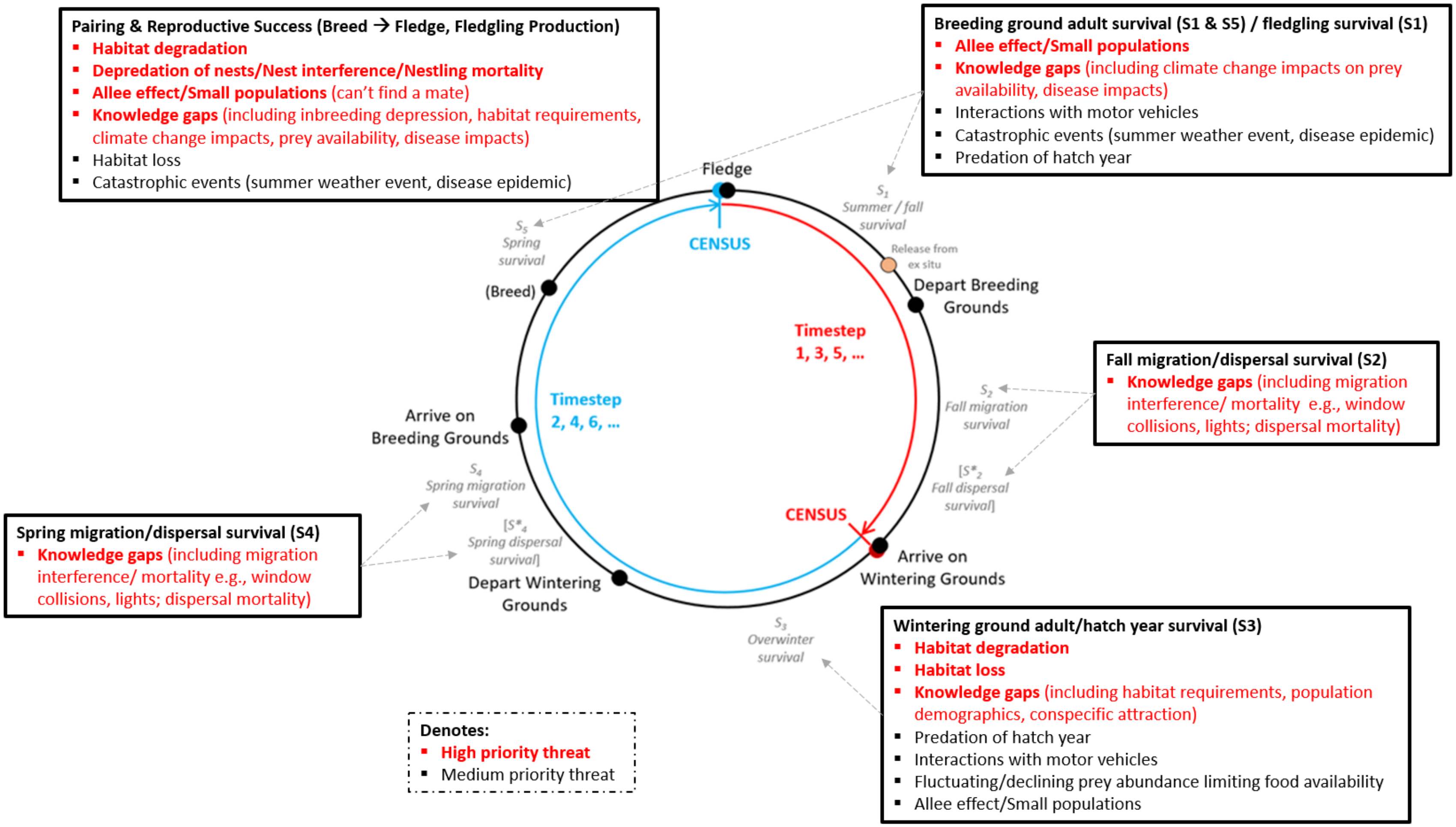

Figure 3. Priority threats to *L. l. migrans* across its full annual cycle range and the demographic parameters they impact mapped onto a schematic diagram of the full annual life cycle as defined in the population viability analysis model. Threats were prioritized for action based on magnitude of impact and feasibility of mitigation in the next ten years. See PVA text (Appendix C) for a more detailed discussion of the life cycle and its treatment in the demographic model.

Knowledge Gaps

Many knowledge gaps exist for this species that impact the ability of population managers to select and deliver the most effective conservation actions. Differentiating individual dispersal movements from mortality is a major challenge with this species and current limitations of available tracking technology (i.e. size of tags, spatial extent of radio-tracking network) severely hamper efforts to address questions surrounding migration and dispersal.

The following list describes major areas of research need, informed where practical by the PVA. Research objectives surrounding habitat, demographics, and Allee effect/conspecific attraction are considered a priority for the species across its U.S. range; some additional work is required to further prioritize within these broad themes as part of more detailed action planning (see Action Plans section below). Those research questions underlined below represent key knowledge gaps to support Ontario breeding populations of *L. l. migrans;* an Ontario research sub-committee will be tasked with further developing research priorities and objectives as described in the Canada Action Plan (see Appendix G).

Habitat:

- Increase understanding of the impact or efficacy of different habitat management efforts
    - e.g. habitat management for prey species - evaluate trophic cascades (e.g. shrike prey on grasshoppers, therefore managing habitat for grasshoppers may benefit shrike)
- <u>Assess abundance of prey population for need of intervention/supplemental feeding around nest sites</u>
- Importance of fire suppression as threat (habitat loss/degradation) in Canada
- Identify limiting habitat elements on landscape at different scales (e.g. impaling sites)
- Improve knowledge of impacts of industrial chemicals (herbicide/pesticide), plastics and direct and indirect effects on species to better understand threats and inform Best Management Practices
- <u>Identify U.S. breeding/wintering grounds for *L. l. migrans* and increase understanding of migration routes for migratory populations</u>
- Quantify impact of motor vehicles

Demographics:

- <u>Better understanding of causes of migration mortality</u>
- Local dispersal post-breeding
- Female post-breeding movements and winter survival
- <u>Post-fledging movements and survival</u>
- Identify proportion of males breeding
- <u>Determine the impacts of West Nile Virus/disease on wild populations</u>

Allee effect/conspecific attraction:

- Improve understanding of the role of conspecific attraction throughout FAC to:
    - Inform habitat conservation management
    - Understand impact of winter sociality on breeding
    - Understand the risk and impact of inbreeding depression

***Ex Situ* Population:**

- Investigate methods to manipulate sex ratios in clutches
- Determine the impact of sex ratios within annual groups of released juveniles on wild population demographics

Other Threats:

- Increase understanding of predation as threat in U.S.
- Increase understanding of the effects of climate change on the phenology, availability, and abundance of invertebrate prey

Conservation Goals and Recommended Strategies

Recent PVA results reveal that in the absence of new or increased conservation action, all populations within the defined geographic scope are likely to experience continued declines (Miller 2023, Appendix C).

Given the broad geographic scope of this Conservation Strategy, with regional differences in threats and management options, separate goals and strategies are recommended for each country (Table 2); however, there are common themes to addressing priority threats across the *L. l. migrans* range.

One major theme for conserving *L. l. migrans* is the protection and conservation of *existing* shrike habitat as well as restoration and enhancement of *degraded* habitat throughout the FAC (breeding, wintering, and migration). Recommended strategies rely on developing relationships and engaging key stakeholders and rightsholders as well as appropriate government agencies to ensure sufficient suitable habitat is available and maintained at local and landscape scales. Two key tools to support implementation of these strategies are: the most recent species distribution model (SDM; see Part II, Box 1), which will be used to direct relationship-building to areas predicted to have high levels of suitable habitat in Ontario (Wheeler et al. 2024); and Loggerhead Shrike: An Ontario Landowner's Guide (Wildlife Preservation Canada 2015), which provides BMPs for habitat stewardship in Ontario, based on research on loggerhead shrike habitat use by Chabot et al. (unpublished data). Both of these tools were developed for Ontario but are recommended to be revised as required for use in the U.S.

Other common themes were reducing knowledge gaps, improving wild population demographics through *in situ* and *ex situ* strategies, and promoting direct mitigations, all to address threats that are not sufficiently addressed through habitat management actions or are a result of small population size. Collaborative research, results-sharing, and coordinated action implementation among partners across the U.S. and Canada are recommended to improve effectiveness of recovery actions that address binational threats and knowledge gaps (i.e. habitat use, population demographics, and Allee effect/conspecific attraction).

Insights from the PVA (Appendix C) and subsequent sensitivity testing (Appendix D), designed to assess the impact of gaps in our understanding of *L. l. migrans* population dynamics and impacts of threats to population persistence, supported and informed a One Plan, FAC approach to strategy development. Modeling results provided evidence that releases of captive-bred young from the *ex situ* population can serve as a means of reversing population declines, when integrated with *in situ* actions to address the primary drivers of decline. For Ontario specifically, wild populations were shown to benefit substantially from targeted releases spread across all four Ontario populations; however sustained population growth will only be achieved through concurrently increasing migration survival.


N. Wajmer/WPC

In Ontario, integrated strategies to both improve *in situ* population demographics and increase *ex situ* release numbers are recommended to increase the existing breeding populations in Napanee and Carden to levels that are resilient to stochastic variability and reduce Allee effects. The potential for reintroducing extirpated populations in Ontario (e.g. Manitoulin, Smiths Falls) should be assessed with first steps taken towards securing and improving suitable habitat in these regions. In the U.S., reinforcement of vulnerable small or significantly declining populations or reintroduction of extirpated populations using either *ex situ* breeding or wild population sources is not recommended at this time. A feasibility assessment is required before any conservation translocations are undertaken to evaluate the appropriateness and likelihood of success of such efforts given continued taxonomic uncertainty, demographic considerations, status of local threats, habitat suitability, and ability to secure authorizations for potential release sites. In the meantime, actions must focus on identifying and implementing *in situ* methods for increasing populations (e.g. increasing local breeding success, decreasing mortality, etc.). Pending the results of the feasibility assessment, the priority would be actions towards future reintroduction of shrike in areas of local extirpation in the U.S. (e.g. Michigan, Ohio, Pennsylvania, and New York), however the expected time to implementation may fall outside the scope of this 10-year plan. For all methods of increasing population size, an adaptive management approach that is evidence-based is recommended.

A final recommendation is to improve the long-term sustainability of the LOSH WG by hiring a dedicated coordination and building capacity for implementation. This is a model that has worked for other avian working groups, and is necessary to provide sufficient capacity to implement the Conservation Strategy throughout the subspecies' range in the U.S.

Goals and recommended strategies for progressing towards the conservation vision over the next 10 years are summarized in Table 2. Specific objectives for each recommended strategy are presented as available at the time of writing; additional work is required to finalize all objectives for the U.S. as part of detailed action planning (see next section below). The process by which these goals, strategies, and objectives were reached are described in Part II: *Species Conservation Planning Process*.

Action Plans

The 10-year Action Plan for *L. l. migrans* in Canada, which details the actions required to achieve objectives for Canadian breeding populations, is presented in Appendix G, along with work completed to-date for U.S. populations. Detailed action planning, including the development of 10-year objectives for all preferred strategies for U.S. loggerhead shrike populations, is still to be completed. Continuation of this work will occur within the LOSH WG; however, hiring a dedicated LOSH WG Coordinator will be necessary to carry this work forward. This Conservation Strategy will provide a foundation for additional action planning that will occur at the state level as required by the legislated process for State Wildlife Action Plans.

Oversight, Monitoring, and Progress Tracking

Oversight of the Conservation Strategy will occur through the following organizational structure and communication plan (Figure 4). The LOSH WG will track progress toward the overarching goals in this Conservation Strategy on an annual basis using existing mechanisms (i.e. member reports at monthly and annual meetings). As an immediate need, the LOSH WG will focus on identifying and securing funding for a coordinator to oversee detailed action planning at the working group/regional level in the U.S. This position, at minimum, is necessary in order to feasibly make progress on implementation and allow for proper oversight.

Wildlife Preservation Canada, in addition to specific implementation responsibilities, will coordinate and track actions in Ontario, including those for the conservation breeding program, as outlined in the Canada Action Plan (see Appendix G).

Table 2. Overview of goals, strategies, and objectives for addressing key threats and obstacles to loggerhead shrike recovery across the *L. l. migrans* range in Canada and the United States.

	CANADA	UNITED STATES
THREAT	**HABITAT LOSS**	
GOAL	**Manage/decrease land development or conversion in order to reduce habitat loss across potentially suitable shrike range in Ontario as determined by the SDM.**	**Protect and conserve suitable habitat to ensure sufficient habitat for recruitment, survival, and other species needs.**
STRATEGIES	• Protect and conserve suitable habitat to ensure amount is sufficient for recruitment, survival, and other species needs. ○ *Obj 1. Maintain and/or develop 1:1 relationships with key stakeholders and rightsholders to promote engagement in habitat protection.* ○ *Obj 2. Secure new parcels of land to the program with habitat suitable for shrikes.* ○ *Obj 3. Lobby for policy changes (e.g. industry, municipalities) to improve habitat protections.*	• Protect existing habitat and conserve lands through purchases and other financial incentives. • Improve engagement/create awareness among farmers, private landowners, land managers, and industry on the importance of sufficient suitable habitat for shrike conservation. • Incentivize landowners to maintain existing habitat.
THREAT	**HABITAT DEGRADATION**	
GOAL	**Reduce habitat degradation in order to improve the quality of existing habitat.**	**Restore and enhance habitat quality at local and landscape scales to support shrike.**
STRATEGIES	• Engage rightsholders and stakeholders in restoration and enhancement of existing habitat [using existing Ontario BMPs]. ○ *Obj 1. Work with communities and partner organizations to plan vegetation management activities in sensitive habitat.* ○ *Obj 2. Provide incentives to landowners for implementing habitat stewardship measures.* ○ *Obj 3. Develop an outreach program to educate landowners on loggerhead shrike habitat requirements.* ○ *Obj 4. Ensure existing broader grassland management plans (e.g. provincial government, other conservation plans) incorporate loggerhead shrike habitat requirements.*	• Develop shrike specific habitat management practices (i.e. BMPs) and deliver/communicate to land managers and landowners. ○ *Obj 1. Build relationships with landowners and managers (e.g. Natural Resources Conservation Service, land trusts) to address multiple threats to habitat.* ○ *Obj 2. Manage habitat quality using Farm Bill programs, conservation easements, grazing leases, financial incentives.* • Facilitate and support implementation of BMPs on priority lands. • Incentivize landowners to create new habitat.

	CANADA	UNITED STATES
THREAT	**KNOWLEDGE GAPS**	
GOAL	**Expand knowledge base on loggerhead shrikes in order to develop more effective recovery actions.**	**Work in partnership to address knowledge gaps and threats, including those relating to habitat, demographics, and Allee effect/conspecific attraction in a strategic/coordinated fashion, to improve *in situ* population demographics and support other goals and strategies.**
STRATEGIES	• Support and/or conduct research to address existing knowledge gaps on loggerhead shrike population demographics and habitat use across the FAC. ○ *Obj 1. Develop research plans for priority knowledge gaps.*	• Pursue research to address knowledge gaps and identify threats. • Pursue funding to facilitate research, coordination of efforts and dissemination of results. • Create mechanisms for developing collaborations and sharing results of research. • Identify actions and, as necessary, undertake actions to address threats to improve *in situ* population demographics (e.g. directly reduce mortality/increase reproduction vs. more indirectly via habitat restoration/management).
THREAT	**SMALL POPULATION / ALLEE EFFECT**	
GOAL	**Increase population size to 25 pairs in both Carden and Napanee in order to decrease vulnerability to demographic stochasticity and minimize Allee effect.**	**For small populations, increase population size to a level that is resilient to stochasticity (e.g. catastrophic weather events).**
STRATEGIES	• Increase *ex situ* release numbers. ○ *Obj 1. Fill available holding spaces at existing partner facilities to increase number of birds in* ex situ *population.* ○ *Obj 2. Increase holding capacity at current facilities to allow for greater retention of hatch-year birds.* ○ *Obj 3. Recruit new conservation breeding facilities to increase available breeding spaces and number of birds in* ex situ *population.* ○ *Obj 4. Identify and implement effective mate pairing methods to increase* ex situ *pair success and number of fledged young per nest.* ○ *Obj 5. Identify and implement effective husbandry methods to decrease mortality events in the* ex situ *population.*	• Investigate *ex situ* methods to augment small populations to above 50 birds (25 breeding pairs) in combination with habitat restoration and management (research/ adaptive management approach). • Reintroduce shrike in areas of local extirpation (research/adaptive management approach).

	CANADA	UNITED STATES
	○ *Obj 6. Improve existing field enclosures and expand release capacity of existing release sites to maximize number of juveniles released.* ○ *Obj 7. Recruit birds from the wild population to improve* ex situ *population demographics.* ○ *Obj 8. Incorporate genomics into population management strategies to improve* ex situ *population demographics.* ○ *Obj 9. Address knowledge gaps pertaining to husbandry/management of* ex situ *population to improve population demographics (e.g. nutrition).* • Improve *in situ* loggerhead shrike population demographics. ○ *Obj 1. Develop effective nest protection methods to increase the number of fledged young per nest.* ○ *Obj 2. Deliver education and outreach to mitigate direct threats to survival and reproduction, e.g. nest predation, nest disturbance, road mortality, anthropogenic waste.* ○ *Obj 3. Develop contingency plans to mitigate effects of catastrophic events, integrated across* in situ *and* ex situ *populations.* ○ *Obj 4. Use effective conservation breeding and release methods to maximize hatch-year survival and recruitment.* ○ *Obj 5. Collaborate with U.S. researchers to maintain knowledge transfer and further FAC conservation measures.*	
GOAL	**Assess potential for re-establishment at additional sites to expand distribution in Ontario.**	
STRATEGIES	• Identify additional sites for population re-introduction/re-establishment outside of existing core areas and promote maintenance of those habitat areas.	

<table>
<tr><th></th><th>CANADA</th><th>UNITED STATES</th></tr>
<tr><td></td><td>Obj 1. Assess availability of existing habitat in areas identified as containing suitable habitat in the refined loggerhead shrike SDM.
Obj 2. Develop relationships with key stakeholders and rightsholders to promote engagement in habitat protection/restoration and awareness of loggerhead shrikes (to be integrated with related activities addressing habitat loss & degradation).</td><td></td></tr>
<tr><td>CHALLENGE/ OBSTACLE</td><td colspan="2">UNCERTAIN LONG-TERM SUSTAINABILITY OF THE LOGGERHEAD SHRIKE WORKING GROUP (LOSH WG)</td></tr>
<tr><td>GOAL</td><td colspan="2">Improve LOSH WG sustainability to ensure implementation of Conservation Action Plan.</td></tr>
<tr><td>STRATEGIES</td><td colspan="2">Increase membership/capacity.
Build a dedicated team to coordinate and lead action plan development and implementation, e.g. a Working Group Coordinator and 6 state/province level staff/collaborators.
Obj 1. Develop a business plan for fundraising for this purpose.
Identify allocation path for salaries and funding avenues in common with other species at risk that may benefit from conservation actions for loggerhead shrike.</td></tr>
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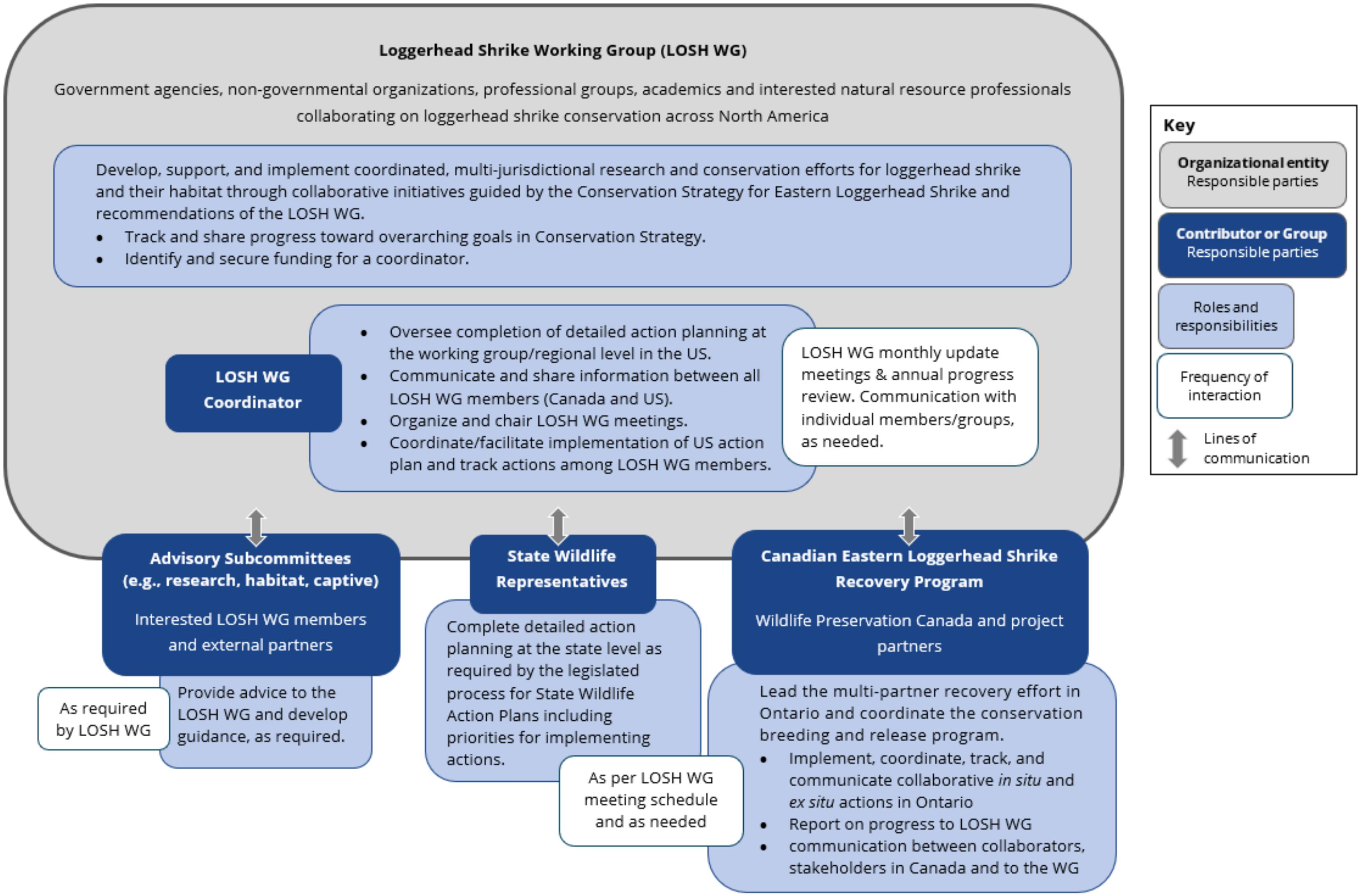


Figure 4. Organizational structure and communication plan for the oversight, monitoring, and progress tracking of the Conservation Strategy for Eastern Loggerhead Shrike.

L. Dotto,
ImageInnovation
Photography

Part II: Species Conservation Planning Process

Part II: Species Conservation Planning Process

Effective conservation planning and implementation of efforts to recover eastern loggerhead shrike (*Lanius ludovicianus migrans*) requires adaptive integration of novel insights from recent research with existing knowledge. Towards that end, a project was conceived to develop a 10-year full annual cycle (FAC) Conservation Strategy, informed by a population viability analysis (PVA). This process was deemed necessary to ensure the long-term viability of the *migrans* subspecies. Central to the process was the One Plan Approach (Byers et al. 2013), where management strategies are developed by all responsible parties and for all populations of a species, whether *in situ* or *ex situ*, to ensure one integrated conservation plan.

In total, 40 participants from diverse agencies and organizations in Canada and the U.S., and representing both *in situ* and *ex situ* expertise, participated in the Species Conservation Planning (SCP) process (see Appendix A).

Workshop Process Overview

To develop an international management plan for eastern loggerhead shrike, species experts and interested parties engaged in a series of SCP workshops. The SCP process was designed and facilitated by the IUCN SSC Conservation Planning Specialist Group (CPSG) and organized by representatives of the Canadian Species Initiative (CSI), Wildlife Preservation Canada, African Lion Safari, Queen's University, and American Bird Conservancy. The process aligned with CPSG Species Conservation Planning Principles and Steps (Figure 5) and included a PVA.

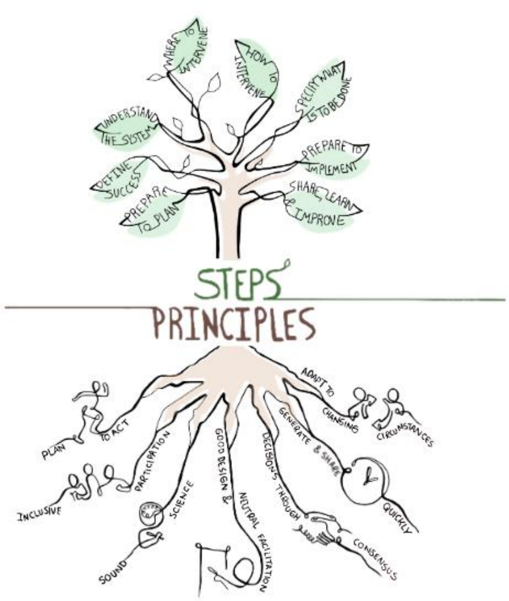


Figure 5. CPSG has seven principles and eight steps that are essential elements in the development and implementation of effective species conservation plans. The principles are represented as stable roots from which all CPSG does grows. The leaves represent the planning steps that continue to evolve in response to the increasing complexity of today's wildlife conservation challenges.

Initial Workshop July 2021: Define Success & Understand the System

The first workshop in the series took place online via Zoom July 14 – 16, 2021. Facilitated by Dr. Phil Miller, Director of Single Species Planning, IUCN SSC CPSG, the workshop included 37 participants from Canada (Ontario) and the U.S. (Indiana, Tennessee, Virginia, Colorado, Arkansas, Ohio, Kentucky, Texas, North and South Carolina), representing academia, zoological institutions, government, non-government organizations, land trusts, the aggregate industry, and cattle producers (see Appendix A). Background presentations were given to provide context and information pertinent to planning (see details in Appendix B). Over three days, participants defined success by formalizing a shared conservation vision for loggerhead shrike and established the geographic scope of the planning process. Early in the visioning process it was agreed that healthy, viable populations of loggerhead shrike across the geographic range of *L. l. migrans* throughout its FAC were necessary to ensure recovery of this focal subspecies. As well, given the similar ecology of loggerhead shrike subspecies, and evidence of intergradation (subspecies crosses), conservation efforts for loggerhead shrike populations across the northeastern species range, regardless of subspecies, are expected to benefit *L. l. migrans* and vice versa.

To help define and understand the system, a threat analysis was conducted which built upon an initial threats and challenges brainstorming exercise by the LOSH WG in November 2020. The analysis identified threats to loggerhead shrike populations and their habitats across the geographic scope and began to characterize their severity and mechanisms. In reviewing threats, participants also teased out challenges to loggerhead shrike conservation and identified the following:

- Lack of awareness
  - Among farmers
  - General public
  - Private landowners
- Lack of interest
  - Farmers/landowners
  - General public
- Reluctance to participate in conservation
  - Lack of appropriate government conservation program
- Loosening of MBTA regulations
- Difficulty to detect and broad range
  - Differentiating dispersal vs. death
  - Poor understanding of individual movements
  - Quantifiable detection probability/survey methodology
- Difficult to distinguish migrants vs. residents
- Difficult to reliably sex birds in hand
- Broad range with different regional threats
- Conservation required among many jurisdictions
- Persecution due to restrictions related to endangered species legislation
- Negative 'butcher bird' perception
- Lack of knowledge of impact of insecticides
- Lack of suitable technology to track individual movements
- Variable landowner priorities
- Unable to access habitat
  - Land tenure/Breadth, etc.
- Outdoor cats/dogs
- Lack of field research funding
- Lack of understanding of loggerhead shrike ecosystem services
- Knowledge gaps on threats at various scales

A summary of the July 2021 workshop can be found in Appendix B.

Workshop Series Aug 2021 – Nov 2022: Understand the System – Population Viability Analysis

A series of online sessions were held focused on the needs of the PVA. Led by CPSG's Dr. Phil Miller, a metapopulation model was developed using Vortex PVA software (Lacy and Pollak 2021). This PVA model was developed to better characterize *L. l. migrans* demography across the FAC in a migratory metapopulation context, identify key demographic rates that would support long-term recovery of the Ontario breeding populations, and highlight important gaps in the knowledge of *L. l. migrans* demography to prioritize future research efforts in both breeding and wintering habitats. A technical team, composed mainly of LOSH WG members, worked to provide demographic data for characterizing each population (see Figure 2) based on their work with the species and historic information.

An initial online workshop was held August 16 –18, 2021 to review the conservation vision and the proposed geographic scope developed in the first workshop and discuss the structure and inputs of the PVA model. To improve understanding of the PVA process and data requirements, background presentations were given by members of the organizing committee introducing PVA as a tool in CPSG's SCP process, reviewing previous PVAs for *L. l. migrans* in Ontario, summarizing existing knowledge of movement ecology of loggerhead shrike across their range and FAC, and summarizing Ontario population trends and demographics, both *in situ* and *ex situ*.

Recognizing the complexities of the species seasonal movement patterns, the inability to differentiate between subspecies in the field, and the similar ecology of subspecies, the group agreed to expand both the taxonomic and geographic scope of the analysis beyond the breeding populations of *L. l. migrans* in Ontario to include, to the extent possible, all loggerhead shrike habitat areas in the central and southeastern United States that are used by *L. l. migrans* (see Figure 2 for the defined geographic scope). Moreover, shrike populations that occupy these habitats, regardless of subspecies or migratory behaviour, were also to be included in the analysis. This decision was rooted in the logic that what is good for loggerhead shrike across the region would also be beneficial to *L. l. migrans* breeding in Ontario.

The group then discussed a series of key topics in development of the PVA model, including how to model metapopulation structure and annual cycle demographics across the geographic scope, and how to integrate threats and management decisions into the PVA process. Input was provided by 20 participants from Ontario, Indiana, Kentucky, North Carolina, Ohio, Virginia, and West Virginia (see Appendix A).

Through a series of smaller, regional meetings supported by organizing team members following this initial workshop, the metapopulation structure was finalized, subpopulation threat assessments continued, and data compiled to parameterize the PVA model for the Ontario subpopulations and *ex situ* population.

November 14 - 16, 2022 a hybrid meeting was held at the Nashville Zoo at Grassmere as part of the annual meeting for the LOSH WG. Participants reviewed work to date including threat assessment and prioritization, the PVA model with Ontario data, and outstanding model input needs.

Remaining data were compiled by the organizing committee and technical team members over the next several months.

The PVA model ultimately included the 14 geographically distinct wild populations (Figure 2) and the genetically managed *ex situ* population. The model simulated events over the FAC of the species (Figure 6). The annual cycle was divided into two distinct timesteps, with each timestep ending with a population census: the first just after migrating birds arrive on the wintering grounds, and the second just before fledging of offspring. The model accounted for variable migratory and dispersal behavior of loggerhead shrikes across the spatial extent of the analysis.

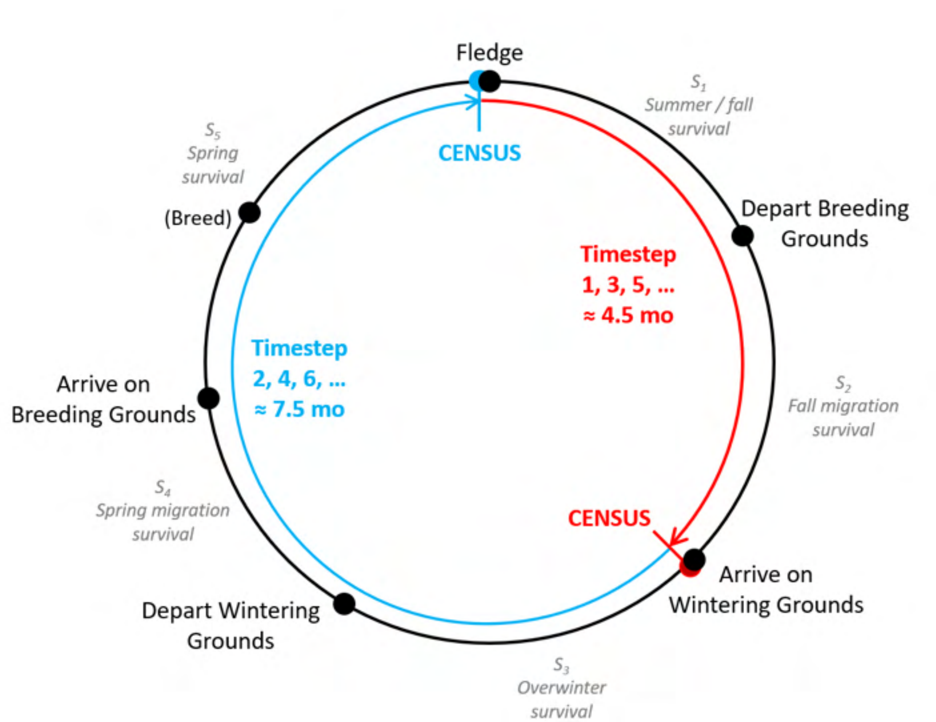


Figure 6. Diagram of the full annual cycle as simulated in the PVA model for loggerhead shrike. Each year is divided into two timesteps, with odd-numbered timesteps (red) including the time period from fledging through autumn migration, and even-numbered timesteps (blue) including over-wintering, spring migration and breeding.

A full participant list is provided in Appendix A. A detailed account of the PVA process and results can be found in *A Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States* (Appendix C).

Final Workshop January 2024: Conservation Strategy Development

A final culminating three day workshop took place January 23 – 25, 2024. Concurrent workshop sessions were held in Toronto, Ontario, Canada and Nashville, Tennessee, U.S. The Canadian sessions were run in-person, while the U.S. sessions were hybrid (online and in-person). Plenary sessions brought all groups together in a hybrid online environment. This workshop was led by

Jessica Steiner (CPSG Canada) stationed in Toronto and co-facilitated by Stephanie Winton (CSI/CPSG Canada) stationed in Nashville. Technical support for interpretation of the PVA results throughout the process was provided by Phil Miller (CPSG) in Toronto and Amy Chabot (African Lion Safari/CSI/CPSG Canada) in Nashville.

Participants were given access to a shared participant drive prior to the workshop which provided access to previous SCP workshop summary reports, relevant status assessments and recovery documents, and published literature.

The desired outputs of this final workshop were:

1. A draft full annual cycle 10-year Conservation Strategy for Eastern Loggerhead Shrike, including 2050 vision statement, indicators of success, a series of goals and strategies, and a start at more detailed action planning,
2. A process identified for completing the written conservation strategy, including action plan, and
3. A proposed leadership structure to support and track implementation of the strategy.

The results of this workshop form the basis of Part I of this report, the Conservation Strategy for Eastern Loggerhead Shrike. A summary of the process for this workshop is given below (see Appendix E for draft workshop agenda).

Summary of Final SCP Workshop Process

The final SCP workshop began January 23, 2024. Opening remarks were given by Jim Giocomo (American Bird Conservancy), and a land acknowledgement was given in Toronto by Lead Facilitator, Jessica Steiner. Given the novel format of the workshop, which included concurrent facilitation of parallel hybrid in-person/online workshops in two locations, the planning process had an additional layer of technical complexity. A working agreement to guide appropriate behaviour during the workshop was introduced, and an explanation of the workshop logistics given, to help the workshop sessions run as smoothly as possible in this format.

Setting the Stage: Background Information

The workshop program began with a series of informational sessions:

- Lead facilitator Jessica Steiner (CPSG Canada) presented a summary of planning work accomplished as part of the SCP process leading up to the workshop, including key outcomes, and an overview of the process for the next three days which included prioritizing where to intervene, developing goals and strategies, and setting the stage for more detailed action planning.

- Amy Chabot (African Lion Safari/CSI/CPSG Canada) gave a presentation summarizing the key takeaways from the initial PVA (see Appendix C) and the results of further modeling and sensitivity testing that had occurred since the last workshop (see Box 1). The summarized results of sensitivity testing are provided in Table 3, and full details on this additional modeling and sensitivity testing is summarized in *Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States: Addendum* (Appendix D).
- After a brief review from Amy Chabot of the Species Distribution Models (SDMs) that were used to help define the geographic scope of the workshop, Hazel Wheeler (Wildlife Preservation Canada) presented key results from recent work to validate the Ontario SDM and quantify the amount of available suitable habitat (see Box 1). Results suggested the availability of suitable habitat does not appear to be a limiting factor for eastern loggerhead shrike in Ontario at this time. However, the need to maintain existing habitat was emphasized, as well as the need for further work to incorporate additional aspects of habitat suitability into the model e.g. landscape configuration and prey abundance.

Table 3. Results of sensitivity testing of parameters in the full annual cycle model developed for loggerhead shrike. Relative impact of individual demographic parameters to deterministic population growth rate has been noted. +++ indicates a parameter to which growth rate was highly sensitive (i.e. changes in this parameter result in relatively larger changes in growth rate). ++ indicates parameters to which growth rate was sensitive but to a lesser degree i.e. “moderate” sensitivity. + denotes parameters to which population growth has little to no sensitivity i.e. “low” sensitivity.

Parameter	Relative Sensitivity of Model
Reproduction	
# fledged young	+++
Sex ratio – female fledged young	+++
% females breeding	+++
% males breeding	+
Mortality	
Fall migration	+++
Spring migration	+++
Age class 0 to 1 mortality – male	+
Age class 0 to 1 mortality – female	+++
Adult (1-2) non-breeding + spring migration – male	+
Adult (1-2) non-breeding + spring migration – female	+
Adult (2-3+) breeding + spring migration – male	+
Adult (2-3+) breeding + spring migration – female	+
Other	
Inbreeding depression	+
Allee effect	++
Initial Pop Size	++
Carrying capacity	++
Supplementation rate	+++
Catastrophe – reproduction	+
Catastrophe - survival	++

Box 1. Summary of Day 1 presentations from the Eastern Loggerhead Shrike *(Lanius ludovicianus migrans)* Conservation Planning Workshop (January 23, 2024).

Full Annual Cycle Population Viability Analysis: Overview
Amy Chabot

Sensitivity testing of the PVA model was conducted to explore which demographic rates are driving the observed declines. This can assist with identifying potential points in the system that could be targeted by conservation actions to benefit loggerhead shrike. Sensitivity testing focused on all parameters of the model, including reproductive parameters (e.g. proportion of males and females breeding, number of fledged young, etc.), mortality (e.g. mortality during migration events), and other parameters (inbreeding, Allee effects, dispersal, catastrophes and carrying capacity). Sensitivity testing was conducted on four focal populations: Carden and Napanee (which contain the majority of the breeding pairs in Ontario but vary in some demographic rates), Illinois-Indiana (a partially migratory population for which demographic data is well supported from field research), and Missouri-Arkansas (year-round resident population for which demographic data is well supported from field research).

Additional model scenarios were run with different input values for carrying capacity, initial population size, and *ex situ* population management and release numbers to inform recovery criteria and test possible population management activities.

Major insights from modeling and sensitivity testing include:

1. All populations experience negative population trends under current demographic rates.
2. Of all the parameters examined, models appeared most sensitive to the number of fledged young produced.
    a. Increases in average reproductive output of mean 3.5 fledged young/brood to 4.0 – 4.5 fledged young/brood helped populations realize a positive growth trend.
    b. U.S. populations were more sensitive (i.e. responded more positively) to smaller increases than Ontario populations i.e. increase from 3.5 to 4.0 fledged young/brood had a stabilizing effect on populations.
    c. Increasing number of females in broods (i.e. skewing sex ratio) resulted in positive population growth.
3. Models were more sensitive to changes in female versus male demographic rates. Positive growth was achieved by decreasing female mortality rates in any age class and increasing the proportion of females breeding.
4. Models for migratory populations were sensitive to mortality during migration events.
5. Supplementation of wild populations using an *ex situ* population can improve overall population size but without additional management to improve demographic rates, trends return to negative after supplementation is stopped. This is true even under scenarios where more *ex situ* birds are released. Further, both improved reproductive rates and reduced mortality rates are needed to reverse population declines and ensure sustained growth. Additionally, supplementation only improves the populations in areas where the supplementation occurred.
6. Increasing the carrying capacity of a region (e.g. available suitable habitat) increases the survival rate of shrike in that population
7. Increasing the initial population size can significantly increase the survival rate (i.e. reduces stochastic impacts at low population sizes such as Allee effect, extinction vortex, etc.)
    a. The model indicated a threshold of 50 birds / population for loggerhead shrike to ensure greatest probability of survival

Recovery targets should consider:

- mean fledged young/brood: min 4 – 4.5
- hatch year mortality rates: max 25 – 30%
- migration survival rates: min 90%
- percentage of females breeding: min 78 – 80%
- initial population size: N > 50 (extinction vortex threshold)
- carrying capacity: maximum possible

The full annual cycle PVA will provide guidance and structure for current and future planning efforts and research goals. Overall, the results of the modeling suggest that to improve outcomes, it is essential to implement both *ex situ* and *in situ* management strategies to increase the wild populations.

Species Distribution Modeling (SDM) and available suitable habitat
Hazel Wheeler

In 2020, an SDM was developed using landscape-level mapping layers (i.e. land cover, climate, habitat, and geology), to predict the existence of suitable habitat for eastern loggerhead shrike (*L. l. migrans*) in southern Ontario. Field surveys were completed in 2022 to ground-truth the SDM and collect additional data on site-level characteristics not adequately captured by landscape-level mapping layers. Researchers also assigned an observer-predicted suitability score to each site based on the presence of required habitat features and their own expert knowledge, as a supplementary validation approach to further understand whether the SDM over or underreports specific suitability categories.

Analyses to validate the SDM indicated that generally, the original SDM overreports suitability (i.e. some habitat identified by the model as higher suitability wasn't necessarily good quality when groundtruthed) suggesting that available *L. l. migrans* habitat is scarcer than what the SDM predicts. However, the SDM more reliably identifies areas of unsuitable habitat (i.e. habitat identified as lower suitability, was generally found to be lower quality habitat). A potential limitation of these analyses is a difference in time periods between the original SDM (model based on 2016/2017 data) and the field surveys (2022 data).

Removing the unsuitable habitat from the model gave a clearer prediction of suitable landscape conditions that are predicted to contain highly suitable site-level habitat. A threshold to determine landscape-level suitable regions for *L. l. migrans* (> .638 = "high") was established through model validation, and field survey data contextualized high-quality local habitat within these regions. The refined model reflects the relationship between landscape and local ecological processes: suitable landscape conditions are essential for the existence of suitable local habitats.

The refined model identifies approximately 361 500 hectares (ha) of predicted suitable habitat in Ontario, representing 3% of southern Ontario and 30% of the original SDM's estimate, the majority of which is concentrated in four current or historical shrike breeding areas: Napanee, Carden, Manitoulin Island, and Smiths Falls (more specifically the Cornwall area of this historic core) (Figure 7). Considering 50 ha to be the minimum territory size for a breeding pair (Environment Canada 2015), Ontario could theoretically support over 7 200 breeding pairs. This is several orders of magnitude larger than the observed population, suggesting that habitat is not a limiting factor in Ontario.

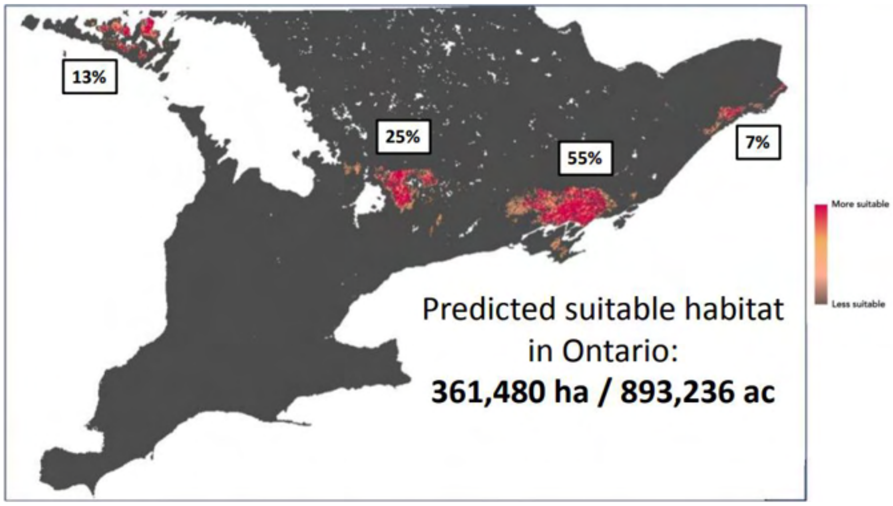


Figure 7. Predicted suitable habitat for eastern loggerhead shrike in southern Ontario based on refined species distribution model. Suitable habitat areas, left to right: Manitoulin Island, Carden, Napanee, and Smiths Falls.

Overall, this modeling highlights:

- **The importance of habitat maintenance**:
    - While the model suggests there is sufficient habitat available for *L. l. migrans*, and intensive habitat restoration is therefore not an immediate need in Ontario, maintenance of existing habitat could ensure that habitat does not become severely limiting.
- **Priority regions for recovery activities:**
    - Priorities for habitat protection and conservation should focus on hotspots of groundtruthed high-quality sites that fall within the refined SDM's "high" category. Many of these sites are outside of but adjacent to the known geographic extent of *L. l. migrans* occurrence and conserving these areas could therefore increase landscape connectivity between isolated habitat patches across southern Ontario.
    - Based on the amount of suitable habitat predicted by the model, Manitoulin Island (~47 000 ha) would be a higher priority region for re-establishing a breeding shrike population compared to the Cornwall region (~25 000 ha). However, modeled habitat extends towards provincial (Quebec) and national (upstate New York) borders and including these additional areas in the model could alter the regional perspective.
- **Further modeling applications:**
    - The finding that the Ontario SDM was reliable at identifying areas of unsuitable habitat could be applied to the existing U.S. SDM (Dr. Stephen Spear et al., unpublished data) to refine the model by removing areas of predicted lower suitability and help focus efforts in those regions.
    - Factors that were not included in the model that could be further examined to determine if habitat areas can support shrike recovery include landscape-level structure (i.e. habitat connectivity) and food resource availability (i.e. insect biomass).

Where to Intervene

The next step in the workshop was establishing a process for prioritizing where in the system to intervene. The organizing committee had previously developed criteria for identifying priority intervention points, to be considered over the 10-year period of the action plan; these were reviewed and agreed upon by the group:

1. Magnitude of impact on species decline - *Which threats have the greatest magnitude of impact on species decline, and therefore are of greatest urgency to address from a biological perspective?*
2. Feasibility of mitigating threat - *Where is it most feasible to intervene successfully, considering socio-cultural, political, technological, environmental, knowledge, resources, uncertainty, and other constraints?*

Given the number and complexity of threats, differing considerations between countries, and the time that has passed since the group last looked at the threat assessment together, summary sheets of threats by country were made available to the group (see Appendix F). Here, threats that had been assessed as contributing to only slow or negligible population decline across the country were removed. Mechanistic drivers were grouped under broad threat categories: habitat loss, habitat degradation, catastrophic events, interactions with motor vehicles, predation of adults/overwintering, predation of hatch year birds, depredation of nests/nest interference/nestling mortality, Allee effect/small populations, and unknown threat level/knowledge gap. Fluctuating/declining prey abundance and interactions with industrial chemicals were additional threat categories with impact on *L. l. migrans* in the U.S. only. These threat categories had been mapped to the FAC to display where in the system they were acting, as in Figure 3. Participants were asked to consider threats at this higher category level for this exercise. U.S. participants were further instructed to take a *migrans*-centric approach during this process, i.e. prioritize threats according to impacts of importance to the *migrans* subspecies, which occupies the U.S. range predominantly during the wintering season.

Participants broke into U.S. (hybrid, Nashville) and Canada (in-person, Toronto) working groups at this time. Working groups spent the next 30 minutes reviewing and discussing information from the threats assessments, including obstacles and challenges identified during that process, and PVA results, including the sensitivity of demographic parameters; CPSG modelers Phil Miller and Amy Chabot were present to answer any questions as needed. Participants were directed to consider the severity of threats as well as their geographic scope, and were then asked to individually score each threat category using the following provided metrics:

IMPACT/URGENCY

Score	Guidance (applied to geographic scope of working group)
1	Severe threat impacting all or almost all populations
2	Severe threat impacting most populations
3	Moderate threat impacting most of the populations OR Severe threat affecting some of the populations OR threat affects a majority of populations with unknown impact.
4	Moderate threat impacting a small proportion of populations.

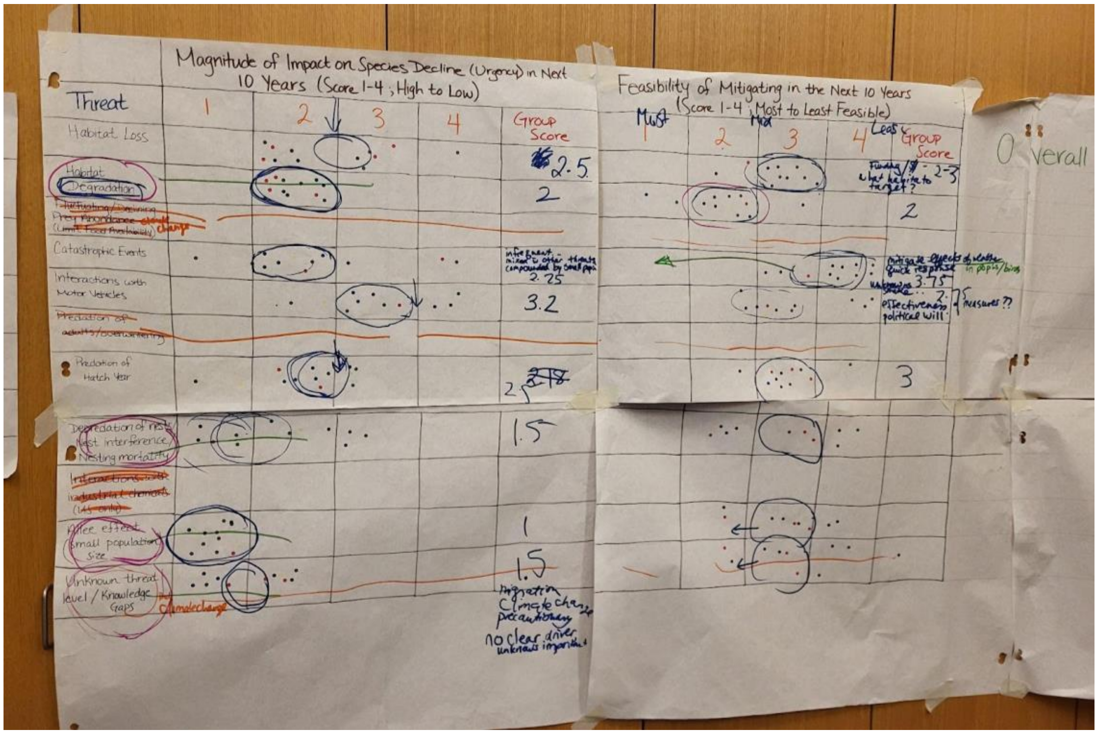
FEASIBILITY

Score	Guidance (applied to geographic scope of working group)
1	Very high feasibility – we can start mitigating this threat almost immediately and have significant positive results within 10 years
2	High feasibility – while some challenges/obstacles exist, these can be surmounted, and we are confident we can begin successful mitigation of this threat in the next 10 years.
3	Medium feasibility – Some challenges/obstacles exist; our ability to overcome is unknown/uncertain but we are reasonably confident we can make some positive change in the next 10 years.
4	Low feasibility – significant challenges/obstacles to overcome which will seriously compromise our ability to successfully mitigate this threat within the next 10 years.

In assessing feasibility, participants were directed to look at the mechanistic drivers and do some rapid prototyping of possible actions, while reviewing relevant obstacles and challenges. Once complete, individual scores were compiled for each working group (Figure 8). The U.S. working group compiled scores in Mural (https://www.mural.co/) to facilitate hybrid participation.

An open facilitated discussion was held to reach group consensus on urgency and feasibility scores for each threat category. Generally, discussion began with threats where there appeared to be relatively good agreement and then moved to those where there appeared to be divergent opinions. Participants were invited and encouraged to share why they had scored a particular way, particularly for any outlying scores. Group consensus scores for threat urgency and feasibility of mitigation were then further prioritized at a national level to identify which threats should be targeted for action in the next 10 years, i.e. where to intervene.

Given the wide spread of scores generated by the U.S. working group, participants took some additional steps in developing group consensus scores for urgency and feasibility. Individual scores were weighted 1 – 4 based on their urgency or feasibility level (i.e. scores of 1 were given a weight of 1 and scores of 4 were given a weight of 4). The sum of the weighted scores was then used to develop a final score for the urgency of that threat and the feasibility of mitigation, colour-coded by severity, which were used to guide discussion and come to group consensus (Figure 8b). These colour categories were then used to prioritize which threats should be targeted for action in the next 10 years based on the urgency to address and feasibility of mitigation.



a)

Threat	Magnitude of impact on species decline in the next 10 years (Urgency) Score 1-4 high to low: 1	2	3	4	Group Score	Feasibility of mitigating in the next 10 years Score 1-4 most to least feasible: 1	2	3	4	Group Score	Overall Priority
Habitat Loss					32					25	High
Habitat Degradation					31					24	High
Fluctuating / declining prey abundance limiting food availability					33					29*	Medium
Catastrophic events					33					43	Low
Interactions with motor vehicles					38					34*	Medium
Predation of adults/overwintering					39					44*	Low
Predation of hatch year					29					38*	Medium
Depredation of nests / nest interference / nestling mortality					28					35*	Medium
Interactions with industrial chemicals (US only)					38					32	Low
Allee effect (small population size)					33					29*	Medium
Unknown threat level / knowledge gaps					35					28	High

* These threats can be more feasibly mitigated when habitat loss or degradation are mitigated

b)

Figure 8. Compiled participant scores for urgency of threats to *L. l. migrans* and feasibility of mitigation in a) Canada and b) the United States. Group Scores in (b) were calculated from weighted sums (methods described in text), with colours indicating high to low Urgency (in order: red, orange, yellow, blue), and low to high Feasibility (in order: red, orange, yellow, blue). *Images are for process illustration purposes only and may not accurately display final scores; results spurred further discussion with final decisions reflected in Table 4.*

Working groups then convened in plenary to share back their overall prioritization for where to intervene in Canada and the U.S. (Table 4), with opportunity for questions and comments between groups. The U.S. working group noted that several categories of threats, such as fluctuating/ declining prey availability, predation of all life stages, and Allee effect, could be more feasibly mitigated by addressing habitat loss or degradation, rather than working to address the threats directly.

Table 4. Threats to *L. l. migrans* prioritized for recovery action, based on magnitude of impact on species decline (urgency) and feasibility of mitigation in Canada and the United States. *denotes threats the U.S. working group identified as being best addressed through activities to restore and protect habitat.

Priority for recovery action	CANADA	UNITED STATES
High	• Habitat degradation • Depredation of nests/nest interference/ nestling mortality • Allee effect/small population, • Unknown threat level/knowledge gap	• Habitat loss • Habitat degradation • Unknown threat level/knowledge gap
Medium	• Habitat loss • Catastrophic events • Interactions with motor vehicles • Predation of hatch year birds	• Prey abundance* • Interactions with motor vehicles* • Predation of hatch year birds* • Depredation of nests* • Allee effect/small population*
Low	N/A	• Catastrophic events • Predation of adults/overwintering* • Interactions with industrial chemicals

The remainder of Day 1 was focused on reframing priority threats into draft 10-year goal statements that described the desired change the group wanted to see within the system and how the change is predicted to positively impact the system and species. Obstacles and challenges to threat mitigation were also discussed in terms of goal development needs. Draft 10-year goals were presented back in plenary at the end of Day 1, with further work into Day 2 to produce a set of refined goal statements for each country on which to build action plans. Finalized goal statements, which were completed post-workshop by participants, are presented in Table 5. While wording differs between the two countries, there is ultimately strong alignment in direction over the next 10 years.

Table 5. Broad implementation goals to recover eastern loggerhead shrike across its full annual cycle.

BROAD THREAT/ CHALLENGE	CANADA	UNITED STATES
Habitat loss	Manage/decrease land development or conversion in order to reduce habitat loss across potentially suitable shrike range in Ontario as determined by the Species Distribution Model.	Protect and conserve suitable habitat to ensure sufficient habitat for recruitment, survival, and other species needs.
Habitat degradation	Reduce habitat degradation in order to improve the quality of existing habitat.	Restore and enhance habitat quality at local and landscape scales to support shrike.
Knowledge gaps	Expand knowledge base on loggerhead shrikes in order to develop more effective recovery actions	Work in partnership to address knowledge gaps and threats, including those relating to habitat, demographics, and Allee effect/ conspecific attraction in a strategic/ coordinated fashion, to improve *in situ* population demographics and support other goals and strategies.
Small populations/ Allee effect	Increase population size to 25 pairs in both Carden and Napanee in order to decrease vulnerability to demographic stochasticity and minimize Allee effect. Assess potential for re-establishment at additional sites to expand distribution in Ontario	For small populations, increase population size to a level that is resilient to stochasticity (e.g. catastrophic weather events)
Uncertain long term sustainability of LOSH WG		Improve LOSH WG sustainability to ensure implementation of conservation action plan

Indicators of Success

Phil Miller (CPSG) gave a short presentation on Day 2 to provide some guidance for, and examples of, defining indicators of success for the vision. The task of developing draft indicators of success was taken on by the organizing team post-workshop; these were reviewed by participants and finalized as they appear in Part I of this document.

How to Intervene

On Day 2, Hazel Wheeler (Wildlife Preservation Canada) summarized the different approaches that have been used to date to reduce threats to *L. l. migrans* in Ontario, including review of their performance to date and lessons learned (see Box 2). Insights from a recent United States Geological Survey (USGS) publication on the effects of management practices on loggerhead shrike were also provided.

The Canada and U.S. working groups spent the remainder of Day 2 brainstorming alternative approaches that could be taken to realize each of their goals. Groups then assessed these alternatives—winnowing and clustering into "themes" as appropriate and discussing additional considerations such as feasibility, cost and time to implementation—to come up with preferred strategies to achieve each goal. Working group recommendations were presented back in plenary with time for open discussion and questions. Working groups continued to refine preferred strategies post-workshop; the final results of this process are summarized in Table 2. While the Canada and U.S. working groups independently established goals and preferred strategies, there were significant parallels (see Part I: Conservation Goals and Recommended Strategies).

Box 2. Summary of Day 2 presentations from the Eastern Loggerhead Shrike *(Lanius ludovicianus migrans)* Conservation Planning Workshop (January 24, 2024)

A Review of Conservation Interventions for Loggerhead Shrike
Hazel Wheeler

Multiple approaches have been taken to support the recovery of shrike populations in Ontario, Canada including conservation breeding and release, habitat stewardship and restoration, public outreach and education, and priority research. Annual habitat surveys and population monitoring allow us to track the status of shrike in Ontario and gauge the impact of the release program through detection of returning captive-bred birds.

Conservation breeding program:
To date the breeding program has released over 1400 captive-bred juveniles, and these releases have been effectively slowing down the rate of decline in wild populations. Return rates for captive-bred birds have been in-line with those of wild birds, and even higher in some years. In recent field seasons, captive-bred birds have made up about a third of the birds found in Ontario, and wild pairing with at least one captive-origin bird have produced up to one half of the fledglings observed in the wild in some years.

Lessons learned:

1. Return rates are higher when birds are released young and in larger groups; release cohorts are planned accordingly.
2. Return rates are comparable if not higher for birds bred at *ex situ* partner facilities vs field breeding in *in situ* enclosures, which provides more opportunity to build the breeding capacity of the program with new partners
3. While the release program has maintained *L. l. migrans* on the landscape, it has not produced sustained increases in the wild population - it is essentially buying time.
4. While methods help prevent local extirpation, re-establishing populations in historic areas (e.g. Smiths Falls and Manitoulin) continues to be a significant challenge.

Priority research:
Research has primarily focused on identifying the migratory routes and overwintering grounds of the Ontario population, a major knowledge gap. Every year a subset of captive-bred juveniles is released with radio tags that are tracked on the Motus Network; a collaborative research initiative spearheaded by Birds

Canada. Data has been largely limited to movement within Ontario as opposed to cross-border movements because of the existing tower array, but the hope is that that will improve as the network continues to expand. In 2018 and 2019, tagged birds were detected in Pennsylvania, most likely during migration.

Habitat stewardship and restoration:
Relationship-building with landowners has been important in maintaining and restoring shrike habitat in core areas. Since 2001 we have worked with approximately 70 landowners to steward around 7,000 ha of shrike habitat through cost-share projects. These projects often focus on maintaining cattle on the landscape such as fencing repair/installation, and installation of water systems to direct grazing cattle to overgrown habitat. Shrub removal in dense areas creates open, suitable hunting habitat for shrike as well as grazing areas for cattle; the brush piles created also serve as hunting and impaling sites. These projects are beneficial for the birds in maintaining their habitat, and for the cattle producers as the projects are generally necessary to support their operations. Given the sometimes thorny response that landowners can have to endangered species, these projects have been one of our most effective ways of engaging local communities in shrike recovery. It takes time to build and maintain these relationships, and they are extremely important to recovery efforts.

Public outreach and education:

- Public resources: Loggerhead Shrike: An Ontario Landowner's Guide
- Grassland and alvar stewardship workshops: Educating local landowners on natural heritage in the Carden, Napanee and Grey-Bruce/Manitoulin regions with a focus on habitat stewardship for grassland birds
- Adopt-a-site program: A community science program, where volunteers complete three surveys for a suite of grassland birds, including shrike, during the spring at their "adopted" sites. The program is used to provide additional capacity and survey coverage in historic areas.
- Landowner dinners: Outreach event designed to share information, and to thank and show landowners appreciation for their dedication to Shrike recovery (due to funding restrictions, this event is no longer ongoing)
- Tours and events: This includes field-site tours and public outreach events

Although difficult to quantify, each of these outreach and educational programs plays a significant role in *L. l. migrans* recovery. Further outreach and education programs could be undertaken if greater access to resources were available.

United States Geological Survey (USGS) publication:
The Effects of Management Practices on Grassland Birds - Loggerhead Shrike (*Lanius ludovicianus*)
(Igl et al. 2023)

This resource summarizes the current knowledge and major findings in the literature on the effects of different management practices on loggerhead shrike as well as specific recommendations for habitat management provided in the literature.

Several relevant points were highlighted:

- Weather affects reproduction; periods of cool weather and above-average rain can lead to high nest failure rates
- Loggerhead shrike is categorized as a climate-stable species, indicating that the species is likely to retain >50% of its current distribution by 2050 across, with potential for range expansion. *However, it was noted by participants this may not be helpful/accurate when considering the migrans subspecies specifically.*
- Low nesting success in highly agricultural landscape, with ~90% nest failure from depredation

- Evidence that shrikes choose nest sites closer to roads (within 100 m) than random in Virginia. In Missouri nests close to roads (within 15 m) tended to have lower production.

Summary of management recommendations from USGS report:

- Offer conservation incentive programs for private landowners
- Maintain/restore vegetation/habitat characteristics and heterogeneous landscapes
- Use grazers to maintain short vegetation, but keep some longer grasses as food reservoirs for small mammals
- Add artificial perches where lacking, but give them some cover
- Reduce pesticides to maintain prey abundance
- Conspecific attraction is important in nest selection of inexperienced breeders, so species breeding ecology needs to be considered when planning habitat conservation or reintroductions

Specify What is to be Done

Day 3 of the workshop process was focused on outlining objectives and actions that needed to be accomplished for each strategy. Participants reviewed SMART actions (Specific, Measurable, Assignable, Realistic/Relevant, and Time-related) and the key elements of action statements including responsible parties, timeline, key collaborators, outcomes, assumptions, and monitoring method. Participants then broke into 3 working groups: Canada *In Situ* Strategies (in-person, Toronto), Canada *Ex Situ* breeding and release (hybrid, Toronto-online), and U.S. Strategies (hybrid, Nashville-online). An action statement template was provided to help guide working groups through this process. The Canada *In Situ* and *Ex Situ* working groups completed detailed action planning post-workshop, and a comprehensive overview of the goals, preferred strategies and actions for eastern loggerhead shrike recovery in Canada can be found in Appendix G. The U.S. working group convened post-workshop to finalize their goals and preferred strategies and outline a plan for future completion of detailed action planning, to be undertaken at a state level. Results of U.S. action planning to-date are also presented in Appendix G.

Prepare to Implement

As there were new participants joining the process for the first time at this workshop, a short presentation was given on the [Loggerhead Shrike Working Group](#) (LOSH WG). This bi-national Working Group was established in 2013, to facilitate collaborative conservation activities and greater coordination between the various groups working with the species across its range. The group was initially established with an eastern North American focus due to the perilous status of the species in this region but has since expanded to include members throughout much of North America.

LOGGERHEAD SHRIKE
WORKING GROUP

To date they have established a coordinated and standardized colour-banding project designed to improve understanding of migratory connectivity and assist in the development of a species genoscape (through feather sample collection while birds are in-hand) and launched Shrike Force to engage community science volunteers in surveys and monitoring, among other initiatives. Work is currently guided by several conservation and management priorities identified when the group was founded, and recommendations from the membership. There are no paid staff, and no one is dedicated to the LOSH WG full-time; all members contribute their time voluntarily to complete tasks and support common goals.

A plenary discussion was initiated to identify a leadership framework for strategy implementation, coordination, and tracking. Participants in the U.S. working group expressed serious concerns about the capacity of the existing LOSH WG to fulfill this function, as current co-chairs are stretched thin, and turnover is expected. Further, it arose that while the LOSH WG has a role in planning, ultimately, implementation of actions will be determined at the state level (i.e. in State Wildlife Action Plans) and challenges with planning and implementation across multiple states were noted (e.g. differing state-specific legislation, resources, frameworks, priorities, etc.).

This discussion highlighted a major need for additional LOSH WG capacity to support successful planning and implementation in the U.S. For this initiative to at the very least "survive," the workshop participants identified the need for at minimum a paid coordinator, and sustained funding to support that position. This need is reflected in the addition of a bi-national range-wide goal to improve LOSH WG sustainability and capacity to implement the action plan by securing a paid coordinator and sustained funding to support that position. With the development of this plan, there will then be an acute need to increase to several paid positions that would allow the group to implement actions on the ground throughout the range. There was some discussion around recruiting additional members to help build capacity, with a focus on diversifying stakeholder representation. Regardless, it was recognized that continuing to rely on volunteer members was not a sustainable approach to moving things ahead; Road to Recovery was noted as a potential model for an effective Working Group structure.

The Conservation Strategy developed in this planning process (Part I) could be an integral part of leveraging that funding: with some further work on developing a more detailed action plan for the U.S., the current Strategy could be polished and re-packaged for fundraising purposes. It was felt that this work could be achieved by smaller subgroups within the LOSH WG.

In the interim, work of individual members will be tracked at the larger annual LOSH WG meeting, perhaps enhanced by the formation of a sub-committee to take on responsibility of tracking progress.

Wildlife Preservation Canada, a LOSH WG member, committed to coordinating and tracking actions in Ontario, in addition to their implementation responsibilities as identified in the action plan for Canada (see Appendix G). Better unification of Canadian and U.S. representatives and interests, and integration of plans was emphasized. Unfortunately, the format of this workshop, with U.S. and Canadian groups working in parallel in separate locations, ultimately created some siloing between the regions that the editors have worked to improve in Part I of this document.


J. Spero/WPC

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E. Royer
Appendices

Appendix A. SCP Participants

Organization	Name	Initial Conservation Planning Workshop (July 2021)	PVA Workshops (August 2021 – November 2022)	Final Conservation Planning Workshop (January 2024)
African Lion Safari	Amy Chabot*	✓	✓	✓
	Andrea Morgan			✓
	Garreth Morgan			✓
Akron Zoo	Laura Cancino	✓		
Alabama Department of Conservation and Natural Resources	Mercedes Bartkovich		✓	
	Eric Soehren			✓
American Bird Conservancy/ Oaks and Prairies Joint Venture	Jim Giocomo*	✓		✓
Appalachian Mountains Joint Venture	Becky Keller	✓	✓	
Arkansas State University	Than Boves		✓	
	Emily Donahue		✓	✓
Beef Farmers of Ontario	Darby Wheeler	✓		✓
Colorado State University	Teia Schweizer	✓	✓	
Environment and Climate Change Canada	Kevin Hannah	✓	✓	
	Christian Artuso	✓	✓	
Granby Zoo	Chelsea Paquette		✓	
Indiana Department of Natural Resources	Allisyn Gillet	✓	✓	✓

Organization	Name	Initial Conservation Planning Workshop (July 2021)	PVA Workshops (August 2021 – November 2022)	Final Conservation Planning Workshop (January 2024)
	Amy Kearns	✓	✓	
Kentucky Department of Fish and Wildlife Resources	Michael Patton	✓	✓	✓
Eastern Loggerhead Shrike Recovery Team	J-P Savard	✓	✓	
Miller Aggregates	Cindy McCarthy	✓	✓	✓
Mississippi State University	Scott Rush			✓
Nashville Zoo at Grassmere	Joe deGraauw		✓	✓
	Rachel Payton			✓
National Aviary	Steve Latta			✓
	Bob Mulvihill			✓
Nature Conservancy of Canada	Mhairi McFarlane	✓	✓	
	Jordan Howard			✓
North Carolina Wildlife Resources Commission	John Carpenter	✓	✓	✓
Ohio Department of Natural Resources	Joseph Lautenbach	✓	✓	✓
Ontario Ministry of Agriculture, Food and Rural Affairs	Christine O'Reilly	✓	✓	
Ontario Natural Heritage Information Centre	Mike Burrell		✓	✓
Ontario Parks	Jennifer Hoare	✓	✓	

Organization	Name	Initial Conservation Planning Workshop (July 2021)	PVA Workshops (August 2021 – November 2022)	Final Conservation Planning Workshop (January 2024)
Ontario Soil and Crop Improvement Association	Maria Ramirez Giraldo	✓		
Ontario Stone Sand and Gravel Association	Ashlee Zelek	✓		✓
Parc Omega	Vicky Carriere		✓	✓
	Audrey Pilon			✓
Queen's University	Alisa Solecki*	✓	✓	✓
	Drew Sauve	✓	✓	✓
San Diego Zoo Wildlife Alliance/ Association of Zoos and Aquariums	Colleen Lynch		✓	
Smithsonian Conservation Biology Institute	Leighann Cline	✓	✓	
	Amy Johnson		✓	✓
	Julie Buschor			✓
South Carolina Department of Natural Resources	Amy Tegeler	✓	✓	✓
Southeastern Avian Research	Cyndi Routledge	✓	✓	✓
Tennessee Wildlife Resources Agency	David Hanni			✓
Toronto Zoo	Jon Spero	✓		✓
University of Arkansas	Brett DeGregorio	✓		
Virginia Department of Wildlife Resources	Sergio Harding	✓	✓	✓

Organization	Name	Initial Conservation Planning Workshop (July 2021)	PVA Workshops (August 2021 – November 2022)	Final Conservation Planning Workshop (January 2024)
Virginia Tech	Carola Haas			✓
West Virginia Division of Natural Resources	Richard Bailey		✓	✓
Wildlife Preservation Canada	Hazel Wheeler*	✓	✓	✓
	Jessica Steiner*	✓	✓	
	Jane Spero	✓	✓	✓
	Helmi Hess			✓

*organizing team members

Appendix B. Initial SCP Workshop: Summary Report

Eastern Loggerhead Shrike
Species Conservation Planning

Workshop 1: Laying the Foundation
July 14-16, 2021

Funded by

Process Design and Facilitation

Organizing Committee

Executive Summary

Loggerhead Shrike (*Lanius ludovicianus*) have exhibited drastic population declines, especially in their northern breeding range. Recent taxonomic assessment indicates shrike in the northeastern part of the range are a distinct subspecies, *L. l. migrans.* Currently, breeding populations of *L. l. migrans* are mostly constrained to Ontario, Canada, migrating to winter ranges in the Atlantic coastal states, within the upper Mississippi Alluvial Valley and states in between (e.g. Pennsylvania). Conservation efforts have been ongoing in eastern Canada (Ontario) since 1992, and more recently through range-wide collaborations with members of the North American Loggerhead Shrike Working Group. A conservation breeding program initiated in the early 2000s has had a stabilizing effect on the wild population through annual releases of juvenile birds in Ontario.

A series of Species Conservation Planning (SCP) workshops for the Eastern Loggerhead Shrike, designed and facilitated by the IUCN SSC Conservation Planning Specialist Group, and organized by representatives of the Canadian Species Initiative, Wildlife Preservation Canada, African Lion Safari, Queen's University, American Bird Conservancy, and the North American Loggerhead Shrike Working Group, will occur in 2021-2022. The first workshop in the series took place virtually July 14-16, 2021 and included 37 participants from Canada (Ontario) and the US (Indiana, Tennessee, Virginia, Colorado, Arkansas, Ohio, Kentucky, Texas, North and South Carolina), representing academia, zoological institutions, government, non-government organizations, land trusts, aggregate extraction industry, cattle ranching, and members of the Loggerhead Shrike Working Group. Over 3 days, participants defined success by formalizing a shared conservation vision for Loggerhead Shrike, established the geographic scope of the planning process, and identified and quantified the severity of regional threats to better understand the system. This workshop laid the foundation for the next stage of the process: conducting a Population Viability Analysis (PVA) to assess the long-term persistence of the shrike population and evaluate potential management approaches. The second workshop series is scheduled for August 16-19, 2021, and will again be virtual.

Eastern Loggerhead Shrike
Species Conservation Planning
Workshop 1: Laying the Foundation

Facilitated by: Phil Miller, Senior Program Officer
IUCN SSC Conservation Planning Specialist Group (CPSG)

DRAFT Agenda

Session 1: July 14, 2021 @ 9am-12pm Eastern/8-11am Central

- Opening welcome and participant introductions
- Background presentations; Q&A
- Generating a long-term vision for Eastern loggerhead shrike (ELOSH) conservation in North America

Session 2: July 15, 2021 @ 9am-12pm Eastern/8-11am Central

- Summary of Session 1
- Presentation and discussion of draft vision statement for ELOSH conservation
- Operational definitions of conservation success
- Analysis of threats to ELOSH: geography and mechanism

Session 3: July 15, 2021 @ 1-4pm Eastern/12-3pm Central

- Summary of Sessions 1 and 2
- Analysis of threats to ELOSH: continued from Session 2
- Overview presentation on population viability analysis (PVA) and its role in conservation planning
- Discussion of issues and questions to address in PVA
- Temperature check and next steps

Session 4: July 16, 2021 @ 9am-12pm Eastern/8-11am Central [Tentative]

Background Presentations

<u>An introduction to the CPSG planning process</u> - *Phil Miller, IUCN SSC CPSG*

The mission of the IUCN Species Survival Commission's Conservation Planning Specialist Group is to create systematic, actionable plans for the conservation of threatened species that incorporate reliable science and the knowledge of everyone involved. This series of Species Conservation Planning (SCP) workshops will focus on conducting a Population Viability Analysis (PVA) to develop the best plan to improve the conservation status of the eastern migratory subspecies of the Loggerhead Shrike (*Lanius ludovicianus migrans*).

<u>Overview of the Eastern Loggerhead Shrike (*L. l. migrans*) biology and status</u> - *Amy Chabot, African Lion Safari*

Loggerhead Shrike have exhibited drastic range-wide population declines, with greatest losses occurring in their northern breeding range. Recent taxonomic assessment indicates shrike in the northeastern part of the range are a distinct subspecies that likely adapted to tallgrass prairie and alvar habitat (characterized by shallow soil over limestone bedrock) around the Great Lakes. This requires a revision of the historic delineation of the *migrans* subspecies range (Miller 1931), which extended from Ontario through the mid-central states. The current range of *migrans* is now largely constrained to Ontario, where breeding is limited to only two core areas, and likely historically extended throughout the states surrounding the Great Lakes. The birds found throughout the rest of the former subspecies range are now understood to be distinct from *migrans*, and are provisionally being identified as *L. l. centralis*. While areas around the Great Lakes have limited abundance currently, species distribution modeling indicates there is suitable habitat with recovery potential outside current areas of occupancy for *L.l. migrans*.

Loggerhead Shrikes require four common habitat elements within a breeding territory: nest sites, perches, hunting areas, and impaling sites. In Ontario, territories in larger patches of suitable habitat, with the potential for multiple breeding pairs, are used for more years and the likelihood of occurrence of shrike increases with an increasing percentage of potential habitat in an area. Further, evidence suggests that there is an aspect of 'social' behaviour involved in site use and the existing presence of shrike in an area appears to be a factor in the occurrence of the species (potentially semi-colonial).

Tracking/banding and genetic data indicate that *migrans* from Ontario migrate and winter to the east in the Atlantic coastal states, west in an area encompassed within the Mississippi Alluvial Valley and in states south of the Great Lakes (e.g. Pennsylvania). A map of the potential geographic range of *L. l. migrans* has been developed based on the species distribution model and eBird data/input from working group members (see Figure 1 below).

Current *in situ* species management activities in Canada and Loggerhead Shrike Working Group collaborative projects summary - *Hazel Wheeler, Wildlife Preservation Canada and Sergio Harding, Virginia Department of Wildlife Resources*

A wide variety of strategies and tools are used in conservation efforts for Loggerhead Shrike:

- Wild population monitoring - dedicated survey efforts since 1992 indicate the population in Canada is declining and has reached a precarious point
- Identification of migratory routes and wintering grounds - tracking captive releases with radio tags through the Motus Network has recently helped discover more about the migratory routes of these birds
- Habitat stewardship - focused on keeping cattle on the landscape
- Public education and outreach through presentations, community events, field site visits, and social media
- Range-wide collaboration through the Loggerhead Shrike Working Group:
    - States and provinces are currently implementing different conservation measures depending on the threats present
    - 8 states/provinces participated in banding in 2021
    - Occupancy and reproductive monitoring in most areas
    - Research on impacts of neonicotinoids
    - Shrike Force program currently being piloted in 3 states to create standardized biomonitoring for this species.

Ex situ species management activities - *Jane Spero, Wildlife Preservation Canada*

The captive population of *L. l. migrans* was initially created with the intention of maintaining genetics and acting as a safety net should the wild population crash entirely, and was founded entirely with Ontario birds. So far the program has acted as a stopgap, helping to maintain the existing wild population and keep it relatively stable while work is undertaken to identify and address main threats, as well as contributing to related research studies. The conservation breeding and release program has been ongoing since the late 1990s and is currently coordinated by WPC with breeding partners at the Toronto Zoo, Nashville Zoo, African Lion Safari and the Smithsonian Conservation Biology Institute in Virginia.

Prior to release the health of the juvenile birds is monitored, they are banded with number and colour bands to identify individuals and year of release, and a subset is equipped with lightweight radio-tag backpacks. The juveniles are released at field sites in Carden and Napanee (Ontario, Canada) using a “soft-release” technique. The released birds have an average return rate of >8% and ~40% of recorded wild fledglings had at least 1 captive-released parent. Previous PVAs conducted in 2009 and 2015 showed the captive release efforts have a stabilizing effect on the wild population. The current release target is ~100 birds/year, but it is anticipated that the capacity of the program will be expanded by the addition of new partner breeding facilities and that the Species Conservation Planning process will help inform release targets for the conservation breeding program going forward.

Vision Statement

A conservation vision is a short ambitious statement that outlines the desired future state for the taxon (i.e. describes what it means to “save the species”) over a long term. Among other components, the conservation vision should consider ecological and/or genetic representation and replication, functionality of populations, and human socio-economic or cultural needs, desires, and concerns.

The vision statement is intended as a communication, collaboration, and fundraising tool to garner support for conservation efforts for Loggerhead Shrike and as a guide for the conservation planning endpoint (i.e. conservation success).

The SCP workshop participants broke into working groups to generate important themes that were incorporated into a 25-year conservation vision for the Eastern Loggerhead Shrike, which was followed-up by a plenary discussion. A smaller group met at the end of Day 1, to synthesize the break-out groups and plenary discussion notes into a unified draft vision statement. Workshop participants then reviewed and refined the statement, then defined the specific management unit for the planning process and created operational definitions for key elements of the vision to be used when analyzing the efficacy of potential management strategies.
Draft vision statement:

We envision self-sustaining populations of loggerhead shrike (*Lanius ludvicianus*) that ensure the long-term viability of *L. l. migrans* in suitable and restored habitat across the subspecies' historic range including breeding, migration, and wintering habitats. Local communities and industries celebrate and understand the birds as an important component of thriving, diverse grassland ecosystems that span public and private lands.

Working operational definitions in vision statement:

Self-sustaining

- No more additions from *ex situ* population
- Population growth rate is stable or positive (lambda ≥ 1.0)
  - The taxon has grown in abundance to its habitat carrying capacity across the range (long-term optimistic condition)

Note: Habitat management may be/will likely be ongoing

Viability (Note: consider replacing with “persistence”)

- Abundance not declining (i.e. self-sustaining)
- Genetically healthy: minimum loss of genetic diversity, low inbreeding depression
- Minimal risk of abundance declining to dangerously low levels resilience

Across the subspecies' historic range

- New breeding populations within identified historic range in both Canada and the US

Threat Analysis: geography and mechanism

Geographic scope:

During the visioning process, workshop participants defined the management unit for this planning process as:

> Populations of loggerhead shrike (*Lanius ludovcianus*), throughout their full annual cycle, that ensure the long-term viability of the genetically distinct *L. l. migrans* subspecies.

As such it was determined that the geographic scope should include breeding, migration/ dispersal, and winter habitat of *L. l. migrans*. The organizing committee proposed a geographic scope based on available evidence to date (Figure 1). The map combines genetic data from extant populations and museum specimens (Chabot and Lougheed, 2021), potentially suitable habitat identified by Species Distribution Modelling (SDM; Spear et al. 2018), abundance data from eBird records, and input from the Loggerhead Shrike Working Group. Birds genetically identified as *migrans* are currently found breeding in southern Ontario. Historically *migrans* likely ranged east in Canada through Quebec and the Maritime provinces, as far south as the Carolinas and as far west as central midwestern states and Manitoba, although some of these birds are dispersers or, in the east, may represent museum specimens sampled in what were once intergrade zones between subspecies when *migrans* was more plentiful (Chabot and Lougheed, 2021).

The group generally agreed with the geographic scope presented, but identified several needs for refining the map including (1) defining the geographic scope of polygons in Arkansas, Virgina, North and South Carolina (for which SDM was not conducted), and (2) updating the colour scheme to identify areas in the US that are both wintering and breeding grounds for *L. l. migrans.* These revisions will be incorporated and a new map presented at the next workshop.

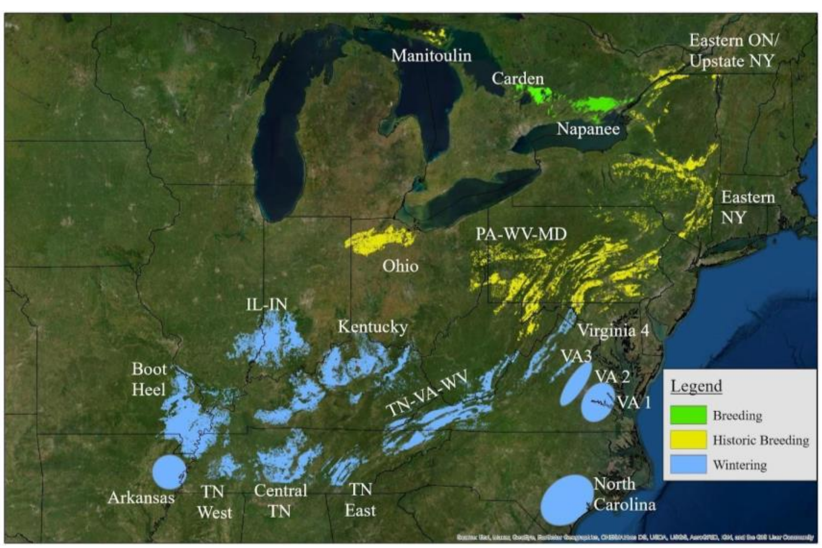

Figure 1. Map of the proposed geographic scope for the *L. l. migrans* Species Conservation Planning process, delineating potentially suitable habitat (by colour) and subpopulations (by names). Habitat was mapped as a binary (presence/absence) of potential suitable shrike habitat from a MaxEent analysis for Ontario and several northeastern states, and the model was trained by data provided from Loggerhead Shrike Working Group members. Colour of breeding vs wintering is based on eBird notation of this delineation.

Threat Analysis:

A threat analysis helps define and understand the system; specifically, where are the greatest threats, their intensity, and how to mitigate them. These analyses will form the basis for working group themes and discussion topics for the duration of an SCP workshop.

Threats and challenges to Loggerhead Shrike conservation were identified by the Loggerhead Shrike Working Group during the Working Group's 2020 Annual Meeting (Figure 2). This preliminary threat mapping exercise was further built upon in the first SCP workshop by compiling information on spatial distribution, intensity, and mechanism of threats.

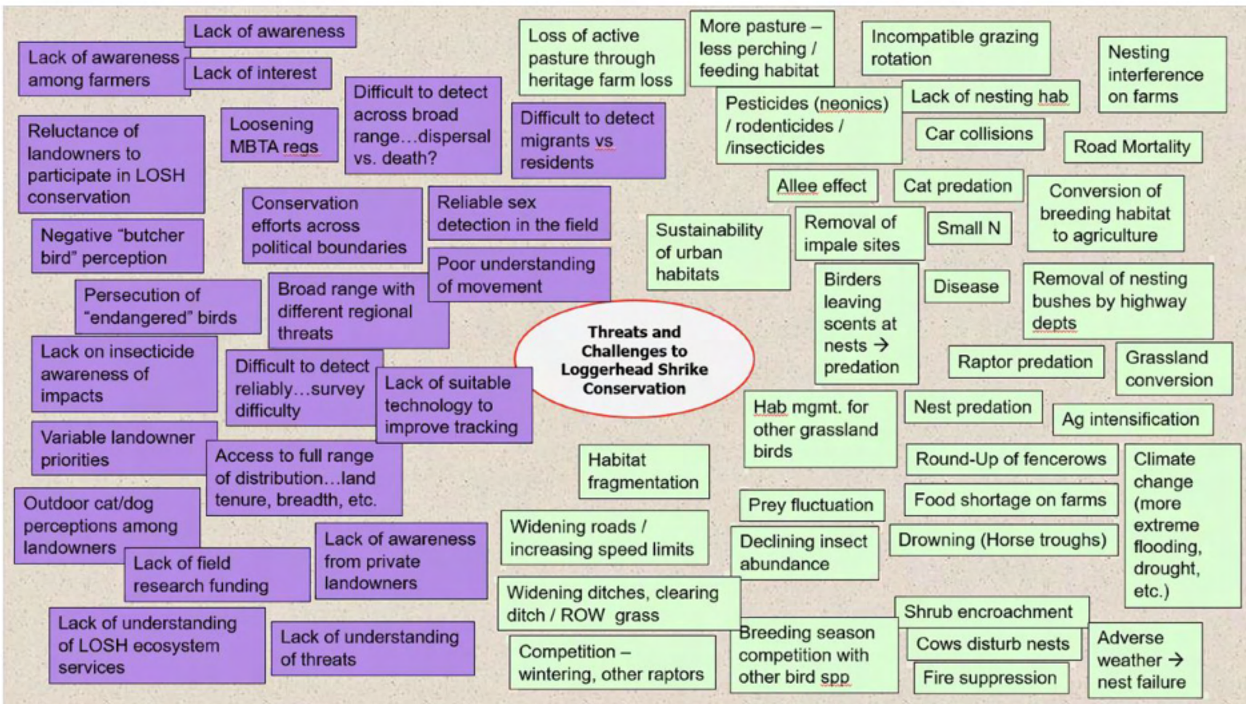

Figure 2. Threats and challenges to Loggerhead Shrike conservation (contributed to by the Loggerhead Shrike Working Group, 2020). Biological threats are shown in light green (right side of diagram), and challenges to successful management which may not necessarily be biological are shown in purple (left side).

The division of regional working groups was discussed and several grouping options were considered including divisions based on life cycle stages (breeding, migration, wintering). The following groups were formed based on habitat/threat similarity and availability of regional representatives:

1) **Region A:** Ontario (Manitoulin, Carden, Napanee, Eastern ON) and New York (Upstate, Eastern)
2) **Region B:** Virginia (Coastal Plains, Piedmont, NW, SW) and North Carolina
3) **Region C:** Tennessee (East, Central, West), Kentucky, Indiana/Southern Illinois, Ohio, Pennsylvania, West Virginia, and Maryland
4) **Region D:** Arkansas and Missouri (Boot Heel)

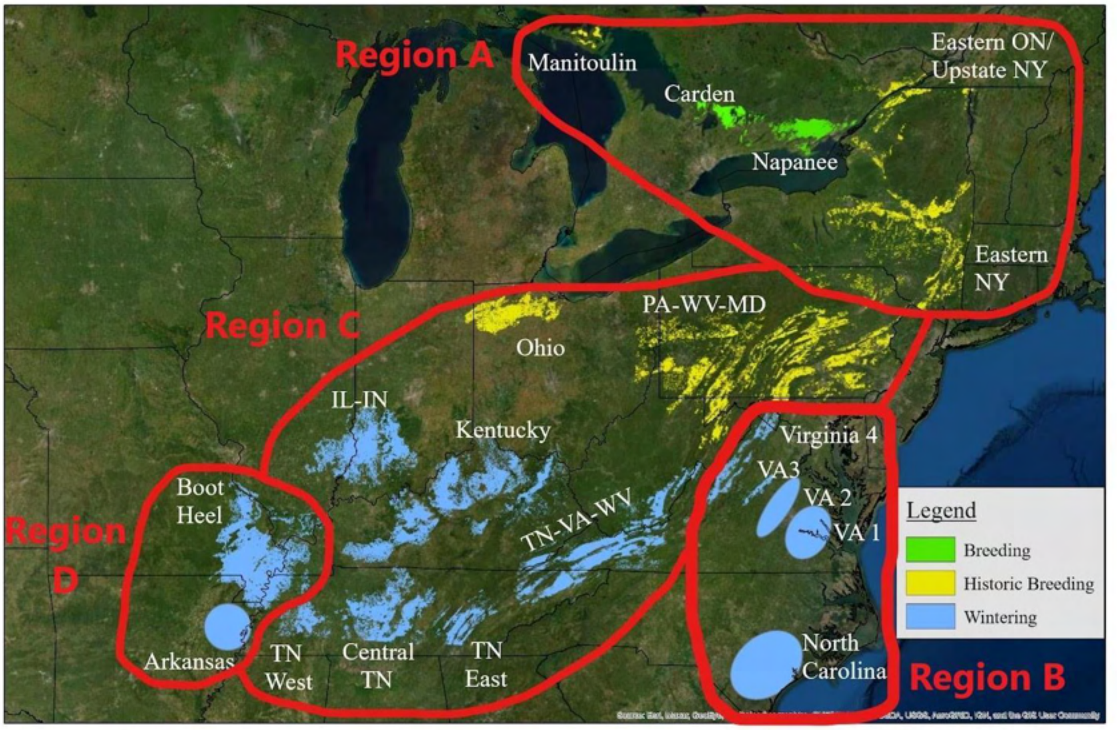

Figure 3. Regional division of subpopulations into four working groups.

SCP participants split into these groups to review and revise the current threats list and characterize the severity of each threat across each subpopulation/site within their region. Threat severity was ranked according to the following scale:

- minimal - contributes to slow/negligible population decline
- moderate - contributes to rapid population decline
- severe - contributes to very rapid population decline

In a follow-up plenary session each group presented the results of their regional threat analysis, explaining any changes that were made to the list of threats, specific definitions, and points of divergence or differing approaches in the evaluation, as well as highlighting potentially high priority threats for subpopulations or regions based on the initial results of the threat analysis and areas where data was lacking. General points of discussion are summarized with the threat tables below.

Next steps in the threat analysis include reconciling changes or additions of threats between regions and requesting input for states where representatives were unavailable or data was lacking, e.g. NC, WV, MO, PA, NY, MD.

Next Steps

Population Viability Analysis

Population Viability Analysis (PVA) is a tool-based process to facilitate the synthesis of knowledge about a *species* and its *environment*, the predicted *impact of human activities,* and the potential value of alternative management actions designed to mitigate those threats. A PVA can be used to determine the probability of extinction of a species and make predictions about which management route to pursue based on the information available for a given system. Based on past or current population status, the threats present, the intensity of those threats, and possible management options, a PVA can help identify which threats are mainly responsible for population decline and evaluate the potential impact on the population of different management strategies and/or the combination of different strategies (management scenarios). Within the Species Conservation Planning process, the goal is to use a PVA to help set more robust recovery targets for the *L. l. migrans* conservation plan that can be used at a regional scale to inform actions and goal setting and at a federal level be used to guide recovery planning for adoption by government agencies. Workshops 2 and 3 will be devoted to developing and interpreting a PVA for *L. l. migrans*.

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Appendix C. A Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States

A Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States

Report prepared for:

BluEarth Renewables, Calgary, AB, Canada

Report prepared by:

Philip S. Miller, Ph.D.
Director of Science, Single-Species Planning
IUCN SSC Conservation Planning Specialist Group

In collaboration with:

Eastern Loggerhead Shrike PVA Technical Team

March, 2023

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Amy Chabot, African Lion Safari
Hazel Wheeler, Wildlife Preservation Canada
Alisa Solecki, Queens University
Jim Giocomo, American Bird Conservancy
Jessica Steiner, Calgary Zoo

March, 2023

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A contribution of the IUCN/SSC Conservation Planning Specialist Group, in collaboration with the Eastern Loggerhead Shrike PVA Technical Team.

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A Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States

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A Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States

Executive Summary

The loggerhead shrike (Lanius ludovicianus) is a small, raptorial passerine endemic only to North America. Populations throughout the species' range have declined significantly since the 1960s, with migratory populations hit the hardest as a result of threats such as rough pasture habitat loss, motor vehicle collisions, and increasing frequency of severe weather events across the range. In particular, remnant populations of L. l. migrans in southeastern Ontario have been reduced to a very small number of birds and require targeted management to reduce the risk of extinction. The federal Recovery Strategy for the loggerhead shrike in eastern Canada lays out a set of management goals and actions designed to stimulate recovery. Even with the existing Recovery Strategy in place, important management issues remain unresolved. To help address these needs, data on habitat use and population demographic structure have been amassed from on-going color banding of wild and captive shrike. Effective conservation planning and implementation of efforts to recover loggerhead shrike in Ontario requires integration of these new insights with existing knowledge.

Towards that end, a project was conceived and designed by conservation experts from African Lion Safari (Ontario), Wildlife Preservation Canada, the IUCN SSC Conservation Planning Specialist Group and others to provide an Overall Benefit to loggerhead shrike by developing a recovery implementation plan, with quantifiable actions, timelines, goals and assessment criteria, through which recovery will actually be realized. Part of that process involves creating a quantitative population viability analysis (PVA) for the species in the project area. Population viability analysis (PVA) can be a very useful tool for addressing the types of critical endangered species management questions laid out in the Introduction of this report. These tools and techniques are very well-suited for investigating current and future demographic dynamics of loggerhead shrike in eastern North America, and can assess the relative consequences of alternative management strategies to suggest which practices may be the most effective in managing populations that are threatened with continued decline or extinction. This report describes the process of PVA development and implementation.

Geographically, the analysis included four habitat areas in southern Ontario (Carden, Napanee, Manitoulin, and Smiths Falls) and ten areas in the United States from northern Illinois to southeastern Arkansas, and from coastal South Carolina north to northern Virginia. These areas were identified through combining detailed observational data on bird presence with habitat suitability modeling. This geographic area formed a metapopulation in which populations occupying these habitat areas could exchange individuals through time. In particular, the Ontario populations and the Northern Illinois population in the United States were obligate migrants who leave their breeding grounds in the autumn and (for the most part) return to those areas in the spring. In combination with other partial migratory or non-migratory populations, the resulting metapopulation structure becomes quite varied and complex.

Species experts across the scope of the project area were asked to characterize threats to loggerhead shrike populations in their local habitats. The threats were classified according to a standardized biodiversity threat classification scheme to facilitate consistent interpretation and communication. Each threat was categorized on a qualitative scale that considered the degree to which that threat contributed to significant, moderate, or negligible population decline in specific habitat areas. A composite scoring system was used to rank threats to facilitate comparison of threat intensity among

populations in the study area. A general pattern emerged in which the most western populations (Illinois-Indiana, Missouri-Arkansas, Northern Illinois) were scored with the highest level of composite threat, with the Napanee population in Ontario also identified as having significant threats impacting its stability. In contrast, populations on the eastern margin of the project area in Virginia, North Carolina, and South Carolina tended to show the lowest level of threat.

An attempt was then made to combine these threat data with an analysis of historic trends in loggerhead shrike population abundance across the project area. Absolute abundance estimates for the United States are not available for the species through time in the Breeding Bird Survey (BBS) database, so we had to rely on a more generic abundance index for analysis. These index values can be used to estimate rates of population change over time (lambda, λ) that remain relatively robust. All populations in the project area exhibit declining abundance, with mean annual growth rates in the range 0.91 – 0.97. Because of the relatively coarse resolution of both the BBS abundance data and the results of the threat analysis, it was not possible to meaningfully associate a given threat score for a specific population and its estimate rate of decline. Nevertheless, the threat analysis provides abundant information on the types of threats to be mitigated in each population through active management, which is important knowledge to inform specific recovery planning activities.

The simulation model used in this PVA was built using the popular software package Vortex. This package is particularly well-suited to construct this type of full-annual-cycle (FAC) model. Vortex tracks the fate of each individual in a given population through time according to use-defined input, and can also track the movement of individuals among different populations resulting from dispersal or migration. Population dynamics is modeled as a stochastic process, meaning random variation in environmental conditions within a population results in random fluctuations in birth and death rates which can negatively impact the stability of small wildlife populations. The Vortex model used here was highly customized in order to implement complex rules for migration and dispersal – particularly when those movements are primarily a function of the birthplace or origin of a given individual. In addition, Vortex is uniquely capable of simulating the dynamics of ex situ (captive) population dynamics which are often quite different than their wild population counterparts. An ex situ populations can then be explicitly linked to one or more wild populations through collecting genetically suitable birds from ex situ institutions (zoos and aviaries) and releasing them into the wild. All these detailed processes and more were incorporated into this model, representing a significant increase in detail, complexity and realism.

After extensive consultation with species experts who band and monitor birds across the range of the project area, a complex dataset of input parameters was assembled and used to construct the simulation model. After some testing and refinement, simulated populations across the project area demonstrated rates of decline into the future (20-year projection) that were comparable to observed declines in the corresponding wild populations. If these declines are allowed to continue, the small loggerhead shrike populations in the Carden and Napanee habitats in Ontario would likely disappear within the next two to three decades. To mitigate this risk, a set of scenarios was created that simulated the release of young birds (fledglings) produced in the ex situ population. Based on our understanding of the demographics of the ex situ population, and if that population can continue to produce fledglings at the current rate, wild populations in Ontario can significantly benefit from annual releases of young birds – even when those releases are spread evenly across all four Ontario habitats instead of targeting one or two populations (Carden and Napanee) as priority sites.

However, the underlying reproduction and survival rates of the wild populations must be sufficiently robust so that the successes obtained through releases can be maintained. The PVA tool was used to evaluate the conditions within wild populations that could result in continued population growth after releases from the ex situ population are terminated. Initial results from these complex analyses suggest that a key variable impacting wild population growth is survival of birds during migration. Additional work is needed to explore this feature of the current model in more detail.

General model complexity – including highly detailed migration/dispersal mechanics, relatively large loggerhead shrike abundance estimates in select U.S. populations, and the inclusion genetic processes impacting population viability and management – requires significant computational capacity to properly conduct the analysis. As a result, the analysis presented here is only preliminary and would benefit from additional attention including:

- Continued testing of general model structure to confirm proper performance
- Systematic exploration of model sensitivity to uncertainty in specific input parameters
- Refinement of ex situ population demographic dynamics
- Assessment of a wider range of ex situ release scenarios, including increasing space-limited carrying capacity to increase number of fledglings available for release

Project coordinators and associated collaborators are currently discussing strategies for moving this work forward with the intention of revising the PVA and using insights gained from the analysis to craft detailed and effective management recommendations in a collaborative, structured, and facilitated environment. Through continuation of this process, this group will make positive contributions to loggerhead shrike recovery in Canada and the wider eastern United States.

Introduction

The loggerhead shrike (*Lanius ludovicianus*) is a small, raptorial passerine endemic only to North America. While a definitive taxonomic description of the species remains unresolved, it has been suggested that loggerhead shrike populations occupying eastern North America belong to three subspecies: *L.l. migrans* in southeastern Canada (mainly Ontario), *L.l. ludovicianus* in central and southern portions of the eastern United States, and a newly-proposed subspecies, *L.l. centralis*, found in the midwestern United States around the Great Lakes (Chabot and Lougheed 2021). It is difficult to distinguish between individuals of different subspecies in the field, although molecular genetic techniques can be successful in assigning proper taxonomy to an individual.

As a species, the loggerhead shrike has experienced precipitous range-wide population declines of at least 70% since 1966 (Sauer et al. 2017). Migratory populations have undergone the most drastic declines of as much as 19% per year over both the long (1966-2015) and short term (2005-2015) (Sauer et al. 2017). Partners in Flight lists the loggerhead shrike as a Common Bird in Steep Decline, which is defined as a species that has lost more than 50% of its global population in the last 40 years (Sauer et al. 2017). In response to these alarming declines, an *ex situ* insurance population was established with approximately 40 wild fledgling founders obtained from nests in Ontario in 1997 and 1998. Since 2003, the majority of the hatch-year birds produced through this program have been released in suitable habitat in Ontario to augment the wild population. The remainder of hatch-year birds are retained to maintain optimum captive population size and age structure. The steep population decline of wild loggerhead shrike in Ontario has been lessened due to those captive-reared shrike that have returned after migration and contributed to population productivity by breeding with wild or other captive-reared birds. However, there is some evidence to suggest that reproductive success among pairs including at least one captive-reared bird may be lower than their wild counterparts (Tischendorf 2015). Despite potential issues such as this, the federal Recovery Strategy for the loggerhead shrike in eastern Canada (Environment Canada 2015) includes continued conservation breeding as a high priority goal.

Even with the existing Recovery Strategy in place, important management issues remain unresolved. To help address these needs, data on habitat use and population demographic structure have been assembled from on-going color banding of wild and captive shrike. Effective conservation planning and implementation of efforts to recover loggerhead shrike in Ontario requires adaptive integration of novel insights with existing knowledge. As a component of that planning effort, a detailed population viability analysis (PVA) has been developed that attempts to address the following important questions underlying successful shrike management in Ontario and the United States:

- How do birds belonging to the *L.l. migrans* subspecies distribute themselves across the landscape as they breed in suitable habitat in Ontario and then migrate southward to suitable wintering habitat in the United States? Can we describe obligate migratory and non-obligate dispersal behavior of these birds from one year to the next?
- What are the target demographic rates (fledgling production, juvenile and adult survival) that are likely to lead to sustained population growth and viability of loggerhead shrike populations currently breeding in Ontario?
- What types of demographic data are needed in order to more effectively assess long-term recovery success for loggerhead shrike in Ontario?

The current analysis, following on from previous work by Tischendorf (2009; 2015), features a highly detailed spatial metapopulation structure over a seasonal cycle of reproduction (fledgling production), survival, and movement (migration and/or dispersal). The analysis also explicitly includes a captive population component that facilitates evaluation of alternative captive-reared release strategies for their value in improving wild population stability without compromising the viability of that valuable source population. In this report, the structure and function of the PVA model is described, with discussion of the data used as input to the simulation. Results of model scenarios representing select management options are summarized, and the implications of the overall analysis are presented.

Process for Developing the Population Viability Analysis

The PVA project, as a component of the larger species conservation planning process, was initiated in August 2021. By this time, the ongoing Covid-19 pandemic had delayed consistent progress on the project, thereby pushing back the start date for the PVA element. Also because of the pandemic, an in-person meeting format was replaced by employing a series of virtual sessions online. These sessions were attended by species experts to discuss the conceptual basis of population viability analysis, its application to loggerhead shrike population dynamics, and to assemble and discuss the data that were available for wild and captive populations that would be necessary to inform input parameters for the analysis.

Work on the PVA continued through 2022, culminating in an in-person workshop hosted by the Nashville Zoo (Nashville, TN, USA) in November of that year. Those who were unable to travel to the meeting site due to continued pandemic-related travel restrictions were invited to participate through hybrid remote technologies. A preliminary version of the PVA model was presented at this meeting, followed by detailed discussions around generating final estimates of key population parameters to use as input to the analysis. Work continued on model development and implementation through frequent online communications and periodic online meetings between PVA Team members and additional species experts as needed. A list of online and in-person workshop participants is provided in Appendix I.

Identifying the Taxonomic and Spatial Scope of the Analysis

Loggerhead shrike in Ontario are a unique subspecies (*Lanius ludovicianus migrans*) that historically occurred throughout a much larger range in northeastern North America, as suggested by a taxonomic review of the species (Chabot and Lougheed 2021). Populations to the south and west of the range of *L. l. migrans*, are more correctly identified as a distinct subspecies, *L. l. centralis* (Chabot and Lougheed 2021). Spatial autocorrelation analysis, supported by results of banding returns, suggest that dispersal occurs among the subspecies (Chabot and Lougheed 2021). Assessment of stable hydrogen isotopes (deuterium) supports the immigration of *L. l. migrans* into the range of *L.l. centralis* (Chabot, unpublished data). To a lesser degree, immigration is also occurring into Ontario, but is more likely occurring from within the historic range of *L. l. migrans* (Chabot, unpublished data), where breeding is occasionally documented in eBird. Dispersal among populations is likely facilitated by the migratory movements of shrike in the range of *L. l. migrans*, and in particular Ontario, where the species is an obligate migrant. Eastern migratory populations of *L .l. migrans* demonstrate weak migratory connectivity, unlike the western obligate migrant subspecies *L. l. excubitorides* (Chabot et al. 2011). The southern extent of the geographic boundary of the model is based on data from shrike banded in Ontario with a unique leg-band combination that were subsequently re-sighted during the wintering season, or during migration. The model and the resultant conservation strategies that will be developed as a product of this simulation using this model's results reflects the importance of understanding and managing migratory species throughout the entire spatial and temporal scales experienced by the species across its full annual lifecycle (Rosenberg et al. 2016).

Migratory populations of loggerhead shrike in Ontario display complex migration and dispersal dynamics (Chabot 2011). Individual birds may return to their natal breeding population in the spring after overwintering in favorable habitat in the United States following the autumn migration; they may return to Canada but to a different population for breeding; or they may remain in the U.S. for one or more breeding seasons before possibly returning to their population of origin. As a result of these variable movement patterns, even banded birds may be difficult to follow throughout their lifespan. Birds can be undetected for some time before being re-sighted, with their whereabouts in the intervening period unknown. In addition, and also owing to the realities of banding representative samples of any single population, individuals which may be vagrants of unknown origin can be detected and banded in a given habitat through time.

Based on the information summarized here, and recognizing the complexity of the species' seasonal movement patterns, the PVA Team and workshop participants agreed to significantly expand both the taxonomic and geographic scope of the analysis beyond the breeding populations of loggerhead shrike in Ontario. More specifically, the decision was made to include, to the extent possible, all loggerhead shrike habitat areas in the central and southeastern United States that are used by migrating shrike that typically spend their breeding seasons in Ontario. Moreover, shrike populations that occupy said habitats – even those birds that remain in these habitats throughout their lifespan – were also to be included in the analysis. This decision was rooted in the logic that what is good for loggerhead shrike across the region would also be beneficial to those birds that routinely use breeding habitats in Ontario. This is a core principle of the concept of full-annual-cycle (FAC) models for assessing demographic processes in migratory species (e.g., Hostetler et al. 2015; Schuster et al. 2019). In our case, we were also interested in being able to track the location of individuals belonging to *L. l. migrans* that might spend a portion of their adult lives somewhere other than their natal breeding grounds in Ontario. We were able to do this effectively only by expanding the taxonomic and geographic scope of the analysis, as is described in more detail below.

As a result of this decision, our next task was to define the geographic extent of the analysis. The map for loggerhead shrike habitat was constructed using a combination of citizen science observation data and habitat suitability modeling. The observational data was obtained from eBird Range Geospatial Data from the Cornell Lab of Ornithology (eBird 2021). This range includes areas where the species has been observed for at least one week for each season (pre-breeding migration, breeding, post-breeding migration, and non-breeding). Because LOSH migrate very early in the season relative to other species, it was determined that only including standard breeding and non-breeding seasons would omit the beginning of this species' actual breeding season; therefore the range for pre-breeding migration season was treated as breeding season range. The observation map included the range for non-breeding season, pre-breeding migration, and breeding season, omitting only post-breeding migration because LOSH have been known to occur in areas which are minimally suitable during post-breeding migration.

Habitat suitability mapping was modified from a species distribution model (SDM) for loggerhead shrikes in North-eastern North America by S. Spear (unpublished data). This technique utilized 12 different models and simulated the probability of LOSH occupying a site based on factors such as the geology and land use. The resultant map was a gradient of potential site suitability from 0 models predicting site occupancy to all 12 models predicting occupancy. For the purposes of this PVA, only sites that were predicted to be suitable by 2/3 of the simulation models were deemed to be potentially habitable. This map was then merged with the observational data map from eBird and subdivided into different populations based on geography, political boundaries, and diverse threats to shrikes between regions. These population boundaries were discussed and agreed upon in the stakeholder meeting and loggerhead shrike PVA workshop in Nashville, TN in November 2022.

The result of this analysis is presented in Figure 1. Population labels used throughout this report are provided below, with obligate migratory populations underlined.

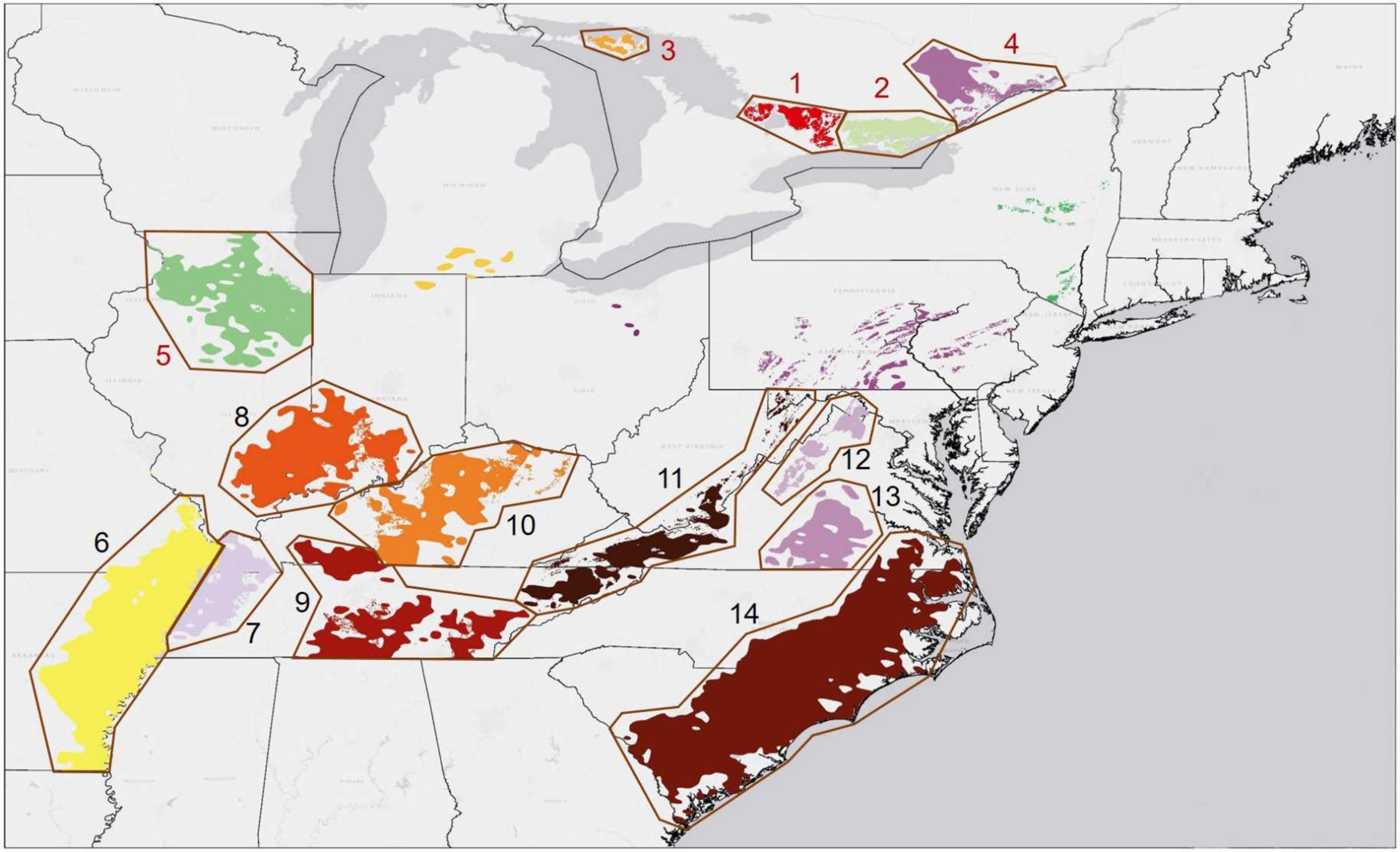


Figure 1. Map of the spatial extent of the population viability analysis for Loggerhead Shrike. Labels for each population: 1. Carden; 2. Napanee; 3. Manitoulin; 4. Smiths Falls; 5. Northern Illinois; 6. Missouri-Arkansas; 7. West Kentucky-Tennessee; 8. Illinois-Indiana; 9. Central Tennessee; 10. Kentucky; 11. Appalachian Plateau; 12. Virginia Valleys; 13. Piedmont; 14. Coastal. Numerical identifiers in red text denote obligate migratory populations. Habitat identified in Michigan, Ohio, Pennsylvania and New York was not included in this analysis. See text for more information on methodology used to identify these habitat areas.

Ontario, Canada
1. Carden
2. Napanee
3. Manitoulin
4. Smiths Falls

United States
5. Northern Illinois
6. Missouri – Arkansas
7. West Kentucky – Tennessee
8. Illinois – Indiana
9. Central Tennessee
10. Kentucky
11. Appalachian Plateau (West Virginia, Virginia, Tennessee)
12. Virginia Valleys
13. Piedmont (central Virginia)
14. Coastal (North Carolina, South Carolina)

An Analysis of Threats to Loggerhead Shrike Populations in the Project Area

As a preamble to hopefully inform the structure and function of the PVA, an analysis of threats to loggerhead shrike populations and their habitats was conducted. These threats and challenges to loggerhead shrike conservation were initially identified by the Loggerhead Shrike Working Group during that group's 2020 Annual Meeting. This preliminary threat mapping exercise was the basis for the threat analysis undertaken during the first loggerhead shrike Species Conservation Planning workshop, held online in July 2021, which assigned intensity levels to all identified threats across the geographic scope of the analysis defined earlier in this report.

Recognizing the likelihood of spatial variation in the presence and impact of threats, the larger project area shown in Figure 1 was divided into four regions based on anticipated similarities of loggerhead shrike habitat types and general threats, as well as the availability of regional representatives with knowledge of the area. Workshop participants reviewed and revised the threat list within their region, and characterized the severity of each threat across each subpopulation/site within that region. Following the July 2021 workshop these revised and ranked threat lists were collated, and threats re-categorized under a standardized biodiversity threat classification scheme (MFFP 2021).

Detailed data on the quantitative impacts of specific threats to loggerhead shrike reproduction, survival or habitat quantity/quality are not available. As a result, the threat analysis features a qualitative comparative approach to ranking threats based on considerations of their general severity. The classification scheme adopted here includes the following impact categories and their corresponding color values in the final assessment:

- No data (white): information to categorize the threat was unavailable
- Minimal (green): contributes to slow/negligible population decline
- Moderate (yellow): contributes to rapid population decline
- Severe (red): contributes to very rapid population decline

The final threat assessment can be found in Appendix II.

A simple method was created for ranking the threat categories in order to derive an aggregate threat score within each population. White, green, yellow, and red cells were assigned numerical severity values of 0, 1, 2, and 3 respectively. The proportion of each category in a population was calculated, and the raw threat score for a specific population (TS_{Pop}) was then calculated according to:

$$TS_{Pop} = \sum_{i=1}^{4} P_i S_i$$

where P_i is the proportional frequency of threat category i and S_i is the severity of that threat. In order to remove the influence of the uninformative (white) cells, a revised threat score TS^*_{Pop} was calculated by revising the proportion of each informative threat category after the uninformative cells were removed and then applying the above equation across green, yellow and red threats.

These threat scores are summarized in Table 1. The population units with the highest aggregate threat score TS^*_{Pop} were Illinois-Indiana, Northern Illinois, and Missouri-Arkansas. Along with the West Kentucky-Tennessee population, these three units comprise the western-most group of populations included in this PVA. At the other end of the scale, three of the four population units with the lowest threat scores are on the eastern margins of the U.S. portion of the project area: Appalachian Plateau, Piedmont, and Coastal. These results may suggest a longitudinal gradient of threats across the southern extent of the project area, with threats to loggerhead shrike being viewed as more prominent in the west and to a comparatively lesser extent in the east.

Table 1. Summary of threat analysis for each population included in the project area. See text for methodologies used to categorize and score threats for each population.

		$S=0$		$S=1$		$S=2$		$S=3$				
Population	Total	White	P_0	Green	P_1	Yellow	P_2	Red	P_3	TS	TS*	RANK*
Carden	35	2	0.06	14	0.40	18	0.51	1	0.03	1.51	1.61	8
Napanee	35	2	0.06	12	0.34	19	0.54	2	0.06	1.60	1.70	4
Manitoulin	35	2	0.06	24	0.69	8	0.23	1	0.03	1.23	1.30	14
Smith's Falls	35	6	0.17	11	0.31	16	0.46	2	0.06	1.40	1.69	5
Coastal	36	0	0.00	23	0.64	13	0.36	0	0.00	1.36	1.36	13
Piedmont	34	18	0.53	9	0.26	7	0.21	0	0.00	0.68	1.44	12
VA Valleys	36	19	0.53	9	0.25	5	0.14	3	0.08	0.78	1.65	7
Appalachian Plateau	36	0	0.00	19	0.53	17	0.47	0	0.00	1.47	1.47	11
IL - IN	36	4	0.11	6	0.17	22	0.61	4	0.11	1.72	1.94	1
KY	36	1	0.03	18	0.50	15	0.42	2	0.06	1.50	1.54	9
Central TN	36	1	0.03	18	0.50	11	0.31	6	0.17	1.61	1.66	6
West KY - TN	36	1	0.03	19	0.53	14	0.39	2	0.06	1.47	1.51	10
MO - AR	36	0	0.00	16	0.44	13	0.36	7	0.19	1.75	1.75	3
Northern Illinois	32	9	0.28	5	0.16	15	0.47	3	0.09	1.38	1.91	2

Guidance for PVA Model Development

Population viability analysis (PVA) can be a very useful tool for addressing the types of critical endangered species management questions laid out in the Introduction of this report. These tools and techniques are very well-suited for investigating current and future demographic dynamics of loggerhead shrike in eastern North America, and can assess the relative consequences of alternative management strategies to suggest which practices may be the most effective in managing populations that are threatened with continued decline or extinction.

A common method for conducting a PVA involves demographic projections using a matrix modeling approach (Caswell 2001). Cohorts of individuals – usually defined on the basis of age and sex – are followed through time as they transition from one state (e.g., age class) to the next as a function of survival probabilities over a defined timestep, typically a year for species that follow annual breeding cycles. Both extrinsic (changes in habitat quality, interactions with human populations) and intrinsic (inbreeding impacts, density dependence) factors that introduce variation over time in mean rates of reproduction and/or survival can be included in this approach, but the ability to account for the full range of these factors in a matrix modeling approach can be limited. Moreover, the specific sensitivity of very small populations composed of just tens of individuals to stochastic variation in expected likelihoods of survival or breeding can be difficult to fully simulate in models that numerically aggregate those individuals into cohorts, where the fate of any one individual is not explicitly determined.

By contrast, individual-based (sometimes "agent-based") models determine the fate of each individual through time according to specified probabilities of surviving or reproducing on the basis of their age, sex, geographic location, or other variables as appropriate. The growth (or decline) of a population is then an emergent property of those individual outcomes. By accounting for each individual in the population, genetic factors like inbreeding depression and loss of genetic diversity can be explicitly included as forces shaping population dynamics. However, with this level of detail comes the cost of computational capacity, since it is increasingly impractical – and ultimately impossible – to simulate the dynamics of large populations distributed widely across an expansive landscape. While this limitation can be an obstacle, PVA practitioners are typically studying small and declining wildlife populations that are, therefore, suitable for effective study using this approach.

Vortex, an individual-based simulation software package written for PVA (Lacy and Pollak 2022; Lacy et al. 2021), was chosen for this analysis. The Vortex package is a simulation of the effects of a number of different natural and human-mediated forces – some, by definition, acting unpredictably from year to year – on the health and integrity of wildlife populations. Vortex models population dynamics as discrete sequential events (e.g., births, deaths, sex ratios among offspring, catastrophes, etc.) that occur according to defined probabilities. The probabilities of events are modeled as constants or random variables that follow specified distributions. The package simulates a population by recreating the essential series of events that describe the typical life cycles of sexually reproducing organisms. See Figure 2 for a generalized diagram of a typical annual life-cycle (or timestep) as simulated in Vortex.

An additional advantage of Vortex is the ability to explicitly simulate the detailed demographic dynamics of ex situ (captive) populations and their use in augmenting wild populations through release strategies. The software can replicate breeding strategies that are specifically designed to reduce the rate of loss of genetic diversity in these valuable populations, such as setting up breeding pairs according to the degree of relatedness (mean kinship) between prospective mates. By using this valuable feature of the simulation software, key questions can be explored around the design of ex situ breeding strategies that can effectively support wild populations while at the same time reducing the genetic and demographic impact of selecting specific individuals for release.

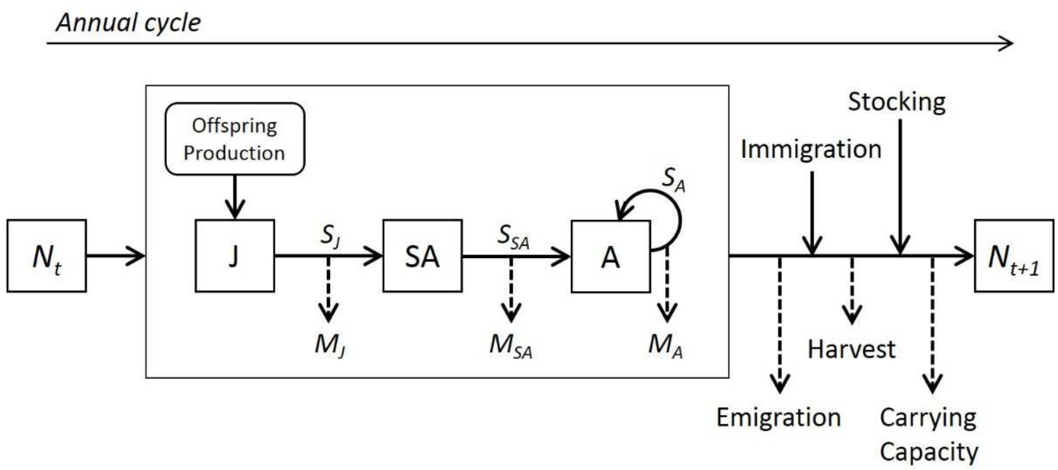


Figure 2. General schematic diagram depicting the series of events making up a typical annual cycle (timestep) in the PVA modeling software package Vortex, representing simulated change in population abundance from N_t to N_{t+1}. Enclosed portion of the diagram shows the production of juveniles (J) and the transition of individuals among the juvenile, subadult (SA) and adult (A) stages, determined by annual age-specific survival (S_x) rates and their complimentary mortality (M_x) rates. On the right side of the diagram, processes above the timeline act to increase population abundance, while those below the timeline decrease abundance. The aggregate effect of these various demographic processes results in a new population abundance at the end of the timestep. For more information on *Vortex*, see Lacy et al. (2021).

PVA methodologies such as the Vortex system are not intended to give absolute and accurate "answers" for what the future will bring for a given wildlife species or population. This limitation arises simply from two fundamental facts about the natural world: it is inherently unpredictable in its detailed behavior; and we will never fully understand its precise mechanics. Consequently, many researchers have cautioned against the exclusive use of absolute results from a PVA in order to promote specific management actions for threatened populations (e.g., Ludwig 1999; Beissinger and McCullough 2002; Reed et al. 2002; Ellner et al. 2002; Lotts et al. 2004; Lacy 2019). Instead, the true value of an analysis of this type lies in the assembly and critical analysis of the available information on the species and its ecology, and in the ability to compare the quantitative metrics of population performance that emerge from a suite of simulations, with each simulation representing a specific scenario and its inherent assumptions about the available data and a proposed method of population and/or landscape management. Interpretation of this type of output depends strongly upon our knowledge of loggerhead shrike biology, the environmental conditions affecting the species, and possible future changes in these conditions. Under thoughtful and appropriate interpretation, results from PVA efforts can be an invaluable aid when deriving meaningful and justifiable endangered species recovery criteria (Himes Boor 2014; Doak et al. 2015). Overall, population models used in PVA provide a framework not only for analyzing complex situations impacting endangered species persistence, but also for documenting assumptions and methods underlying the analyses, reviewing and improving population assessments, and integrating new threat information into our collective understanding of species dynamics.

Design of the Loggerhead Shrike Metapopulation Model in Vortex

The map of the PVA project area (Figure 1) portrays a landscape where loggerhead shrike in the northern portions of their range migrate in the autumn to wintering areas to the south. Taken together, the 14 habitat areas in this map comprise a metapopulation, with individual populations linked by potential exchange of birds through time. Vortex allows for this type of metapopulation structure and the specification of probabilities of movement (migration or dispersal) of birds between populations at different times of the calendar year. Details of this movement will be discussed later in this section.

Another key element of this model is the decision to divide the annual breeding cycle into two distinct model timesteps (Figure 3). This decision was based on a desire to be as explicit as possible in describing the various components that make up a full annual cycle for migratory loggerhead shrike and the specific nuances of those components across the spatial landscape. Note that this is an expansion of the typical annual cycle used in many PVAs using Vortex (Figure 2) or similar software packages.

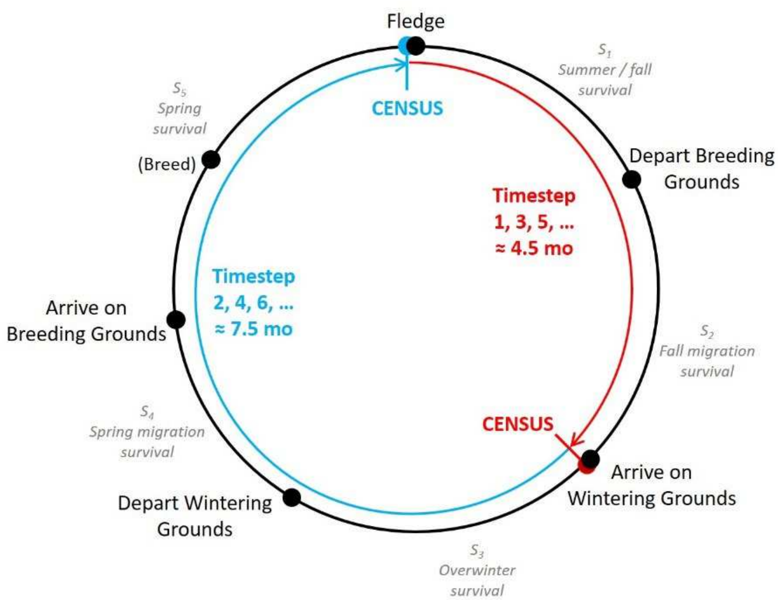


Figure 3. Schematic diagram of the annual life cycle of migratory loggerhead shrike as defined in the PVA model. Each year is divided into an odd-numbered timestep (red font) featuring fledging in the spring and autumn migration, and an even-numbered timestep (blue font) that features overwintering, spring migration, and breeding. Each timestep ends with a census that occurs just after migrating birds arrive on wintering grounds (odd timesteps) and just before fledging of offspring (even-numbered timesteps). Dispersal of birds in non-migratory populations can occur during each migration event. See accompanying text for more information on model structure and function.

The basic Vortex model structure is based on a pre-breeding census methodology. Therefore, the annual cycle usually begins just before production of offspring (in this case, fledging of young) and a census is then taken the following year at the same point in the cycle. In this loggerhead shrike model, we define two timesteps per breeding cycle, with the first timestep comprised of fledging, survival from fledging to autumn, and autumn migration through to arrival on wintering grounds. A mid-year census is taken at the end of this first and each subsequent odd-number timestep. The second timestep of the year includes overwintering, spring migration and arrival on the breeding grounds, and reproduction until just before fledging occurs. A second census for that year is taken at the end of the second and each subsequent even-numbered timestep. By adopting this more detailed description of the annual breeding cycle, we are able to specify particular habitats to which birds are likely to migrate, the cost to survival of that migration event, and the probability of an individual bird's return to their natal breeding grounds or to some other population in the project area. Additionally, we can specify rates of non-migratory or dispersal movements of individuals across U.S. populations in either odd or even timesteps.

Importantly, through customization of the model using state variable designations in Vortex, the PVA model can track the locations through time of birds that were fledged from any of the populations comprising the metapopulation. In other words, at either of the two model timesteps within a year, we can identify the location of birds that were fledged in the Ontario populations but are residing at least temporarily in one of the habitat areas in the United States. These data may be informative for understanding how native Ontarian or other migratory birds disperse across the landscape through time.

Overall, this approach to describing the temporal and spatial nature of loggerhead shrike movement across their breeding cycle represents a complex and advanced application of Vortex for population viability analysis. This general approach to constructing our loggerhead shrike PVA is fully consistent with the philosophy of development and implementation of full-annual-cycle (FAC) models, specifically those that adopt an individual-based modeling (IBM) approach. Reviews of FAC models (e.g., Hostetler et al. 2015) highlight the strengths and weaknesses of IBMs in relation to matrix-based and other model types, which will be discussed in more detail later in the report.

Finally, we note here that the present PVA structure is more fine-grained than the recent analysis by Tischendorf (2009; 2015), where a matrix model using an annual timestep was used to describe the growth dynamics of shrike breeding in Ontario without explicit depiction of migration across a metapopulation landscape. While the previous effort included thorough analysis of past population dynamics as a basis for developing parameters for the predictive model, our goal was to utilize the capacities of the Vortex environment to explore loggerhead shrike metapopulation dynamics in a more detailed manner.

Analysis of Historic Population Abundance Trends in the Project Area

In order to better inform our specification of demographic characteristics of loggerhead shrike populations in our PVA, we assessed past trends in population abundance in habitat areas that broadly aligned with our population boundaries per Figure 1. These trend data can be valuable for providing a basis for inference regarding population-specific demographic rates when more detailed data are unavailable.

For U.S. populations, Breeding Bird Survey (BBS) data describing abundance index were used to estimate trends in relative abundance over time. Transforming abundance index data into reliable population size estimates is notoriously problematic, as discussed in depth in the fishery science community when trying to apply data on catch per unit effort, or CPUE (e.g., Maunder et al. 2006). Nevertheless, using these data to gain some insight into changes in general abundance can be more reliable, and are used for the present analysis. The time period of analysis for U.S. populations was 1965 to 2019 based on available data. Abundance data for Ontario are restricted to the Carden and Napanee populations as birds are seen only occasionally in the Manitoulin and Smiths Falls areas. Shrikes in extant Ontario populations are tracked in the wild through habitat surveys, nest monitoring and color-banding by Wildlife Preservation Canada. The time period of analysis for Ontario populations was 2004 to 2020, even though the dataset extends back to 1991. 2004 was chosen as the starting point for analysis because that is the year in which systematic releases from the captive population began. The mean annual rate of geometric population growth for each of the populations in our analysis was calculated using the standard equation:

$$N_t = N_0 \lambda^t$$

where N_0 and N_t are the estimated population size or abundance index in year 0 and year t, respectively, and λ is the geometric mean annual population growth rate.

The Ontario populations show marked differences in mean population growth rate of the time period of analysis (Figure 4), despite their geographic proximity. Despite these differences, both populations show declines in abundance over the time period analyzed. The observed difference in growth is not surprising given the very small abundances for each population and the associated impact of increased stochastic variability in demographic rates that is much more pronounced in populations composed of just a few tens of individuals (Morris and Doak 2002). This variation also results in deviations between observed and predicted abundances in any given year. Overall, however, the characterization of population change by the use of mean λ gives a reasonable measure of the relative changes in growth across both populations.

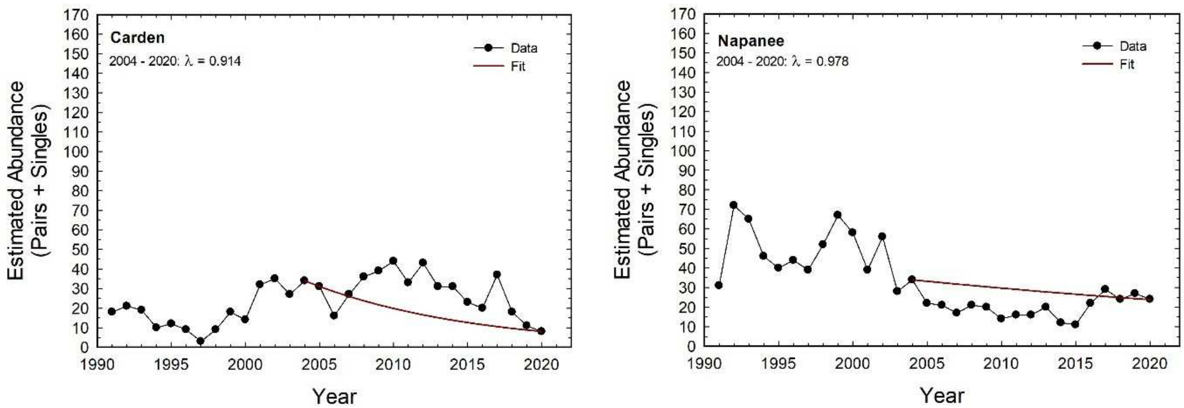


Figure 4. Breeding season abundance estimates for Loggerhead Shrike inhabiting the Carden and Napanee populations in Ontario. Curves give the mean change in abundance each year assuming a constant growth rate λ.

Similar to the Ontario populations, each of the statewide datasets for populations in the U.S. show declines in loggerhead shrike abundance index over the time period used for analysis (Figure 5). Mean growth rate estimates range from a minimum of λ = 0.9313 in Virginia to a maximum of λ = 0.9795 in Indiana, with most states demonstrating growth rates of approximately λ = 0.94 to 0.95. The data for Indiana and West Virginia indicate the lowest index of abundance across all the states analyzed here, suggesting that the reliability of those estimates may be further reduced relative to larger populations.

Input Data for PVA Simulations

This section describes the input parameter values that were used for the model scenarios comprising this PVA. The bulk of the discussion focuses on the primary "status quo" scenario that attempts to broadly simulate current metapopulation dynamics, without including any management activities that would be expected to change the system from its current state. Those parameters used in the preliminary suite of management scenarios are discussed where appropriate.

Throughout the specification of input parameters, the seasonal dependence on reproduction, mortality and/or movement is accomplished through the use of a "modulus" function in Vortex. The modulus function simply returns the remainder when one number is divided by another. The remainder of timestep Y=1,2,3,4... divided by 2 is equal to 1 in odd-numbered timesteps and equal to 0 in even-numbered timesteps; we can then use this function to control the events that occur in summer/autumn or winter/spring.

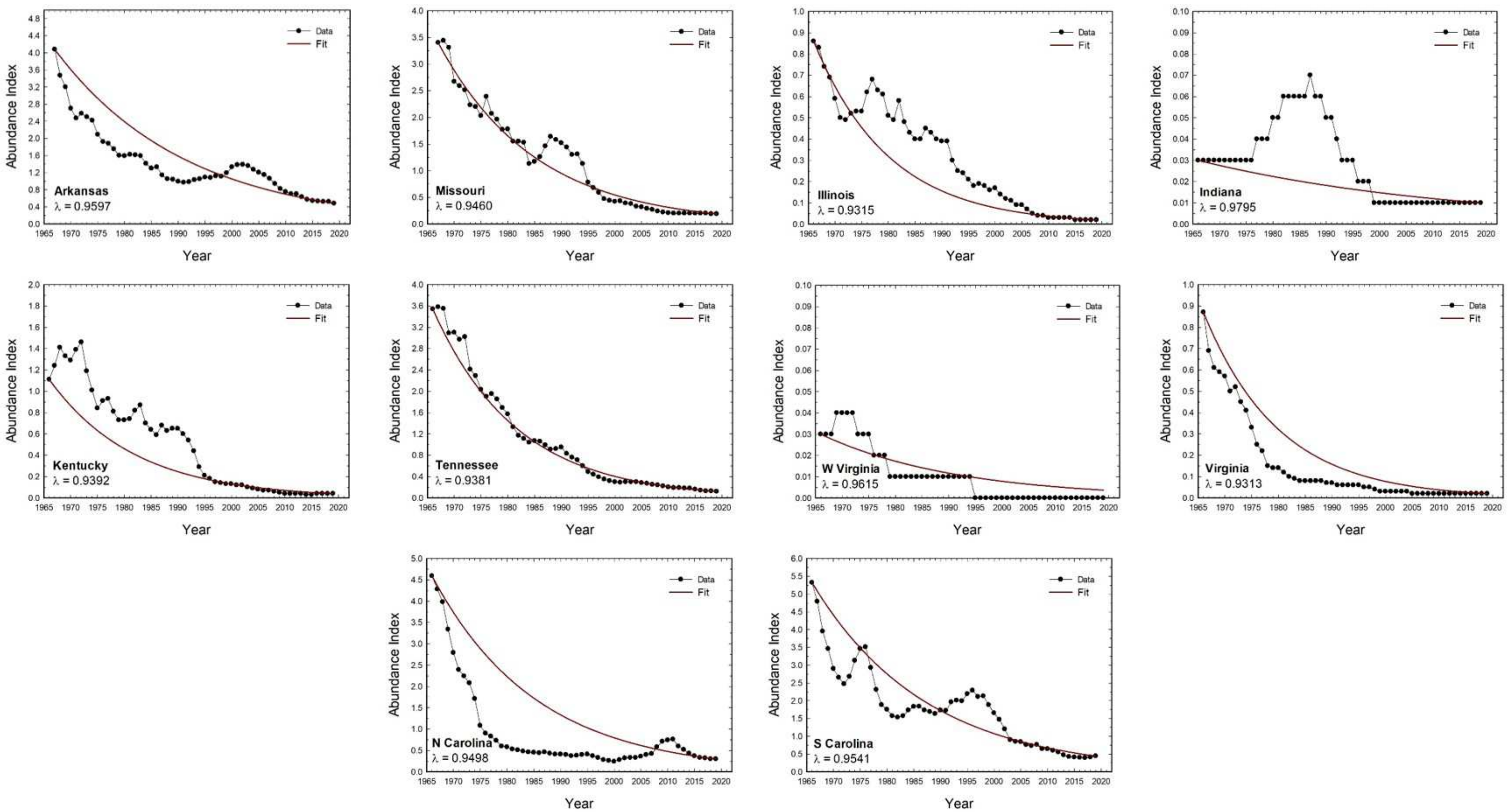


Figure 5. Statewide breeding season abundance estimates for Loggerhead Shrike in the United States. Curves give the mean change in abundance each year assuming a constant growth rate λ.

Overall, demographic rates in U.S. populations were refined based on data derived from the North American Loggerhead Shrike Working Group's coordinated color-banding and monitoring efforts. Where data were lacking, estimates were informed by data from Ontario, but in consultation with individual Working Group members.

General model characteristics

All model scenarios discussed here were conducted using Vortex version 10.5.7 (August 2022). Because Vortex models population dynamics as influenced by stochastic demographic variability across years, multiple replicates of a given scenario are required to obtain reliable estimates of overall population performance. Therefore, each scenario was repeated 100 times. The duration of each simulation was 20 years (40 timesteps). As data for both wild and captive populations was available through 2020-2021, we set the initial date for the model to being prospective projections as spring, 2022. Ideally, both the duration of each simulation and the number of replicate iterations would be increased above what is used here. In this case, significant computational limitations were prevalent owing to the relatively large abundance estimates for some U.S. populations (see below for more detailed information). Other characteristics of the model greatly increased model complexity and seriously increased model run times

Initial population abundance and habitat carrying capacity

Each population in the simulation begins with an estimate of current abundance as of the starting date of the simulation, with the youngest birds aged at just less than one year old, i.e., fledged the following spring. The two primary Ontario populations (Carden and Napanee) were initialized from monitoring data through 2020. U.S. population estimates were based upon the published population estimates corresponding to state by Bird Conservation Region geographic units that matched the loggerhead shrike areas of concentration for the Eastern subspecies (Partners in Flight 2020). The population estimates derived from Breeding Bird Survey (BBS) data were adjusted using species-specific adjustment factors, including Detection Distance Adjustment categories, Pair Adjustments, and Time of Day Adjustments (Rosenberg and Blancher 2005; Will et al. 2020).

Population estimates that came directly from analysis of BBS data were far too large to be suitable for analysis using an individual-based simulation approach like Vortex. Consequently, these initial abundances were scaled downward to values that were tractable for our simulation environment. Specifically, the goal was to maintain population abundances that were large enough to simulate population dynamics with some level of realism while also allowing the models to run efficiently.

In the typical Vortex modeling framework, a population is allowed to increase in abundance under favorable demographic conditions (and without explicit specification of density dependence) until the carrying capacity K is reached. When this occurs, individuals are randomly removed (simulating additional mortality under these limiting conditions) according to the age and sex structure of the population in order to bring the population back down to the value of K. In this manner, we therefore simulate a ceiling-type density dependence. Because of the issues discussed above with accurately simulating current population abundance, we were forced to adopt a simple estimate of carrying capacity that was equivalent to twice the assumed initial abundance. In this way, and by carefully adjusting initial abundance to satisfy a desired level of realism, we are confident that the growth dynamics of most if not all of the U.S. populations are not significantly affected by the need for this scaling procedure.

Table 2 shows initial abundance and carrying capacity values used in all simulations. The largest populations – Missouri-Arkansas, West Kentucky-Tennessee, and Coastal – were scaled to a maximum abundance of 2,000 individuals. The remaining U.S. populations were scaled to approximately 40% of the estimated abundance from analysis of BBS data. The birds in each population were assigned sex and age in accordance with a stable age distribution calculated by Vortex using the reproduction and mortality parameters specified for that population.

In addition, initial abundance for the captive (ex situ) population must also be specified. Extensive data from the International Studbook for *L.l. migrans*, managed by experts in Canada and the United States within the Association of Zoos and Aquariums (AZA) and Canadian Association of Zoos and Aquariums (CAZA), were used to initialize the ex situ population with 70 individuals as of 31 December 2021. In addition to the overall abundance, each living individual in the ex situ population is identified by its age, sex, ancestry, and pairing status as of the stated date. In this way, a full accounting of the genetic status of the ex situ population can be tracked over time, facilitating the estimation of loss of gene diversity (heterozygosity) over time and other metrics used to manage ex situ populations to support in situ population management. Assessment of available space within institutions housing loggerhead shrike as of 31 December 2021 indicated that a total of 76 birds could be effectively managed across participating institutions, equivalent to the carrying capacity for that population.

Reproduction

Vortex allows for a flexible definition of reproduction (i.e., eggs, hatchlings, fledglings, or other appropriate development stage) in order to accommodate specific life histories, data availability, etc. For this PVA, the unit of reproductive output was taken to be fledglings. All calculations and expressions of reproductive success moving forward used this as the consistent definition.

We assume loggerhead shrike reproduce once per year in the spring. They are assumed to be monogamous within a given year but can choose different mates in successive years. They are able to breed when they are one year old, i.e., during the next breeding season after they fledge which, in the terminology of our Vortex model, equate to an age of two timesteps. shrike can live to be 16 years old in captivity, although they usually do not live this long in the wild. If they continue to survive, we assume there will be some form of reproductive senescence around 11-13 years of age. All broods have an expected sex ratio of 50% males, but individual broods can fluctuate randomly from this expectation.

Population	**Initial Abundance N_0 (Original)**	**Initial Abundance N_0 (Scaled)**	**Carrying Capacity K**
Ontario			
Carden	10		150
Napanee	25		150
Maintoulin	4		150
Smiths Falls	4		150
United States			
Northern Illinois	3,749	1,500	1,800
Missouri-Arkansas	80,037	2,000	4,000
West Kentucky-Tennessee	4,671	1,840	3,700
Illinois-Indiana	1,524	600	1,200
Central Tennessee	7,356	2,000	4,000
Kentucky	1,772	680	1,400
Appalachian Plateau	1,000	400	800
Virginia Valleys	500	200	400
Piedmont	NA	400	800
Coastal	81,151	2,000	4,000
Ex Situ	70		76

Table 2. Estimates of initial abundance and carrying capacity for each population comprising the loggerhead shrike metapopulation.

Analysis of monitoring data in Ontario revealed that approximately 76±14% and 73±19% of adult females in Carden and Napanee, respectively, were expected to successfully fledge at least one brood of fledglings in an average year. Of those that fledged young in the Carden population, 91% would fledge one brood and 9% would fledge two broods. Analogous data for Napanee showed that 95% of successful females would fledge one brood and 5% two broods. The actual number of fledglings produced was a function of brood number, with Table 3 providing the details of brood size across the two broods that a successful female may produce.

Number of fledglings produced	Percentage (Carden)		Percentage (Napanee)		Percentage (U.S.)	
	Brood 1	Brood 2	Brood 1	Brood 2	Brood1	Brood 2
1	9.7	14.3	7.2		14.9	7.0
2	12.9	21.4	13.5	33.3	15.4	27.3
3	29.0	35.7	24.3	44.5	19.7	40.0
4	27.1	21.4	29.7	22.2	25.1	21.7
5	14.2	7.1	18.0		19.2	3.5
6	5.8		6.3		5.3	0.5
7	4.3		1.0		0.4	

Table 3. Reproductive output (number of fledglings produced) for successful females as a function of brood number in Ontario and across all U.S. populations.

Analogous data for reproductive success across populations in the U.S. is not systematically available. In light of this, we broadly assumed that 75% of adult females occupying these populations would successfully fledge offspring, and that 90% and 10% of those successful females would produce one or two broods, respectively. Exceptions to this assumption were the Northern Illinois and Illinois-Indiana populations, where data suggested just 70% and 55% of adult females, respectively, successfully fledged offspring each year on average. Distribution of fledgling number per brood in U.S. populations (Table 3) was derived by averaging available data for both Canadian and U.S. populations (Kentucky, Coastal (North Carolina), Eastern Tennessee, and the Virginia Valleys).

Analysis of available ex situ population studbook data (Table 4) revealed that approximately 55% of adult females on average are expected to successfully fledge young each year. If successful, a typical female would fledge a single brood with 60.7% likelihood, two broods with 38.8 likelihood, and three broods just 1.5% of the time. We included a "catastrophe"-style event in reproductive output by specifying that some type of event could occur that significantly reduced the probability of females successfully fledging any offspring and, if they were successfully, they would fledge only one brood. This type of circumstance has been observed twice in the past two decades and is considered to be relevant for predicting future reproductive output as well.

Number of fledglings produced	Percentage (Ex situ)		
	Brood 1	Brood 2	Brood 3
1	9.2	6.8	5.0
2	12.4	22.4	15.0
3	15.7	23.6	60.0
4	27.1	21.1	15.0
5	19.6	22.4	5.0
6	13.2	3.7	
7	2.8		

Table 4. Reproductive output (number of fledglings produced) for successful females as a function of brood number in the North American ex situ population.

Finally, we assume that all adult males are equally capable of successfully pairing with an adult female each year. In other words, we do not assume any form of breeding hierarchy on the basis of social or physiological differences between males at the outset of the breeding season.

Mortality

There are very few data on age- and sex-specific mortality rates for loggerhead shrike in eastern North America. Some information on sex ratios among banded adult birds sampled during monitoring efforts suggests bias towards one sex or the other, but the samples are small in any one state and there is no consistent pattern to guide informed decisions on population-specific mortality values for the PVA. In light of this, an attempt was made to calibrate mortality rates in an iterative fashion to generate simulated trajectories for specific populations that were similar to those obtained from BBS abundance index data (Figure 5). However, as there are many factors that combine to determine population growth in Vortex – not the least of which were the complex migration/dispersal dynamics to be described below – we were unable to tune mortality with sufficient detail to closely match model trajectories with observed population abundance index data. We consequently resorted to using similar mortality rates across populations that generated reasonable rates of population decline among all populations comprising the simulation model. A summary of population-specific mortality rates is given in Table 5.

Mortality rates for the ex situ population were calculated directly from studbook data with the assistance of Colleen Lynch (Riverbanks Zoo and Garden, Columbia, SC, USA), author of the species Annual Breeding and Transfer Plan. The summer hatch year mortality rate includes only the period of time between fledging and the average date of release, which is about 62 days after hatch, or approximately 45 days after fledging. Mortality for those birds that are not part of a release cohort is accounted for by an extra harvest of birds during the collection of birds for release (see below). The proportion made up by these individuals is calculated from studbook data, determining the number that die between the mean date of release and the end of their first timestep (approximately 31 October). The mortality rates for adults were derived from non-linear regression of timestep-specific mortality data calculated from the studbook (Figure 6):

$$\text{Mortality rate (females)} = 0.0642 + 0.0000324e^{[0.3249*\text{Age}]}$$

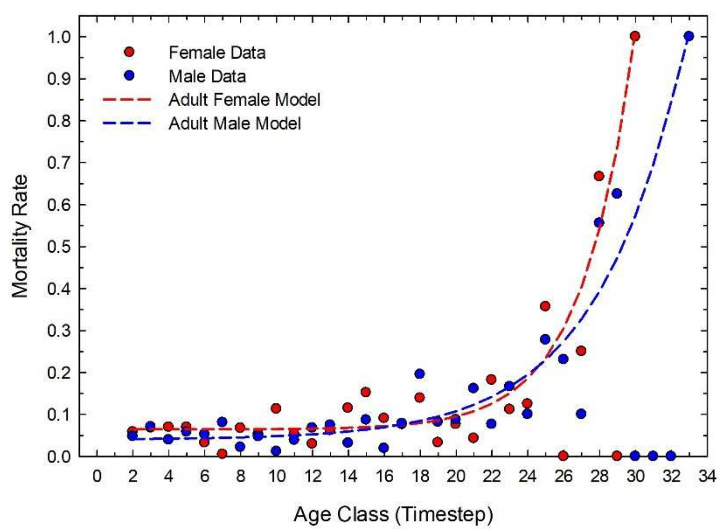
$$\text{Mortality rate (males)} = 0.0397 + 0.0011e^{[0.2062*\text{Age}]}$$

The proportional values resulting from the regression functions were transformed to percentages for proper use in Vortex.

Population	Hatch Year (Summer)	Hatch Year (Winter)	Adult (Age-1+)
Ontario			
Carden	55	40	12 / 16
Napanee	55	40	12 / 14
Maintoulin	55	40	12 / 16
Smiths Falls	55	40	12 / 14
United States			
Northern Illinois	55	40	12 / 15
Missouri-Arkansas	60	40	15 / 18
West Kentucky-Tennessee	60	40	16 / 19
Illinois-Indiana	60	40	15 / 18
Central Tennessee	60	40	16 / 18
Kentucky	60	40	16 / 19
Appalachian Plateau	60	40	15 / 18
Virginia Valleys	60	40	15 / 18
Piedmont	60	40	15 / 18
Coastal	60	40	15 / 18
Ex Situ	8.75	8.9	Function (see text)

Table 5. Mean timestep-specific mortality rates for wild populations in Canada and the U.S., and for the North American ex situ population. Values for adult mortality are reported as [odd summer timestep / even winter timestep]. Environmental variability in mortality, expressed as a standard deviation around binomial mean rate, was set at 15% - 20% of the mean value (coefficient of variation = 0.15 – 0.2). In the ex situ population, environmental variability was set at 0 as essentially all variability in the highly managed ex situ environment is due to intrinsic demographic stochasticity, a process built into the Vortex algorithms. See text for more information on derivation of mortality rates.

Figure 6. Mortality rates for male and female adult loggerhead shrikes in the ex situ population, derived from analysis of historic studbook data. Curves give functional form of timestep-specific mortality using standard non-linear regression techniques.



Metapopulation migration and dispersal dynamics

As noted previously, the dispersal element is likely the most complex component of this model, but also takes full advantage of the benefits that come with adopting an individual-based approach to population dynamics simulation in an FAC context. To begin our discussion of this process, we assumed that all birds of both sexes and across the age spectrum – from recently fledged birds to older adults – engage in migration and dispersal activities. Furthermore, a mortality cost to these movements was included, defined as a percent survival of individuals that migrated or dispersed. Movement cost rules were as follows:

- Autumn migration from obligate migratory populations (Ontario, Northern Illinois): 85% survival
- Spring migration to obligate migratory populations: 85% survival
- Dispersal between U.S. populations, both seasons: 90% survival

Migration of obligate migrants and dispersal of non-obligate migrants was made possible by the creation of a "digital banding" process within Vortex in the form of assigning an Individual State Variable (see Lacy et al. 2021). Every bird in the simulation (including those comprising the initial groups of birds in each population at the start of the simulation) was tagged with a variable labeled ORIGIN that recorded the numerical identifier (see Figure 1) of the population in which an individual started the simulation or was fledged. Regardless of where that individual moved through its life, the value of ORIGIN would remain unchanged. This variable was then used as a variable in the specification of a bird's final destination as a function of its place of birth – its origin.

General rules for governing individual movements among breeding populations were based on results of genetic (Chabot 2011) and stable hydrogen isotope data (Chabot, unpublished data). Methods and rules were as follows:

- Breeding subpopulation was designated as a) obligate migrant (Ontario subpopulations and Northern Illinois), b) partially migratory (Indiana-Illinois, Kentucky, Appalachian Plateau, Virginia Valleys) or c) non-migratory (Arkansas-Missouri, Western Tennessee, Central Tennessee, Piedmont, Coastal) based on consultation with Loggerhead Shrike Working Group members, using results from the coordinated color-banding and monitoring program.
- Shrikes originating from Ontario were allowed to migrate equally to all possible wintering grounds (i.e. subpopulations) with the exception of the Coastal region. Wintering movements into this area were twice as high as elsewhere, as banding data suggests a preferential eastern movement to the Atlantic Coastline (Loggerhead Shrike Working Group, unpublished data). Migration rates and movements were also informed by an outlier analysis of winter-season molted feathers (6^{th} rectrices or 9^{th} secondary wing feather), or by breeding-ground origin molted feather (1^{st} primary wing feather).
- Shrikes originating from Northern Illinois were allowed to migrate equally among the closest southern non-migratory populations, based on the parsimonious assumption that wintering movements to subpopulations further east was unlikely. Migration rates and movements were also informed by an outlier analysis of winter-season molted feathers (6^{th} rectrices or 9^{th} secondary wing feather), or by breeding-ground origin molted feather (1^{st} primary wing feather).
- Migration of shrikes from partially migratory and resident populations was restricted to and apportioned equally among the closest neighboring population (i.e. a bird was not allowed to migrate through a suitable wintering area to a more distant area).
- Dispersal rates within each breeding subpopulation (i.e. the percentage of birds that returned to their natal or previous breeding area) were based on results of previous analysis of nuclear microsatellite markers using the program BayesAss+ (Chabot 2011). Where possible, rates were adjusted based on monitoring of color-banded breeding shrikes.
- Dispersal rates and movement patterns among breeding populations (i.e. the percentage of birds within a wintering area that returned to a breeding area other than their natal or previous breeding

site) were determined based on banding data and spatial autocorrelation analysis of nuclear genetic microsatellites.

a. A small proportion of birds from partially migratory populations were allowed to remain in their over-wintering grounds outside their natal area.
b. Birds from resident populations were allowed to migrate to the nearest southern, eastern or western neighboring breeding areas. Northern movements were not allowed, as it is much less likely based on banding return data (Chabot 2011). Dispersal was proportioned equally among neighboring populations.
c. Birds originating from Northern Illinois were allowed to remain in their wintering area, return to southern Indiana-Illinois, or migrate to Ontario. Proportions were based on outlier analysis of stable hydrogen data.
d. A small proportion of Ontario migrants were allowed to remain as a breeder in the population they migrated to, based on outlier analysis of stable hydrogen data. Within southern Indiana-Illinois, a small proportion of Ontario birds were allowed to disperse to Northern Illinois – genetic analysis of shrike from Northern Illinois suggests movement from Ontario to this Northern Illinois. As migration and dispersal are correlated in shrike (Chabot 2011), the most parsimonious assumption for the mechanisms is that the Ontario birds originate from the wintering ground nearest to Northern Illinois, which is southern Indiana-Illinois.

These rules were used to create two separate movement matrices, with row and column headings labeled as populations: one matrix for migration/dispersal in the autumn (odd timesteps) and a second matrix for analogous movements in the spring (even timesteps). The cells described the probability that an individual bird would move from its current location (row heading) to its final destination for that movement event (column heading). After repeated checking of the functional form of these seasonal movements, the two matrices were combined to describe the full range of movement possibilities for a given bird starting in a specific population in the appropriate timestep. To reiterate, the key feature of this PVA model component is the ability to specify where a bird is likely to move in a given season, based on where that individual begins its movement event and the bird's population of origin.

A full description of the rules for spring migration can be found in Appendix III.

<u>Mechanics of ex situ population management and release scenarios</u>

In addition to the basic demographic characteristics of the ex situ population described previously, other aspects of this population are summarized here. Specifically, we assumed that mating pairs for the ex situ population were chosen on the basis of minimizing the relatedness between the individuals making up a potential pair. A static list of mean kinship values (MK: Ballou and Lacy 1995) is calculated for this population each year by Vortex and is then used to create pairs that minimize MK for that pair. This protocol reduces the rate of accumulation of inbreeding in an intensively managed population and, by extension, slows the rate of loss of genetic diversity. As an added protocol, the model restricts matings to those with a mean kinship between the parents (inbreeding coefficient of offspring) of less than 0.25, i.e., full sibling or parent-offspring pairs. While this may not be a consistent feature of the existing ex situ breeding program, it represents a level of genetic management that helps to ensure long-term ex situ population viability.

Releases from the ex situ population to one or more wild populations is accomplished with the Translocation module in Vortex. Specific individuals are harvested according to any number of criteria, transferred to a temporary holding facility in order to properly maintain their individual identity, and are then supplemented to designated recipient populations. In this case, fledglings are selected for release in the latter part of summer (i.e., odd timesteps), as wild populations prepare for their autumn migration. Since mortality across all populations takes place in our model before the selection of birds for release, the mortality rate for new fledglings in the ex situ population includes only the period of time between fledging and the average date of release, approximately 45 days after fledging. To account for additional mortality among those birds not selected for release, we harvest an extra number of birds and then apply a 92.2% survival rate to the full group of selected birds. Detailed analysis of the studbook indicates that approximately 81% of new fledglings are to be harvested to create the release cohort and the additional mortality of birds not selected for release. Additionally, we impose a rule for selection whereby birds are chosen for release only if their mean kinship to the ex situ population is greater than the average mean kinship of all fledglings to the population. In this way, the selection of birds for release does not adversely affect the genetic diversity of the population. Monitoring of newly-released birds indicates a post-release survival rate to onset of migration of 76% (Imlay et al. 2010).

In this analysis, releases take place for the first 10 years of the 20-year simulation in order to assess population stability both during and after periods of augmentation from the ex situ population as a function of underlying demographic dynamics in wild populations. Three distinct release scenarios are tested:

- All selected fledglings released to Carden
- All selected fledglings released in an even distribution to Carden and Napanee
- All selected fledglings released in an even distribution to all four Ontario populations

Each of these release scenarios was evaluated with and without the restriction around selecting individuals for release on the basis of their mean kinship value. This was done to assess the potential for a relaxed genetic selection criterion to facilitate harvesting a larger number of birds for release and the associated genetic cost (in terms of reduced genetic diversity retention) to the source population.

Results of PVA Simulations

No Releases Scenario

The No Releases scenario serves as a baseline for evaluating population performance in the absence of augmentation of Ontario populations through releases from the ex situ population. Note that in the figures that follow, each seasonal census is included to demonstrate the seasonal nature of abundance in these migratory populations. Specifically, each census at the end of an odd timestep is 0 which corresponds to the migratory populations leaving their breeding grounds and moving south to their wintering grounds. In even timesteps, most of the birds return north to their breeding grounds to renew the annual cycle, with the census at the end of this timestep a function of the demographic processes occurring throughout the two timesteps that comprise the annual cycle.

Without releases, the very small Ontario populations decline rapidly towards extinction (Figure 7A). By the end of the 20-year trajectory (composed of 40 timesteps), each of the four shrike populations in Ontario have become extinct. Detailed analysis of model output (not shown here) indicates that a very small number of Ontario birds are expected to remain in the U.S. wintering grounds. However, the population decline observed in the breeding populations in Ontario is not a result of larger numbers of birds remaining in wintering grounds, but instead the consequence of high rates of mortality and perhaps low rates of fledgling production.

The United States populations show analogous rates of population decline in the No Release scenario (Figure 7B). Note that with some exceptions, particularly the obligate migratory Northern IL population, many of these populations increase at the end of the first timestep (autumn) as many resident birds remain in their breeding habitat and other birds from migratory and non-migratory populations arrive for the winter. However, unsustainable demographic rates drive populations into decline at an average rate of 4% - 8% per year (annual λ = 0.92 – 0.96). This decline is similar to what is shown in the analysis of BBS abundance index data (see figure 5), although the simulation generates slightly higher rates than calculated from the BBS data. The decline of the Northern Illinois population is especially striking, with 30% - 50% reductions in abundance over the first couple of years. A review of the rates of dispersal into and out of this population suggest that this decline is largely the result of a significant net outflow of migrants from this population each year, although relatively high rates of mortality (as used in this model) no doubt also contribute to population instability.

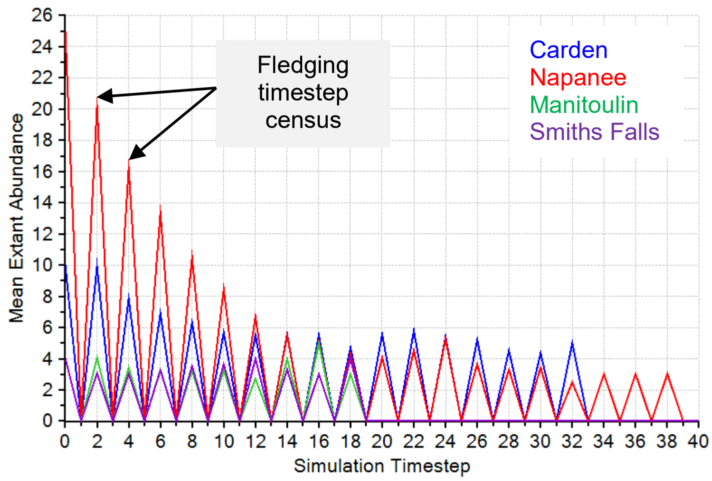


Figure 7A. Mean extant abundance trajectories of Ontario populations in the No Release scenario. Model iterations that decline to extinction are not included in the calculation of mean abundance.

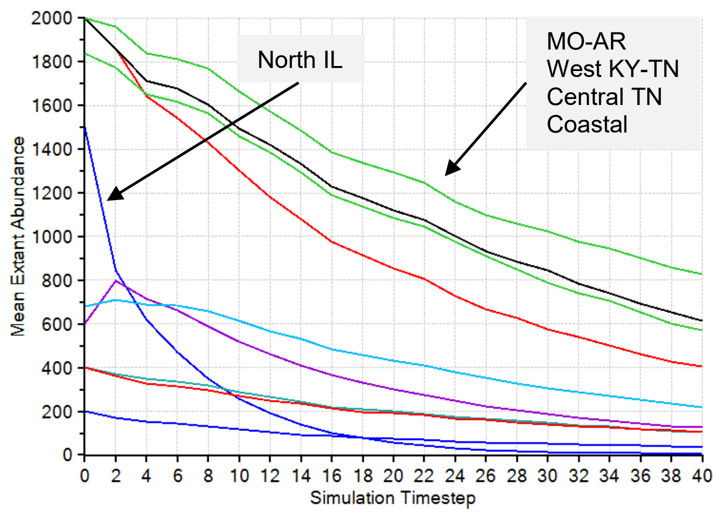


Figure 7B. Mean extant abundance trajectories over 20 years for United States populations in the No Release scenario. Model iterations that decline to extinction are not included in the calculation of mean abundance. Census data for autumn (odd-numbered) timesteps omitted for clarity.

Releases from the Ex Situ Population

Ontario populations receiving birds fledged from the ex situ population show significant responses during the time when releases occur, but the magnitude of response can be strongly dependent on the nature of the release protocol (Figure 8). Not surprisingly, releases of birds exclusively to Carden lead to a substantial increase in population abundance, reaching nearly 75 birds in the spring census in year 10.

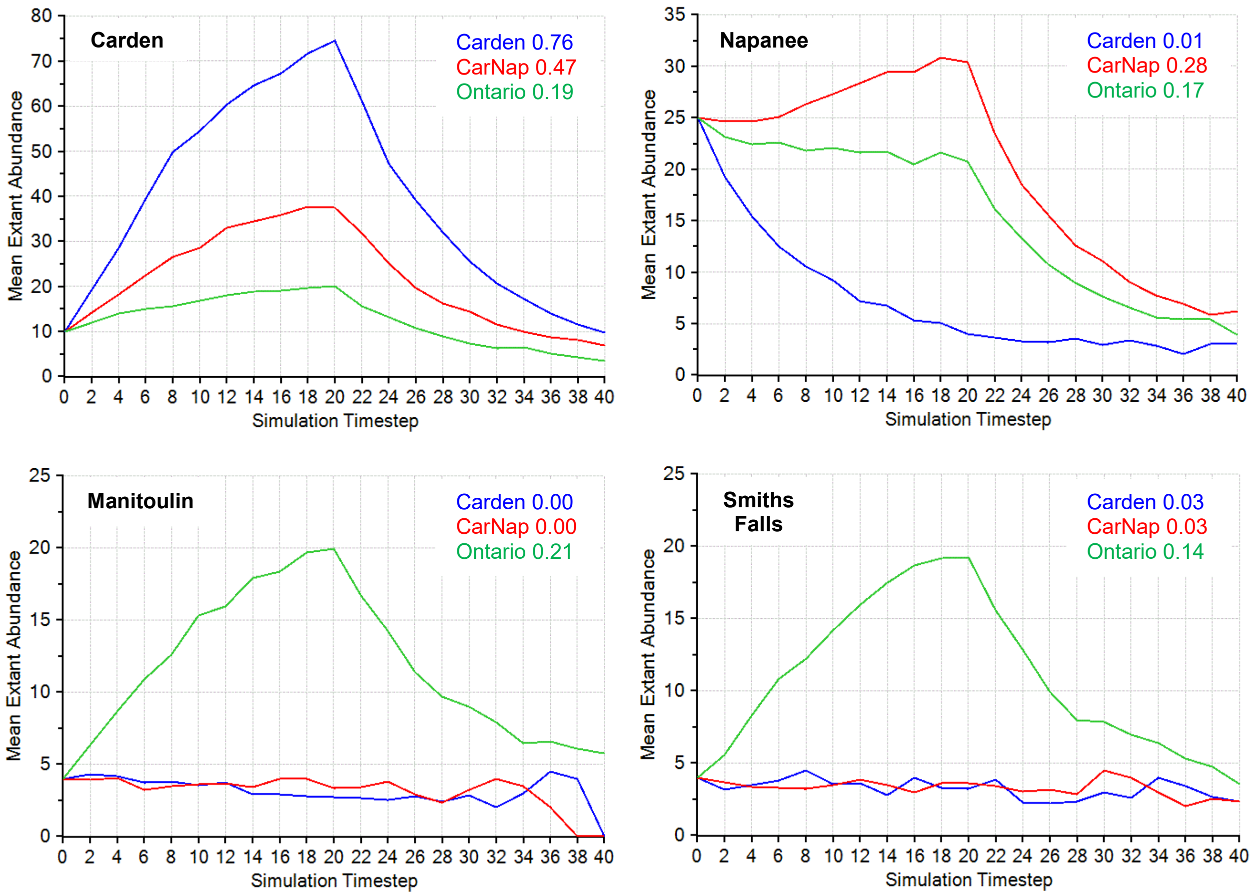


Figure 8. Mean abundance of extant Ontario populations over 20 years in response to alternative ex situ release strategies. The release strategies are listed in figure legends in the top-right of each plot: Carden, all birds released to Carden; CarNap, birds released in equal proportions to Carden and to Napanee; Ontario, all birds released in equal proportions to each of the four Ontario populations. Numbers in each plot legend give the likelihood of population persistence at the end of the 20-year simulation (40 timesteps). See accompanying text for more information on scenario definitions. Census data for autumn (odd-numbered) timesteps omitted for clarity.

When releases are dispersed to Carden and Napanee or to all four Ontario populations, the Carden population responds positively but to a lesser degree as fewer birds are released and are expected to return to that population through time. When birds are released to both Carden and Napanee, the Napanee population shows a rather small population response, with the population increasing to just over 30 individuals by year 10. Restricting the releases to Carden puts the Napanee population in significant risk of extinction, in a manner that is basically identical to the scenario in which there are no Ontario releases. Releases of birds across the four Ontario populations does not benefit the returning breeding Napanee population through the duration of the release effort. The two remnant populations in Manitoulin and Smiths Falls receive no measurable benefit of releasing ex situ birds to Carden or Napanee, but these populations can increase significantly to approximately 20 birds when releases are implemented across all four Ontario populations.

Despite these short-term benefits of releases from the ex situ population, terminating these releases leads to an immediate return after simulation year 10 to the consistent rate of population decline seen in the No Release scenario. In terms of population survival at the end of the 20-year simulation, the Carden population shows a likelihood of between 0.19 and 0.76 depending on the nature of the release effort. Because Napanee is not a direct recipient of the full complement of releases in any one scenario, the likelihood of persistence for this population ranges from 0.17 to just 0.28 under the best-case release scenario. Both the Manitoulin and Smiths Falls populations, starting with very small remnant abundances, show no better than a 0.21 likelihood of persistence when ex situ birds are released in equal proportions across Ontario. While most of these reported chances of population persistence are quite small, overall they represent a marked increase over the No Release scenario where the likelihood of persistence of each Ontario population was 0.0 at simulation year 20.

Relaxing the mean kinship constraint on selecting individuals for release from the ex situ population resulted in a slight increase in the number of birds available for augmenting wild populations. Analysis of custom model output (not shown here for brevity) showed that a relaxed selection procedure resulted in 5-10 additional birds available for release in typical years. If releases are restricted to Carden, the spring population abundance would increase from about 75 individuals under MK-restricted releases to 85 individuals when restrictions are relaxed. As expected, the benefit of a larger release cohort is not as significant when releases are spread across a larger number of recipient populations.

The ex situ population appears to be demographically robust under the conditions simulated here and is able to maintain a population abundance very near the space-limited carrying capacity across ex situ institutions, even when fledglings are being removed for release to the wild (Figure 9A). Note in this figure that the population is impacted by the additional selection of release birds in the absence of the mean kinship restriction, but this impact is very minor and the population grows to a stable abundance immediately after the termination of releases. Additionally, the removal of the mean kinship restriction on selection of birds for release appears to have negligible impact on population-wide gene diversity in the ex situ population (Figure 9B).

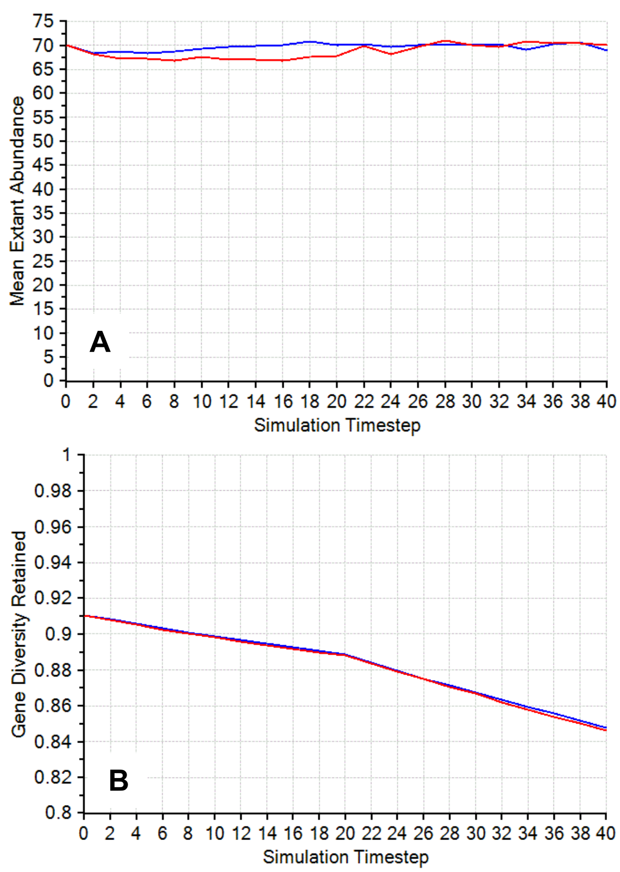


Figure 9. Mean extant abundance trajectories (A, top panel) and proportion gene diversity retained (B, bottom panel) over 20 years in simulated ex situ populations in which fledglings are selected for release to wild populations in Ontario either with (blue plot) or without (red plot) a selection criterion based on maintaining low mean kinship (MK) in the ex situ population. The starting GD value in Figure 9B reflects the amount of original gene diversity captured by the wild founders to the ex situ population and the consequences of intensive management applied to that population prior to the onset of the demographic simulation. Data for autumn (odd-numbered) timesteps omitted for clarity. See accompanying text for more information on scenario development and implementation.

Releases from the Ex Situ Population with Improved In Situ Demographics

Additional scenarios were created that explored Ontario population performance under what were intended to be favorable conditions of reproduction and survival for those populations. Specifically, the proportion of adult females that successfully fledged at least one brood was increased from approximately 74% to 78%, and the adult mortality rates in odd (baseline value: 12%) and even timesteps (baseline value: 16%) were improved to 10% and 12%, respectively. These improvements were thought to be within reason biologically and feasible through one or another form of population management, while also considered sufficient to see marked improvement in longer-term population growth dynamics.

Figure 10 shows a representative set of results for this analysis. The plot shows abundance in the Carden population under the Carden release protocol, where all the fledglings selected from the ex situ population are released to the Carden population for each of the first 10 years of the 20-year simulation (40 timesteps). By the end of the release period, the Carden population increased in abundance from 75 individuals under baseline demographic conditions to 87 individuals when demographic conditions were improved. However, following termination of the release effort, the population once again demonstrated a rapid rate of decline, regardless of the underlying demographic conditions set forth in the model scenario. By the end of the simulation, there was only a very small improvement in population abundance under improved demographic conditions.

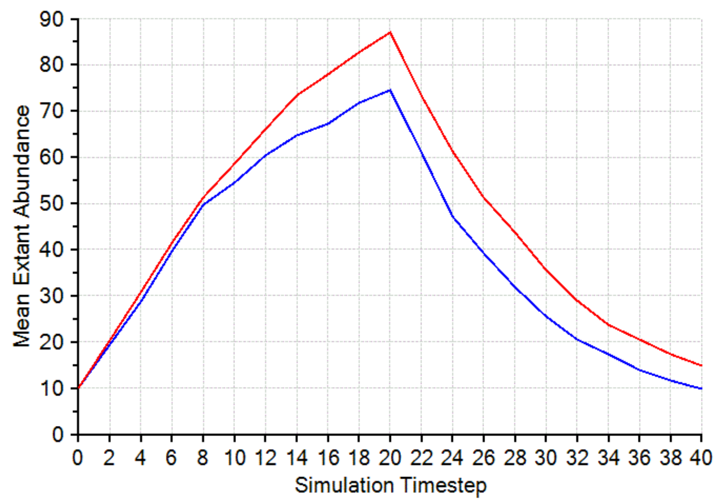


Figure 10. Mean extant abundance trajectories over 20 years for the Carden population, and implementing a strategy of releasing 100% of ex situ birds to the Carden population. The blue plot assumes the baseline demographic values, while the red plot assumes improved annual rates of fledgling production and adult mortality. Census data for autumn (odd-numbered) timesteps omitted for clarity. See accompanying text for more information on scenario development and implementation.

In light of the continued observations of Ontario population decline following the release program, even with attempted improvement to underlying demographic rates, an additional model was developed to look at conditions for sustained population stability. Specifically, the model explored the cost to migration for Ontario birds (summarized on page 18), where our current models assumed 85% survival of migrating birds in both autumn and spring migratory events. Taken together, these migration survival rates suggest that a typical bird migrating from and to a population in Ontario has a (0.85)(0.85) = 0.723 or 72% chance of surviving migration in a single year. This is on top of the survival probabilities in either the breeding or wintering grounds that are also included in the model. Because of this relatively high cost to migration currently employed in the model, this additional exploratory scenario improved survival of each migratory event from 85% to 98%. The goal with this scenario is to evaluate the sensitivity of the current model to changes in a given input parameter, in this case, annual migration survival for Ontario birds. [Note: Due to overall model complexity (run duration of individual iterations) and time constraints, the scenario presented here includes just 10 iterations. Specific results should not be taken as fully representative of a scenario run with a larger number of replicates, but general model behavior can be inferred from this exploratory sample.]

An example of the results of this exploratory analysis for the Carden population is shown in Figure 11. In this particular scenario, fledglings released from the ex situ population are distributed to all four Ontario populations in equal proportions for the first 10 years (20 timesteps) of the simulation. The increased survival rate among birds migrating from and returning to Carden each year appears to dramatically increase population growth during the ex situ release phase, resulting in a 100% increase in the number of birds counted on the breeding grounds in model year 10 (timestep 20). Furthermore, in contrast to the steady rate of population decline that follows the release phase when migration survival is low, the simulated Carden population experiencing higher rates of migration survival shows initial signs of stabilized abundance across the second ten years of the projection. Inspection of the results from this scenario for the other Ontario populations (not shown here) indicate the same general result, even for the remnant populations in Manitoulin and Smiths Falls. Even more importantly, the high risk of local population extinction observed in the low survival scenario for both Manitoulin and Smiths Falls is largely eliminated when migration survival is increased to the level tested here.

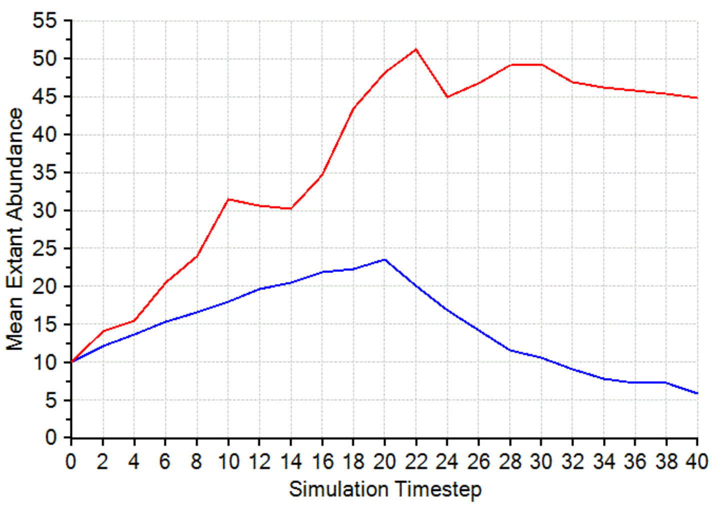


Figure 11. Mean extant abundance trajectories over 20 years for the Carden population, implementing a strategy of releasing fledglings from the ex situ population to all four Ontario populations and assuming improved demographic rates as per the results shown in Figure 10. Additionally, the red plot assumes a survival rate of 98% for either the autumn or spring migration event, increased from 85% in the original scenario (blue plot). Census data for autumn (odd-numbered) timesteps omitted for clarity. See accompanying text for more information on scenario development and implementation.

Discussion and Conclusions

In this project, an individual-based simulation model was built in an attempt to realistically portray complex demographic and migration/dispersal dynamics of loggerhead shrike populations distributed across portions of southern Ontario, Canada and the eastern United States. This population viability analysis (PVA) is in response to a recognized need for improved species management across the region in the face of sustained declines in population abundance since at the least the 1990s.

Overview of PVA Development Process and Demographic Model Performance

In preparation for this analysis, the PVA Technical Team decided on the appropriate geographic scope and identified a total of 14 habitat areas in Ontario and the U.S. that would serve as loggerhead shrike population locations. These populations were capable of exchanging individuals through time, thereby creating a metapopulation structure across the landscape. The Team then developed a threat analysis designed to improve our understanding of specific human activities that could negatively impact shrike populations and their breeding and/or wintering habitats. In addition, abundance index data from the North American Breeding Bird Survey (BBS) were used to estimate rates of population decline over the past several decades. The goal of this work was to associate population decline rates with a characterization of threat intensity for that same geographic area. Independently, these analyses successfully highlighted certain populations that appeared to be subjected to higher cumulative levels of threats than other populations, as well as populations that have been declining at comparatively higher rates than other populations (at least as measured by abundance index).

However, we were unable to meaningfully associate cumulative threats to specific populations and their historic rates of decline. There is certainly some unwanted variance in the threat scores across populations due to different perspectives and levels of experience among experts who scored threats for specific populations in their geographic area. While not ideal from a quantitative analysis perspective, in no way does it negate the value of the threats analysis as conducted here. The aggregate threat scores, and the identification of specific threats and the underlying mechanisms that contribute to risk of population decline, are valuable information to be used for recommending management of populations and their habitats to improve long-term viability. As loggerhead shrike conservation planning proceeds, opportunities exist for strengthening the value of the threat analysis both qualitatively and quantitatively if appropriate data exist (e.g., Hames et al. 2006; Currey et al. 2012; Lacy et al. 2017).

The population dynamics model developed for this project, using the Vortex software package, is a complex, individual-based simulation of regional metapopulation viability of a migratory species. In fact, in both scope and detail, it is likely to be one of the most complex Vortex models to be constructed to date. A calendar year, the most commonly-used time interval for PVAs of a higher-order annual breeder, is here divided into two distinct timesteps that are separated by seasonal migration. The seasonal migration events describe probabilities of movements of individual birds across fourteen separate populations, with these probabilities contingent on the season in which movement is occurring and the geographic origin of each individual controlling decisions on the destination for a given movement. Finally, this model features explicit simulation of an ex situ population with a very different annual breeding structure, detailed genetic management protocols, and a complex mechanism of translocation of fledged birds to one or more wild populations according to defined frequencies, intensities, and success rates (e.g., post-release survival).

Because of this complexity, extensive testing of model performance is required to gain confidence that the model is generating expected results. A particular PVA model may not fully accurately predict future population abundance or trajectories; given our incomplete understanding of current population dynamics for the great majority of wildlife species, seeking to achieve such accuracy should not be the primary goal of the analysis (e.g., Brook et al. 2003; Drechsler et al. 2003; McCarthy et al. 2003). The loggerhead shrike has been monitored and studied for decades in North America, yet significant gaps remain in our fine-scale knowledge of reproduction, survival, movement patterns and the like – data that provide the foundation for a fully informative PVA. Collecting these data over many years across expansive habitats presents considerable challenges that are difficult to overcome. Despite these practical challenges, species experts provided a valuable body of data that was used to build a credible model of loggerhead shrike metapopulation dynamics in the project area. Initial testing of model output so far confirms that that various components of the model are working as intended, and that the results obtained from individual scenarios are reliable portrayals of expected outcomes.

Successfully calibrating population-specific demographic rates to generate accurate trends in abundance over time is particularly difficult in metapopulation models such as the present analysis. A case in point is the Northern Illinois population, where the current PVA model predicts a very rapid rate of decline and near certain extinction within 15 years in the absence of any management intervention. As discussed in this report, a strong negative migratory outflow of individuals from this population through time surely contributes to the simulated rate of decline in this population which is considerably higher than that observed through monitoring efforts. The PVA process itself is a valuable tool for generating and testing hypotheses about our understanding of a complex wildlife population and how it might respond to alternative management interventions. Additional exploration of the factors contributing to the decline of this and other populations in our PVA model is a high priority in order to improve overall model realism and reliability.

Our model consistently predicts continued declines in loggerhead shrike abundance for all populations comprising the metapopulation in Ontario and the eastern United States – rates of decline that generally mimic observed trends in abundance across the region. Releases of new fledglings from the intensively managed ex situ population can serve as a means of reverse population declines if conducted with appropriate intensity. The release scenarios explored in this PVA suggest that all four Ontario populations included in this analysis can benefit substantially from distributed releases. However, when releases are terminated, poor demographic performance within a recipient population can result in renewed declines in abundance as underlying reproductive rates are not sufficient to overcome loss of individuals through mortality both within seasonal habitats and during migration/dispersal events. Initial attempts to improve demographic performance by increasing reproductive output and decreasing adult mortality in these Ontario populations did not result in a successful outcome. However, a final scenario targeting increases in migration survival appears to significantly improve population performance and may yield sustained population growth after releases are terminated.

From the results of this preliminary analysis, it is clear that a deeper exploration of alternative release strategy design and in situ demographic performance is needed. In particular, a more extensive analysis of the sensitivity of model output to uncertainty in demographic input parameter values would be a valuable addition to the current analysis. Tischendorf (2009; 2015) developed a matrix model for loggerhead shrike in Ontario and included a sensitivity analysis of this type. This earlier analysis highlighted survival of juveniles to one year of age as a major factor influencing population growth. There is no reason to refute that finding in the present analysis. However, the detailed individual-based metapopulation model discussed in this report is structured very differently from the stage-based approach of Tischendorf and may therefore reveal more detailed insight into the different factors at play in both in situ and ex situ populations that influence wild population viability.

Next Steps for Loggerhead Shrike Conservation Planning in the Project Area

Additional refinement and expansion of the current demographic simulation model would make a valuable contribution to future conservation planning for loggerhead shrike in the project area. Activities would include the following:

- Continued testing of general model structure to confirm proper performance
- Systematic exploration of model sensitivity to uncertainty in specific input parameters
- Refinement of ex situ population demographic dynamics
- Assessment of a wider range of ex situ release scenarios, including increasing space-limited carrying capacity to increase number of fledglings available for release

Results from the expanded PVA effort would yield valuable evidence in support of creating effective conservation management recommendations for the species across the project area.

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Appendix I

PVA Development Process Workshop Participants

Name	Organization	PVA Workshop I (Aug 2021)	PVA Workshop II (Jan 2022)	PVA Workshop III (Nov 2022)
Christian Artuso	Environment and Climate Change Canada			
Richard Bailey	West Virginia Division of Natural Resources			
Than Boves	Arkansas State University			
Mike Burrell	Ontario Natural Heritage Information Centre			
Lee Burton	Loggerhead Shrike Working Group			
John Carpenter	North Carolina Wildlife Resources Commission			
Vicky Carriere	Parc Omega			
Amy Chabot	African Lion Safari			
Leighann Cline	Smithsonian Conservation Biology Institute			
Joe Degraauw	Nashville Zoo			
Randy Dettmers	US Fish and Wildlife Service - Northeast			
Em Donahue	Arkansas State University			
Allisyn Gillet	Indiana Department of Natural Resources			
Jim Giocomo	American Bird Conservancy			
Kevin Hannah	Environment and Climate Change Canada			
Sergio Harding	Virginia Department of Wildlife Resources			
Jennifer Hoare	Ontario Parks			
Amy Johnson	Smithsonian Conservation Biology Institute			
Amy Kearns	Indiana Department of Natural Resources			
Becky Keller	Appalachian Mountains Joint Venture			
Joseph Lautenbach	Ohio Department of Natural Resources			
Colleen Lynch	Riverbanks Zoo and Garden/Association of Zoos and Aquariums			
Mercedes Maddox	Alabama Game and Fish Commission			
Cindy McCarthy	Miller Aggregates			
Mhairi McFarlane	Nature Conservancy of Canada			

Name	Organization	PVA Workshop I (Aug 2021)	PVA Workshop II (Jan 2022)	PVA Workshop III (Nov 2022)
Phil Miller	Conservation Planning Specialist Group			
Christine O'Reilly	Ontario Ministry of Agriculture, Food and Rural Affairs			
Chelsey Paquette	Granby Zoo			
Michael Patton	Kentucky Department of Fish and Wildlife Resources			
Cyndi Routledge	Southeastern Avian Research			
Drew Sauve	Queen's University			
J-P Savard	Loggerhead Shrike Recovery Team			
Teia Schweizer	Colorado State University			
Alisa Solecki	Queen's University			
Jane Spero	Wildlife Preservation Canada			
Jessica Steiner	Wilder Institute/Calgary Zoo			
Amy Tegeler	South Carolina Department of Natural Resources			
Hazel Wheeler	Wildlife Preservation Canada			
Stephanie Winton	Wildlife Preservation Canada/Canadian Species Initiative			

Appendix II

Threat Analysis for Loggerhead Shrike Populations in the Project Area

Table II.1. Standardized stress and threat classification (based on MFFP 2021) of threats to loggerhead shrike and the mechanistic drivers as identified in the July 2021 species conservation planning workshop, and the demographic impact of the identified threats. See Table II.2 for threat intensities across loggerhead shrike populations.

Standardized stress and threat classification	Threat and Mechanistic Driver(s)	Demographic Impact
1.1 Ecosystem conversion	Habitat loss	Reduced carrying capacity
1.1.2 Low-density housing areas	Housing/cottage development	
1.3.1 Parks and sports fields	Recreational development (shooting range, golf, others?)	
2.1 Annual and perennial non-timber crop	Agricultural intensification (cash crops)	
3.2.3 Quarries & sand pits	Aggregate development	
3.3.4 Solar farms/3.3.2 Wind farms	Renewable energy development (solar, wind)	
2.3.1 Outdoor extensive livestock operation (on pasture)	Habitat loss-summer	
	Loss of active "rough" pasture (Agricultural intensification: shrubs removed and grass/veg "managed", removal of barbed wire)	
	Habitat loss-winter	
	Loss of active "rough" pasture (Agricultural intensification: shrubs removed and grass/veg "managed", removal of barbed wire)	
1.2 Ecosystem degradation	Habitat degradation	
1.1.1 Dense housing & urban areas	Conversion to suburban housing	
2.3.1 Outdoor extensive livestock operation (on pasture)	Incompatible grazing rotation	
	Reduction in / removal of nest shrubs	
4.1.1 Roads	Road improvements (widening, ditch cleaning)	
5.2.5 Management/control of terrestrial plants or fungi	Reduction in/removal of nest shrubs due to human persecution (people don't want shrike on their land)	
7.3.2 Vegetation succession	Native shrub encroachment	
8.1.2 Terrestrial plants (specific to non-native)	Non-native shrub encroachment	
1.2 Ecosystem degradation OR 1.3 Indirect ecosystem effects	Incompatible management with other grassland bird species	
No applicable standardized threat classification		
1.3 Indirect ecosystem effects	Fluctuating / declining prey abundance limiting food availability	Increased mortality; reduced fecundity(?)
11.1 Habitat shifting & alteration	Climate change impacting timing and abundance of invertebrate prey/Natural and anthropogenic climate change resulting in fluctuations/Direct effect on prey abundance due to climate change	

Standardized stress and threat classification	**Threat and Mechanistic Driver(s)**	**Demographic Impact**
2.1 Species mortality	Catastrophic events	
11.5.1 Storms & severe weather	Summer Natural weather event (storms, etc.)	Increased mortality; reduced fecundity
	Winter Natural weather event (storms, etc.)	
4.1.1 Roads	Interactions with motor vehicles	Increased mortality of fledglings, inexperienced juveniles, adults
	Car/truck collisions	
	Predation of adults/overwintering	Increased mortality
8.1.1.24 *Felis catus* - Domestic cat	Free-roaming cats	
No applicable standardized threat classification	Terrestrial wildlife (native) -- snakes, mammals	
	Raptors / corvids (native)	
	Predation of hatch year	
8.1.1.24 *Felis catus* - Domestic cat	Free-roaming cats	
No applicable standardized threat classification	Terrestrial wildlife (native) -- snakes, mammals	
	Raptors / corvids (native)	
	Depredation of nests	
8.1.1.24 *Felis catus* - Domestic cat	Free-roaming cats	
No applicable standardized threat classification	Terrestrial wildlife (native) -- snakes, mammals	
	Raptors / corvids (native)	
2.1 Species mortality &/or 2.2 Species disturbance	Catastrophic events	Increased mortality; reduced fecundity
9.4.1 Garbage	Anthropogenic debris (plastic baling twine, netwrap etc. - entangled nestlings)	
2.1 Species mortality &/or 2.3.7 Reduced reproductive success	Disease epidemic	
8.4 Pathogens (8.4.2 Viral pathogens; 8.4.4 Worm induced disease)		
9.3.3 Herbicides & pesticides	Interactions with industrial chemicals	
	Herbicide application along fencerows	
	Pesticide application to limit agricultural pests	
2.2 Species disturbance	Nest interference	Reduced fecundity
6.1.8 Wildlife observation/photography	Presence of birders / photographers	
2.3.2 Competition	Fluctuating / declining prey abundance limiting food availability	Increased mortality; reduced fecundity(?)
No applicable standardized threat classification	Interspecific competition (e.g., American kestrels)	
2.3.8 Other	Direct effect on prey abundance due to pesticide application	
9.3.3 Herbicides & pesticides		
2.3.6 Skewed sex ratio &/or 2.3.7 Reduced reproductive success	Allee effect	Reduced fecundity

Standardized stress and threat classification	**Threat and Mechanistic Driver(s)**	**Demographic Impact**
No applicable standardized threat classification	Single birds can't find a mate	
LOW IMPACT THREATS (or more data needed)		
1.1 Ecosystem conversion	Habitat loss	Reduced carrying capacity
2.1 Annual and perennial non-timber crop	Loss of Amish/Mennonite communities	
3.2 Mining & quarrying	Strip mining	
1.2 Ecosystem degradation	Habitat degradation	
7.1.2 Suppression in fire regime	Fire suppression	
2.1 Species mortality	Drowning	Increased mortality of fledglings, adults
2.3.1 Outdoor extensive livestock operation (on pasture)	Interaction with water troughs	
1.1 Housing & urban areas	Migration interference	Increased mortality
	Window collisions	
2.2 Species disturbance	Lights (Great Lakes area)	Increased mortality, reduced fecundity
9.6.1 Light pollution		
2.3.1 Outdoor extensive livestock operation (on pasture)	Nest interference	Reduced fecundity
	Presence of farmers or their livestock	
2.3.5 Inbreeding	Inbreeding depression	Reduced fitness

Table II.2. Threat levels across loggerhead shrike populations as assigned in the July 2021 and November 2022 SCP workshops (red = severe - contributes to very rapid population decline, orange = moderate-severe, yellow = moderate - contributes to rapid population decline, green = minimal - contributes to slow/negligible population decline, empty cell = information not available to assess threat for specific population, na = threat not applicable, H = historical threat, U = unknown threat level in an empty cell, or some uncertainty in characterization if in red/yellow/green cells). Low impact or data deficient threats (lower section) were identified based on minimal, unknown, or not applicable threat designations across all populations. Information for Ohio is included here but the state was not included in the PVA. Information was not unavailable to assess threats to loggerhead shrike populations in Pennsylvania, Michigan, and Eastern New York. See Table II.1 for standardized threat classifications and demographic impacts of threats as well as accompanying text and map for more information on metapopulation characteristics and demographic data included in the model.

	Populations														
Threats and mechanistic drivers	**Manitoulin**	**Carden**	**Napanee**	**Smiths Falls**	**Coastal**	**VA Piedmont**	**Virginia Valleys**	**Appalachian**	**IL - IN**	**KY**	**Central TN**	**West KY - TN**	**MO-AR**	**North IL**	**OH**
Habitat loss															
Housing/cottage development	[green]	[yellow]	[yellow]	[yellow]	[green]			[yellow]	[yellow]	[green]	[yellow]	[green]	[green]		
Recreational development (shooting range, golf, others?)	[green]	[yellow]	[yellow]	[yellow]	[green]			[green]	[green]	[green]	[green]	[yellow]	[green]		
Agricultural intensification (cash crops)	[green]	[green]	[yellow]	[red]	[yellow]	na	[green]	[green]	[yellow]	[green]	[yellow]	[yellow]	[red]	[red] H	[red] H
Aggregate development	[green]	[red]	[green]	[yellow]	[yellow]			[green]	[green]	[green]	[yellow]	[red]	[green]		
Renewable energy development (solar, wind)	[green]	[yellow]	[red]	[yellow]	[yellow]			[green]	[yellow]	[green]	[green]	[green]	[green]		
Habitat loss-summer															
Loss of active "rough" pasture	[yellow]	[yellow]	[yellow]	[yellow]	[green]	na	[green]	[yellow]	[red]	[yellow]	[red]	[yellow]	[green]	[red]	[red]
Habitat loss-winter															
Loss of active "rough" pasture	na	na	na	na	[green]	[yellow] U		[green]	[yellow]	[green]	[green]	[green]	[green]	na	[red]
Habitat degradation															
Conversion to suburban housing	[green]	[green]	[green]	[yellow]	[green]			[yellow]	[yellow]	[yellow]	[red]	[green]	[green]	[yellow]	[yellow]
Incompatible grazing rotation	[green]	[green]	[green]	[green]	[green]	[green]	[green] U	[yellow]	U	[green]	[yellow]	[green]	[green]	[green]	[yellow]
Reduction in / removal of nest shrubs	[yellow]	[yellow]	[yellow]	[yellow]	[green]	[yellow]	[yellow]	[yellow]	[yellow]	[green]	[red]	[yellow]	[yellow]	[green]	[green]
Road improvements (widening, ditch cleaning)	[green]	[green]	[green]	[green]	[green]	[green]	[green]	[green]	[red]	[green]	[yellow]	[green]	[red]	U	[yellow]
Reduction in/removal of nest shrubs due to human persecution	[orange]	[orange]	[orange]	[orange]	[green]			[green] U	[green]	[green]	[green] U	[green] U	[green] U		
Native shrub encroachment	[green] U	[yellow]	[red]	[green]	[green]	[green]	[yellow]	[green]	[green]	[green]	[green]	[green]	[green]	U	U
Non-native shrub encroachment	[green]	[yellow]	[yellow]	U	[green]			[green]	[green]	[yellow]	[green]	[green]	[green]	U	U
Incompatible management with other grassland bird species	[yellow]	[green]	[yellow]	[orange]	[green]	[green] U	[green] U	[green] U	[yellow]	[green]	[green]	[green]	[green]	[yellow]	[green]
Fluctuating / declining prey abundance limiting food availability															

	Populations														
Threats and mechanistic drivers	**Manitoulin**	**Carden**	**Napanee**	**Smiths Falls**	**Coastal**	**VA Piedmont**	**Virginia Valleys**	**Appalachian**	**IL - IN**	**KY**	**Central TN**	**West KY - TN**	**MO-AR**	**North IL**	**OH**
Climate change impacting timing and abundance of invertebrate prey / Natural and anthropogenic climate change resulting in fluctuations / Direct effect on prey abundance due to climate change	U	U	U	U	U	U	U		U						U
Catastrophic events															
Summer Natural weather event (storms, etc.)						U	U								U
Winter Natural weather event (storms, etc.)														na	U
Interactions with motor vehicles															
Car/truck collisions															U
Predation of adults/overwintering															
Free-roaming cats						U	U	U	U	U	U	U		U	U
Terrestrial wildlife (native) -- snakes, mammals						U	U	U							U
Raptors / corvids (native)				U		U	U	U				U			U
Predation of hatch year															
Free-roaming cats									U					U	U
Terrestrial wildlife (native) -- snakes, mammals								U		U	U	U			U
Raptors / corvids (native)				U											U
Depredation of nests															
Free-roaming cats									U						U
Terrestrial wildlife (native) -- snakes, mammals															U
Raptors / corvids (native)				U								U			U
Catastrophic events															
Anthropogenic debris (plastic baling twine, netwrap etc. - entangled nestlings)									U					na	na
Disease epidemic	U	U	U	U	U	U		U	U		U	U			U
Interactions with industrial chemicals															
Herbicide application along fencerows					U	U	U	U	U	U	U	U		U	U
Pesticide application to limit agricultural pests					U				U						U
Nest interference															

Threats and mechanistic drivers	Populations														
	Manitoulin	Carden	Napanee	Smiths Falls	Coastal	VA Piedmont	Virginia Valleys	Appalachian	IL - IN	KY	Central TN	West KY - TN	MO-AR	North IL	OH
Presence of birders / photographers															
Fluctuating / declining prey abundance limiting food availability															
Interspecific competition (e.g., American kestrels)												U		na	na
Direct effect on prey abundance due to pesticide application									U						U
Allee effect															
Single birds can't find a mate										U					U
LOW IMPACT THREATS (or more data needed)															
Habitat loss															
Loss of Amish/Mennonite communities													na		
Strip mining											na	na			
Habitat degradation															
Fire suppression	U	U	U	U		na									
Drowning															
Interaction with water troughs						U	U								U
Migration interference															
Window collisions	U	U	U	U					U		na	na			
Lights (Great Lakes area)	U	U	U	U					U		na	na	na		
Nest interference															
Presence of farmers or their livestock							U		U						
Inbreeding depression	U	U	U	U					U	U	U	U	U		U

Appendix III

Additional Information on Rules for Spring Migration and Dispersal

The following pages give estimates of the probabilities of movement of birds that are beginning the spring movement event in a given population (underlined) and are of a given origin. For example (see red text): If a bird is in the Missouri-Arkansas population as the spring migration begins, and if that bird was fledged in Carden, there is a 96% likelihood that the bird will return to Carden in the spring, a 1% likelihood that it will migrate back to Canada but will move to a neighboring population, and a 1% likelihood that it will remain in the Missouri-Arkansas population for the upcoming breeding season.

Missouri-Arkansas Wintering Area

Wintering birds come from:

- Carden
  - Stay = 0.01
  - Return to Carden = 0.96
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Napanee
  - Stay = 0.01
  - Go to Carden = 0.01
  - Return to Napanee = 0.96
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Manitoulin
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Return to Manitoulin = 0.96
  - Go to Smiths Falls = 0.01
- Smiths Falls
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Return to Smiths Falls = 0.96
- N IL
  - Stay = 0.15
  - Return to N IL = 0.7
  - Go to IL-IN = 0.15
- IL-IN
  - Stay = 0.3
  - Return to IL-IN = 0.7
- MO-AR
  - Stay = 0.82
  - Disperse to
    - W KY-TN = 0.06
    - IL-IN=0 .06
    - KY= 0.06

W KY-TN Wintering Area:

Wintering birds come from:

- Carden
  - Stay = 0.01
  - Return to Carden = 0.96
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Napanee
  - Stay = 0.01
  - Go to Carden = 0.01
  - Return to Napanee = 0.96
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Manitoulin
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Return to Manitoulin = 0.96
  - Go to Smiths Falls = 0.01
- Smiths Falls
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Return to Smiths Falls = 0.96
- N IL
  - Stay = 0.15
  - Return to N IL = 0.7
  - Go to IN-IL = 0.15
- IL-IN
  - Stay = 0.3
  - Return to IL-IN = 0.7
- Kentucky
  - Stay = 0.3
  - Return to KY = 0.7
- West KY-TN
  - Stay = 0.82
  - Disperse to
    - MO-AR = 0.045
    - IL-IN = 0.045
    - KT = 0.045
    - C TN = 0.045

IL-IN Wintering Area

Wintering birds come from:

- Carden
  - Stay = 0.01
  - Return to Carden = 0.95
  - Go to Napanee = 0.005
  - Go to Manitoulin = 0.02
  - Go to Smiths Falls = 0.005
  - Go to N IL = 0.01
- Napanee
  - Stay = 0.01
  - Go to Carden = 0.02
  - Return to Napanee = 0.95
  - Go to Manitoulin = 0.005
  - Go to Smiths Falls = 0.005
  - Go to N IL = 0.01
- Manitoulin
  - Stay = 0.01
  - Go to Carden = 0.02
  - Go to Napanee = 0.005
  - Return to Manitoulin = 0.95
  - Go to Smiths Falls = 0.005
  - Go to N IL = 0.01
- Smiths Falls
  - Stay = 0.01
  - Go to Carden = 0.005
  - Go to Napanee = 0.02
  - Go to Manitoulin = 0.005
  - Go to Smiths Falls = 0.95
  - Go to N IL = 0.01
- N IL
  - Stay = 0.295
  - Return to N IL = 0.7
  - Go to Carden = 0.0025
  - Go to Napanee = 0.0025
- IL-IN
  - Stay = 0.7
  - Disperse to
    - MO-AR = 0.1
    - KY= 0.1
    - W KY-TN = 0.1

Central TN Wintering Area

Wintering birds come from:

- Carden
  - Stay = 0.01
  - Return to Carden = 0.96
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Napanee
  - Stay = 0.01
  - Go to Carden = 0.01
  - Return to Napanee = 0.96
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Manitoulin
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Return to Manitoulin = 0.96
  - Go to Smiths Falls = 0.01
- Smiths Falls
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Return to Smiths Falls = 0.96
- Kentucky
  - Stay = 0.3
  - Return to KY = 0.7
- Appal Plateau
  - Stay = 0.3
  - Return to Appal Plat = 0.7
- C TN
  - Stay = 0.82
  - Disperse to
    - W KY-TN = 0.045
    - KY = 0.045
    - Appal Plat = 0.045

Kentucky Wintering Area

Wintering birds come from:

- Carden
  - Stay = 0.01
  - Return to Carden = 0.96
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Napanee
  - Stay = 0.01
  - Go to Carden = 0.01
  - Return to Napanee = 0.96
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Manitoulin
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Return to Manitoulin = 0.96
  - Go to Smiths Falls = 0.01
- Smiths Falls
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Return to Smiths Falls = 0.96
- N IL
  - Stay = 0.05
  - Return to N IL = 0.65
  - Go to IN-IL = 0.2
- IL-IN
  - Stay 0.3
  - Return to IL-IN = 0.7
- Kentucky
  - Stay = 0.7
  - Disperse to
    - W TN = 0.1
    - C TN = 0.1
    - IL-IN = 0.1

Appal Plateau Wintering Area

Wintering birds come from:

- Carden
  - Stay = 0.01
  - Return to Carden = 0.96
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Napanee
  - Stay = 0.01
  - Go to Carden = 0.01
  - Return to Napanee = 0.96
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Manitoulin
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Return to Manitoulin = 0.96
  - Go to Smiths Falls = 0.01
- Smiths Falls
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Return to Smiths Falls = 0.96
- VA Valleys
  - Stay = 0.3
  - Return to VA Valleys = 0.7
- Appal Plateau
  - Stay = 0.7
  - Disperse to
    - C TN = 0.1
    - VA Valleys = 0.1
    - Piedmont = 0.1

VA Valleys Wintering Area

Wintering birds come from:

- Carden
  - Stay = 0.01
  - Return to Carden = 0.96
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Napanee
  - Stay = 0.01
  - Go to Carden = 0.01
  - Return to Napanee = 0.96
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Manitoulin
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Return to Manitoulin = 0.96
  - Go to Smiths Falls = 0.01
- Smiths Falls
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Return to Smiths Falls = 0.96
- VA Valleys
  - Stay = 0.7
  - Disperse to
    - Piedmont = 0.15
    - Appal Plat = 0.15

Piedmont Wintering Area

Wintering birds come from:

- Carden
  - Stay = 0.01
  - Return to Carden = 0.96
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Napanee
  - Stay = 0.01
  - Go to Carden = 0.01
  - Return to Napanee = 0.96
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Manitoulin
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Return to Manitoulin = 0.96
  - Go to Smiths Falls = 0.01
- Smiths Falls
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Return to Smiths Falls = 0.96
- Appal Plateau
  - Stay = 0.3
  - Return to Appal Plat = 0.7
- VA Valleys
  - Stay = 0.3
  - Return to VA Valleys = 0.7
- Piedmont
  - Stay = 0.7
  - Disperse to
    - Coastal = 0.1
    - VA Valleys = 0.1
    - Appal Plat = 0.1

<u>Coastal Wintering Area</u>

Wintering birds come from:

- Carden
  - Stay = 0.01
  - Return to Carden = 0.96
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Napanee
  - Stay = 0.01
  - Go to Carden = 0.01
  - Return to Napanee = 0.96
  - Go to Manitoulin = 0.01
  - Go to Smiths Falls = 0.01
- Manitoulin
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Return to Manitoulin = 0.96
  - Go to Smiths Falls = 0.01
- Smiths Falls
  - Stay = 0.01
  - Go to Carden = 0.01
  - Go to Napanee = 0.01
  - Go to Manitoulin = 0.01
  - Return to Smiths Falls = 0.96
- Appal Plateau
  - Stay = 0.3
  - Return to Appal Plat = 0.7
- VA Valleys
  - Stay = 0.3
  - Return to VA Valleys = 0.7
- Piedmont
  - Stay = 0.3
  - Return to Piedmont = 0.7
- Coastal
  - Stay = 0.97
  - Disperse to:
    - Piedmont = 0.03

Appendix D. A Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States: Addendum

A Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States: Addendum

Report prepared by: Dr. Amy Chabot, Director of Research and Conservation Programs, African Lion Safari, CPSG Canada Regional Resource Center Co-Convenor.

Date: September 10, 2024

Introduction

A demographic model for *L. l. migrans* populations, including both extant populations of *L.l. migrans* and populations of *L. l. centralis* in areas where migratory *L. l. migrans* overwinter, was developed by Miller (2023) using best available demographic and population data as an individual-based population model in Vortex version 10.6.0.0 (Lacy and Pollak, 2023), a widely used PVA modeling software package (Figure 1). The model included two 'time steps' in each 12-month period representing breeding and non-breeding seasons, and thus represented the full annual life cycle for the subspecies. Migration (the seasonal movement to and from a breeding ground) and dispersal (movements among breeding grounds) were modelled as applicable – the model included populations of obligate migrants, partially migratory populations and non-migratory populations. See Miller (2023) for further detail on model structure and demographic rates, including dispersal and migration.

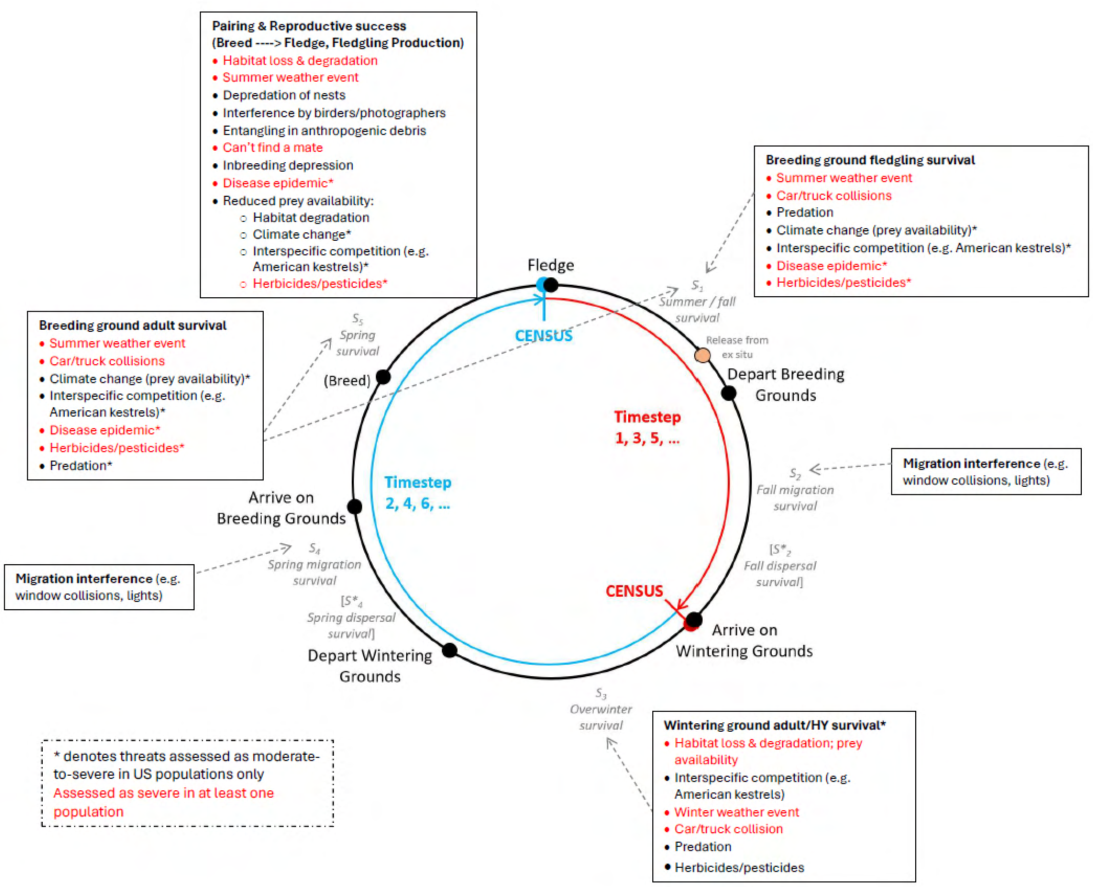

Figure 1. Schematic diagram of the annual life cycle of migratory loggerhead shrike as defined in the PVA model. See Miller (2023) for more details. Threats to *L. l. migrans* across its full annual cycle range (those identified as a priority are shown in red) and the demographic parameters they impact mapped onto

a schematic diagram of the full annual life cycle as defined in the population viability analysis model developed by Miller (2023). Threats were prioritized for action based on magnitude of impact and feasibility of mitigation in the next ten years. See PVA text (Appendix C) for a more detailed discussion of the life cycle and its treatment in the demographic model.

Vortex uses a Monte Carlo simulation approach to model the effect of deterministic and stochastic factors on wild and captive populations. Deterministic events are constant over time (i.e. harvest, habitat loss, contamination and habitat fragmentation); whereas stochastic events are linked to a probability of occurrence and are classified as demographic (i.e. probabilities of survival, reproduction, offspring sex determination), environmental (fluctuations in demographic rates caused by fluctuations on weather, competition, food supply, diseases), catastrophic (i.e. hurricanes, prolonged droughts, oil spills, epidemic diseases) and genetic (i.e. genetic drift, inbreeding). The program generates the specified number of individuals to form the initial population, then each animal moves through different life cycle events such as birth, mate selection, reproduction, mortality, and dispersal, which are determined by the probability of occurrence that are entered into the model. Consequently, each simulation run (iteration) of the model gives a different result. By allowing mean demographic rates to vary within identified limits, the program predicts at the end of the simulation: population extinction risk, the average size of the surviving populations, and genetic diversity retained by the population, among other statistical results. For a more detailed explanation of Vortex and its use in PVAs visit https://scti.tools and www.cpsg.org.

Simulation modelling is a valuable tool for quantitative risk analysis of declining and small populations, both free ranging (in situ) and those managed in human care (ex situ). The most rigorous method for producing the most defensible results would be empirical estimates derived from observation of populations of varying sizes and population trends. However, where this information is lacking, computer simulations can be used to project probability distribution of possible fates under varying scenarios. Computer simulation enables hypotheses to be tested, with results open for challenge and improvement. Further, ranges of plausible values for uncertain parameters can be tested to determine what effects these uncertainties might have on the various aspects of population demography. In this way, computer simulation can indicate which aspects of the biology of the population contribute most to its vulnerability and therefore, which aspects might be most effectively targeted for management. Results can also help prioritize research to address knowledge gaps and identify key parameters that should be monitored to during management to assess the success of conservation efforts.

As noted in Miller's (2023) population viability analysis model for loggerhead shrike – including general model complexity, highly detailed migration/dispersal mechanics, relatively large loggerhead shrike abundance estimates in select U.S. populations, and the inclusion of genetic processes impacting population viability and management – requires significant computational capacity to properly conduct the analysis. As a result, the analysis presented by Miller (2023) were preliminary and would benefit from additional attention including:

- Continued testing of general model structure to confirm proper performance;
- Systematic exploration of model sensitivity to uncertainty in specific input parameters;
- Refinement of ex situ population demographic dynamics; and
- Assessment of a wider range of ex situ release scenarios, including increasing space-limited carrying capacity to increase number of fledglings available for release.

The goal for the population viability analysis was to provide information that would assist in the development of a recovery implementation plan for loggerhead shrike that included improved identification of threats, the identification of measurable actions and timelines to address threats, and specification of assessment criteria across the full annual cycle in eastern Canada and the United States.

Specific questions that modelling work could assist with answering were identified through consultation with species experts and workshop participants, including**:**

- What comprises a "recovered" or stable population of loggerhead shrike?
- What habitat is needed to meet the 'recovered population' goals?
- How can conservation breeding and release most effectively support the recovery of the species?
- What are the key threats affecting loggerhead shrike what is the significance of these threats?
- How effective are the current loggerhead shrike population management activities, specifically, habitat protection under SARA and captive-breeding and release?
- How significant is post-fledging and juvenile mortality as a limiting factor for the Ontario population of loggerhead shrike?
- What demographic data should be used to assess recovery efforts for loggerhead shrike in Ontario?
- What research questions are most significant (i.e. what are the key knowledge gaps)?

The results will assist in directly addressing actions noted in the Ontario Ministry of Environment, Conservation and Parks Government Response Statement for Eastern Loggerhead Shrike, including:

- Identify threats affecting loggerhead shrike on the breeding grounds and evaluate the significance of potential threats.
- Support the securement of loggerhead shrike habitat.
- Conduct annual monitoring at known locations of loggerhead shrike in Ontario.
- Coordinate efforts and share information with other jurisdictions.

Additional analyses as presented in this addendum to Miller's (2023) population viability analysis for loggerhead shrike in Eastern Canada and the United States were conducted to address the next steps identified in Miller (2023) and the above-noted questions. Results were used to guide the final workshop in the species conservation planning process for loggerhead shrike, held in January 2024. All analyses reported herein were conducted using Miller's (2023) model for loggerhead shrike. The input values used for this model are described in Miller (2023). Minor modification to the model were made, specifically, initial population size was reduced, as needed, to 250 individuals to address computational restrictions. A subset of models was repeated, and output compared between to those from Miller (2023). Results indicated that demographic and stochastic process were unaffected by this modification, while simulation run time was significantly improved. All simulations reported herein were run for 40 years, as per Miller (2023) and with 500 iterations for each model.

Sensitivity Testing

Recognizing that there is some uncertainty around model input parameters used in the population viability analysis for loggerhead shrike, sensitivity testing was conducted by varying a single parameter at a time. This can be useful not only in assessing the impact of uncertainty in model results but also for estimating which threats or management actions may have the greatest effect on population viability. Sensitivity analyses for loggerhead shrike were focused on varying parameters for the Ontario populations. Parameters were tested by identify biologically feasible minimum and maximum values around the original, or baseline model value (Table 1).

In addition to addressing uncertainty in parameters, sensitivity analysis was conducted to help address the following questions:

- What are the key threats affecting loggerhead shrike on the breeding grounds and what is the significance of these threats?
- How significant is post-fledging and juvenile mortality in the Ontario population as a limiting factor?

- What factors are most important to quantify in future research and should be the focus of annual monitoring, in a coordinated fashion with other jurisdictions?

Table 1. Parameters estimates used in sensitivity testing for the Carden population.

Parameter	Low	Baseline	High
Reproduction			
# fledged young	2.5	3.5	4.5
Sex ratio at birth - females	40	50	60
% females breeding	69	76	83
% males breeding	81	90	99
Mortality			
Female fledgling mortality (Age class 0 to 1 timestep)	49	55	61
Male fledgling mortality (Age class 0 to 1 timestep)	49	55	61
Female HY mortality to arrival on wintering grounds (1 to 2 timestep)	36	40	44
Male HY mortality to arrival on wintering grounds (1 to 2 timestep)	36	40	44
Female SY mortality during winter, thru migration and to fledge (2+ even timesteps)	14	16	18
Female SY and ASY mortality during breeding and migration thru arrival on winter grounds (2+ odd timesteps)	10	12	14
Male SY mortality during winter, thru migration and to fledge (2+ even timesteps)	14	16	18
Male SY and ASY mortality during breeding and migration thru arrival on wintering grounds (2+ odd timesteps)	10	12	14

Of the reproductive parameters examined in sensitivity testing, the stochastic growth rate of the model was most sensitive to the number of fledged young (Figure 2). Adult female mortality, the percentage of females reproducing, and the sex ratio of offspring (i.e. number of female young) also had a substantial but lesser effect (Figure 2). Of mortality parameters included in sensitivity testing, results indicate that stochastic growth rate was again most sensitive to changes in rates for females, with mortality of female fledged young being of greatest importance (Figure 3). Management strategies focused on improving the recruitment of new female breeders into the population (either through the production of additional clutches and/or increased survival of juveniles) or decrease females juvenile or adult mortality would have the greatest benefit to recovery of the species in Ontario.

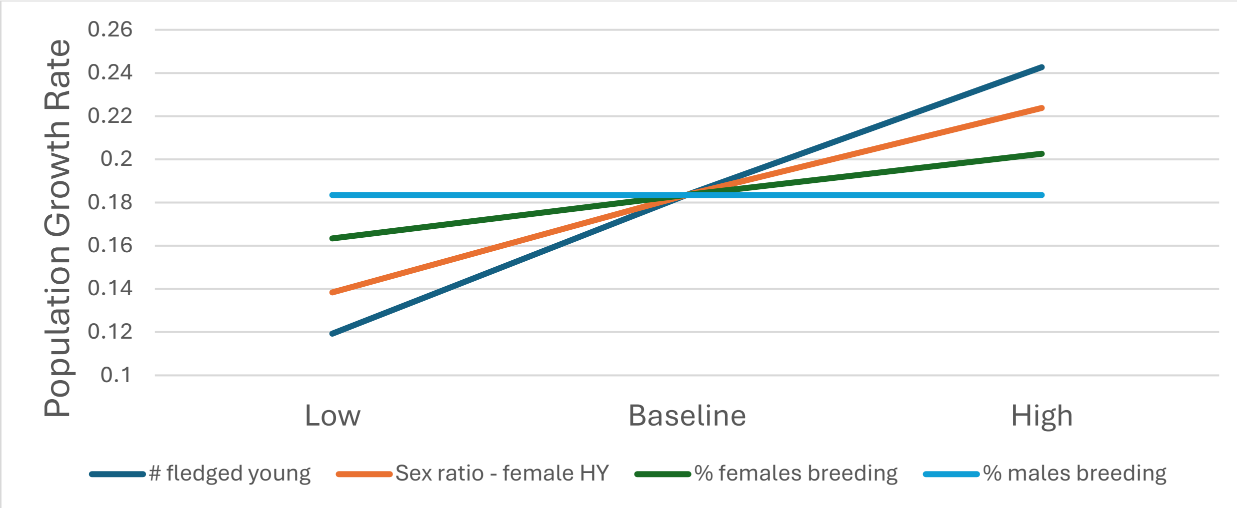

Figure 2. Results of sensitivity testing of reproductive parameters in the PVA model for loggerhead shrike. Values used for ‘low’, ‘baseline’ and ‘high’ rates are found in Table 1. The slope of the line indicates the sensitivity of the model to a specific parameter, with greater slope indicating greater change, or sensitivity in stochastic model population growth rate.

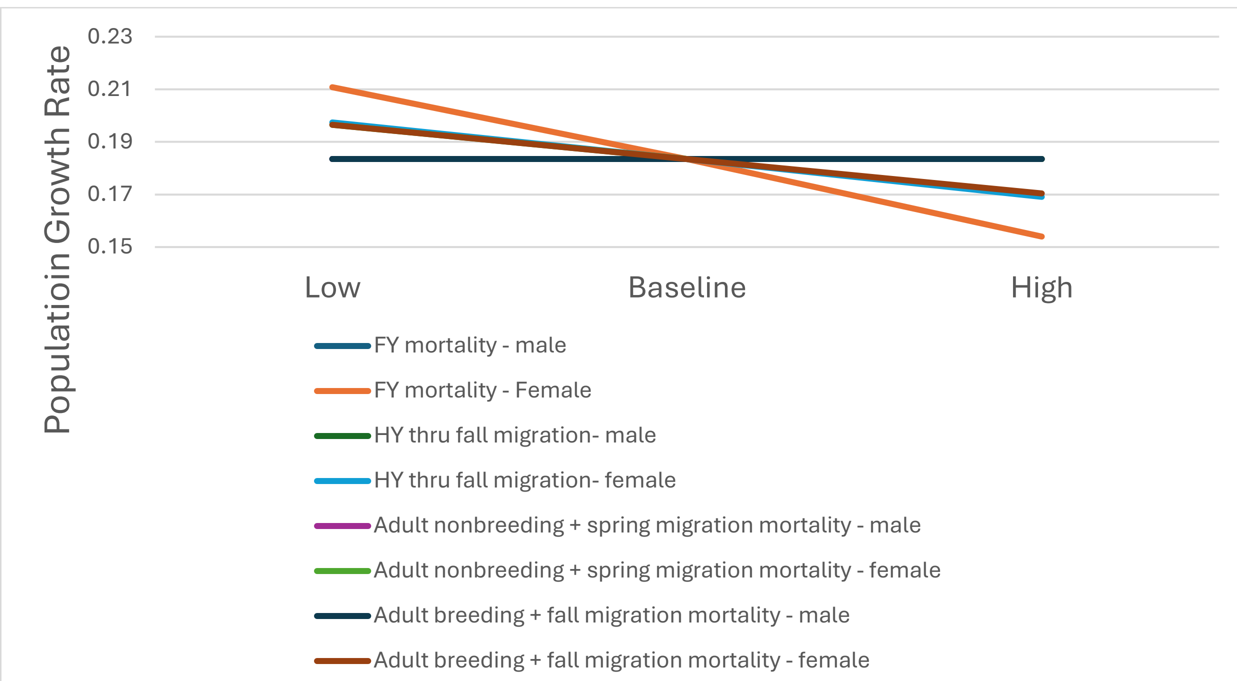

Figure 3. Results of sensitivity testing of mortality rates in the PVA model for loggerhead shrike. Values used for ‘low’, ‘baseline’ and ‘high’ rates are found in Table 1. The slope of the line indicates the sensitivity of the model to a specific parameter, with greater slope indicating greater change, or sensitivity in stochastic model population growth rate. Only female FY (fledged young), HY (Hatch Year) and breeding/migration rates impacted stochastic population growth rate. All other values had no impact, with a slope of 0, thus lines overlap.

Management Scenarios

In addition to using simulation models to test the impacts of our uncertainties in parameter estimates, we can use population viability analysis tools to assess the efficacy of potential management options and, therefore, to more effectively guide species action planning. *L. l. migrans* populations are currently largely restricted to eastern Ontario. Management actions for the species in these areas are largely focused on protecting and enhancing existing habitat, and, as the remaining populations are critically small, on augmentation of wild populations through release of hatch year birds from the conservation breeding facilities. The insurance population was founded in 1997/98. Releases of hatch year birds have been conducted annually since 2000, although this activity has varied in terms of methodology and location. Models were developed to address the following two management related questions:

- How can conservation breeding and release most effectively support the recovery of the species?
- What habitat is needed to meet the ‘recovered population’ goals?

Impacts of Supplementation

A set of models was developed to explore the impact of varying levels of supplementation, both with no change to current demographics characterizing the wild populations in Ontario and under a scenario of improved demographic rates in the wild population.

The current carrying capacity for the ex situ population, used in Miller’s (2023) model, is 76 individuals across all age classes ≥ one year of age. Three additional models were created representing scenarios in which the carrying capacity of the ex situ population was increased, allowing for great numbers of released birds, within feasible expansion rates. The scenarios are as follows:

Scenario 1. Carrying capacity of 144, which would be achievable if the existing 6 facilities increased their capacity to the equivalent of 3 “pods” (i.e. a species-specific facility design recommended for use in the *ex situ* population), each of which is capable of housing 8 shrike.

Scenario 2. Carrying capacity of 192 birds, required each of 6 facilities to increase to a total of 4 pods, or 8 facilities with 3 pods each.

Scenario 3. Carrying capacity of 288 birds, which would be obtained by having 9 facilities with 4 pods each.

In each scenario, 81.4% of all young produced were released. In doing so, it was noted that the number of birds retained was not sufficient to grow the ex situ population as required. Therefore, we revised the models to reduce the number of birds released, allowing for a short period of growth of the ex situ population. The length of the reduced release period in Scenario 1 was based on a growth rate of three new pods per year, which could be achieved by having each of the existing six breeding facilities adding a pod every other year, until they achieved the goals as noted above. In Scenario 2, we estimated the growth rate based on six breeding facilities eventually having four pods each. In Scenario 3, we assumed that three new conservation breeding centers would join the program, with each facility eventually housing 32 birds, in four pods.

Using the revised model input, four models were run for the Carden population, in which augmentation following ex situ population growth was again 81.4% of the total hatch year produced, over a 10-year period, as per Miller (2023). Results indicated that even though the Carden population could increase, similar to Miller’s (2023) results, when releases are terminated, the current demographic rates in recipient populations result in renewed declines in abundance (Figure 4) – in other words, underlying reproductive rates are not sufficient to overcome loss of individuals through mortality during the breeding and non-breeding season and during migration/dispersal.

Recognizing that as management actions are underway, and as sensitivity testing suggested that even modest improvement in a few key demographic rates would lead to population sustainability, we created additional models to explore the impact of augmentation under improved demographic rates. Additional models were created for the Carden population, one modelling the current *ex situ* population configuration (K = 96) and one in which the ex situ population carrying capacity was expanded (K = 192). For each of these, we changed demographic rates according to the data presented in Table 2.

Table 2. Improved demographic parameter estimates used to assess impact of population augmentation in a stable population of loggerhead shrike.

	% females breeding	Mean fledged young per clutch	Hatch year mortality
Improved reproduction (IMP_Repro Model_Carden)	80%	4	Same as baseline
Decreased mortality (IMP_Mort Model_Carden)	Same as baseline	Same as baseline	30%
Improved reproduction and decreased mortality (IMP_Both Model_Carden)	80%	4	30%

Results indicated that population trends would still decline following the cessation of population augmentation if management actions result only in improvement of either reproductive or mortality rates (Figure 4). However, an increasing population trend could be realized with relatively small improvement to both the key mortality and reproduction rates.

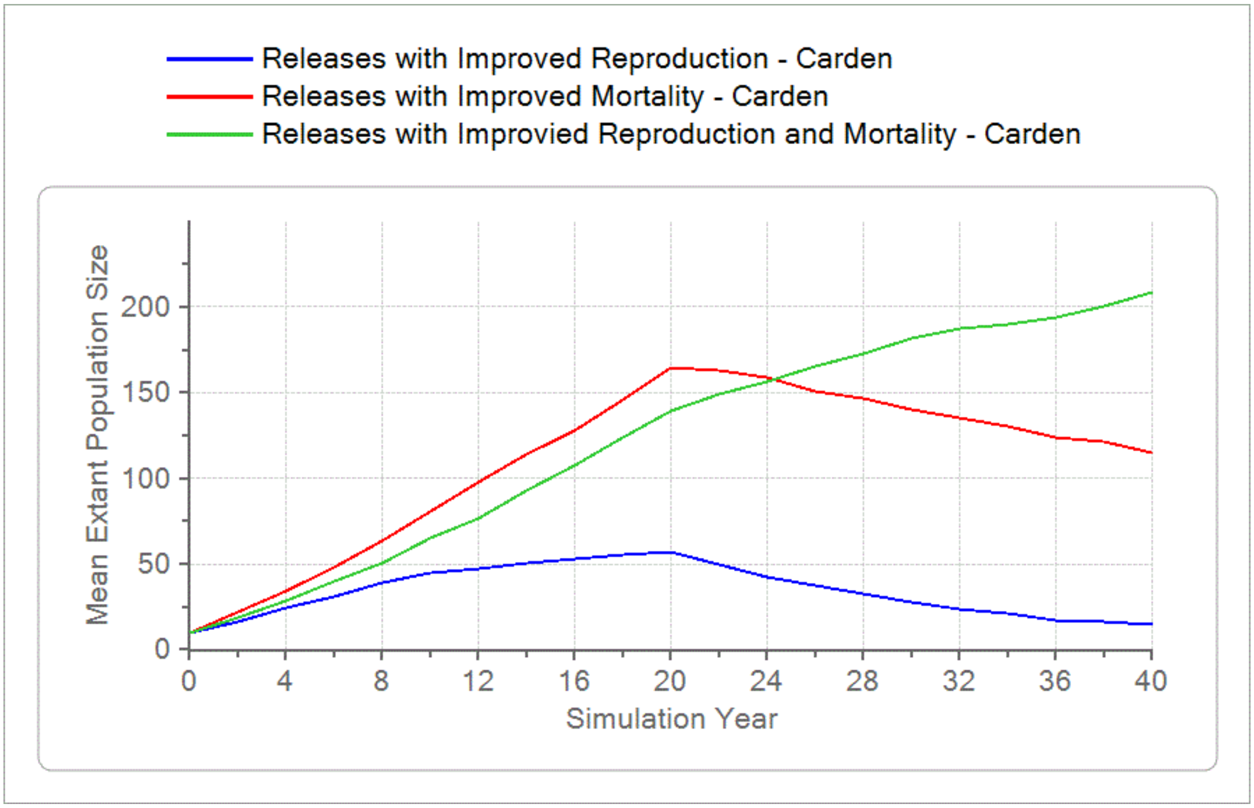

Figure 4. Mean extant population abundance trajectories for 40 years for the Carden population in the Releases with an ex situ population carrying capacity of n=76 with improved demographic rates in which percentage of females breeding has increased by 4%, mean fledged young is increased to 4 young/brood, and mortality of fledged young is 30%. See Table 1 for baseline demographic rates. Census data for autumn (odd-numbered) timesteps omitted for clarity.

Impacts of Carrying Capacity: How much habitat is enough?

Habitat management is the focus of recovery efforts for loggerhead shrike in Ontario. However, questions remain as to how much habitat is needed to sustain a viable population. To address this question and provide guidance on future habitat management activities, we developed additional models for the Carden population using the demographic parameters we found would lead to a stable population (% females breeding = 78%, mean fledged young/brood = 4, and mortality = 30%), and with alternative values for carrying capacity set to 25, 50, 150 or 300 individuals. We assume that this upper limit for K is achievable based on what is known about habitat availability and suitability in the core Ontario breeding areas.

Results indicate that the probability of population survival increases steadily with increasing carrying capacity (Figure 5). However, even at K=300, the probability of survival is still less than 50%, when the Carden population is modeled at the current initial population size (N=10). Results of scenarios investigating the impact of population size on probability of survival (see below), suggests that initial population size influenced results. Further modeling (not shown) using an initial population size of N = 50 (based on results below), with improved demographic rates as noted above, increased the probably of survival to near 100% for carrying capacities larger than K = 150.

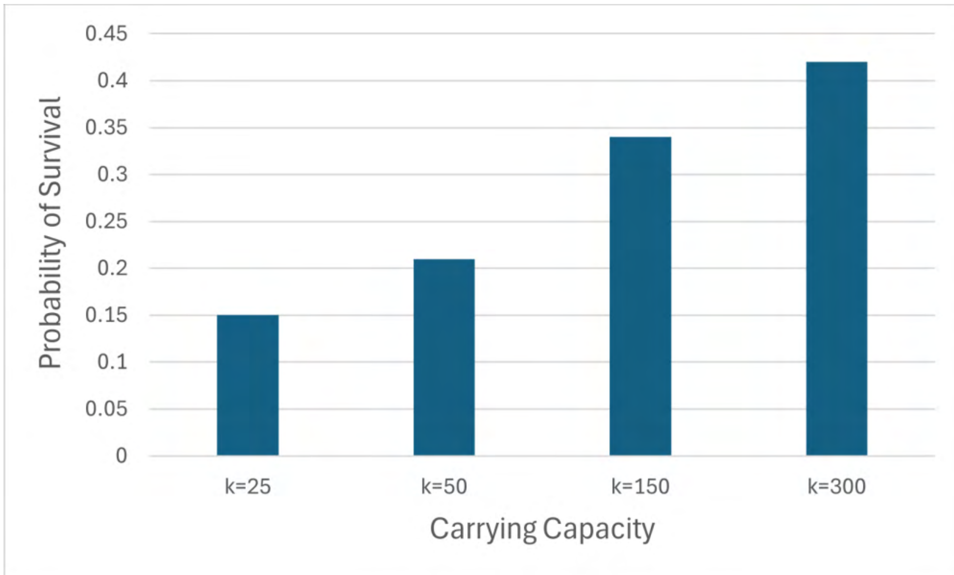

Figure 5. Probability of survival for the Carden population in relation to carrying capacity over 40 years in stochastic simulations of population growth using an initial population size of N=10 and demographic rates that, based on additional modelling, should yield a stable population growth rate (see text for further details).

Recovery Criteria: Using model output to guide species conservation planning

Sensitivity testing of the parameters in the baseline model can help identify what comprises a "recovered" or stable population of loggerhead shrike. Early in the species conservation planning workshop, participants developed a vision for loggerhead shrike in northeastern North America that stated "We envision self-sustaining populations of loggerhead shrike (*Lanius ludvicianus*) that ensure the long-term viability of *L. l. migrans* in suitable and restored habitat across the subspecies' historic range including breeding, migration, and wintering habitats. Local communities and industries celebrate and understand the birds as an important component of thriving, diverse grassland ecosystems that span public and private lands." Additional models were developed to further assist in identifying measurable recovery criteria. Simulations focused on addressing the two following questions:

- What comprises a "recovered" or stable or positive (lambda $\geq$ 1.0) population trend for loggerhead shrike?
- What is the minimum viable population size for loggerhead shrike in Ontario?

Participants used the information from the PVA as they worked to operationalize their vision. This effort was a step toward development of empirical estimates by which the success of conservation management actions could be measured.

What vital rates are needed to achieve a self-sustaining and viable population?

Using data from annual population surveys of the Ontario population (H. Wheeler, personal communication), Miller's (2023) model indicated a negative population growth trend across all populations. Management actions are underway to address the threats leading to the negative population trend and to improve vital rates. Models were run to identify the degree of improvement required to achieve a self-sustaining and viable population of loggerhead shrike, with a focus on vital rates that sensitivity analysis suggested were of greatest importance, including: 1) percentage of females breeding, 2) mean fledged young/brood, and 3) hatch year mortality. Parameters for all three factors were varied incrementally for all four Ontario populations until a combined rate was identified that resulted in a stable to positive population trend. Results suggested that increasing the percentage of females successfully breeding by 4% from baseline, increasing mean brood size by 0.5 fledged young/brood and decreasing mortality of fledged young to 30% from baseline (Table 1) would result in stabilized or increasing population trends in all wild Ontario loggerhead shrike populations (Figure 6).

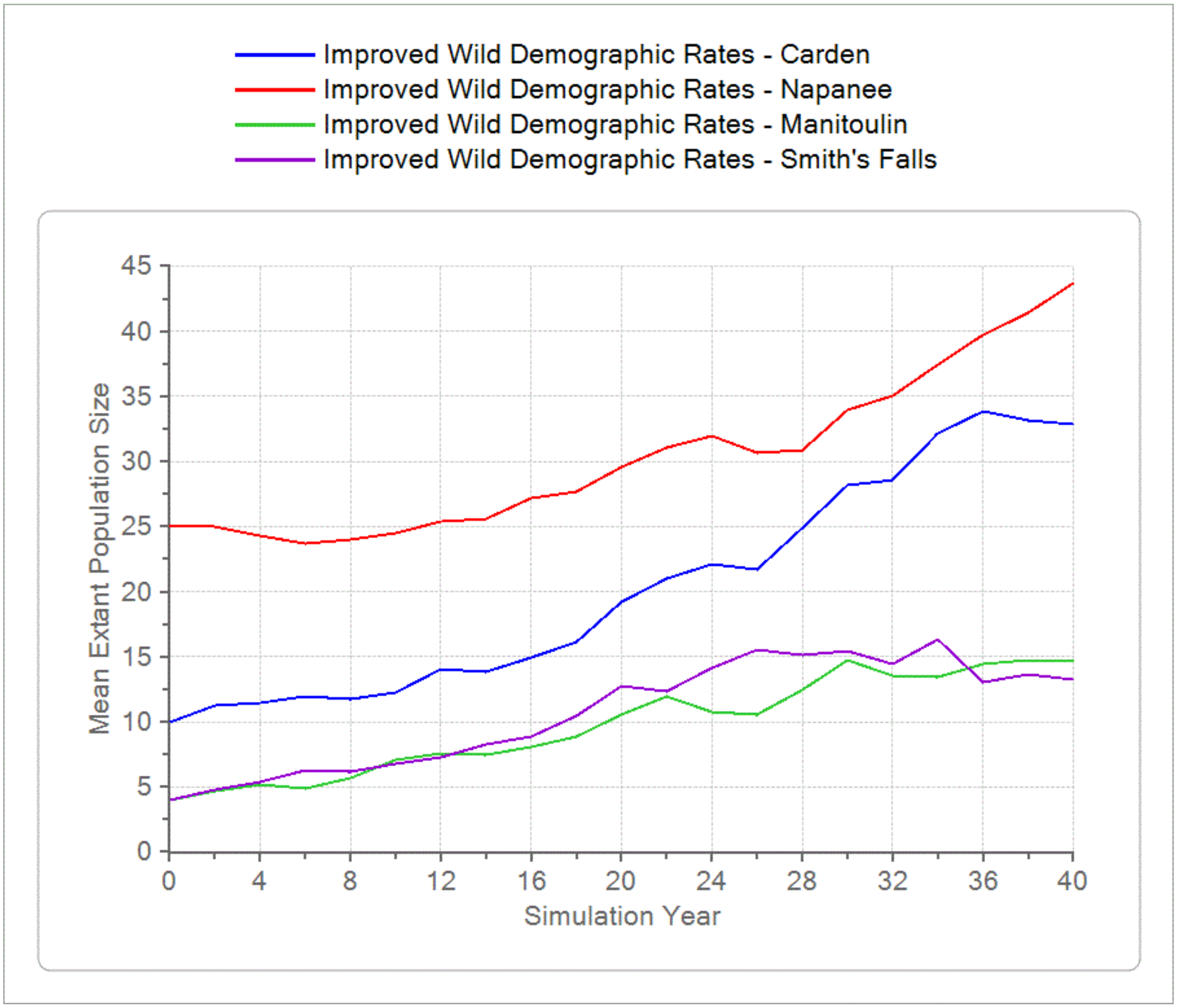

Figure 6. Mean extant population abundance trajectories for 40 years for the four Ontario populations with improved demographic rates, in which percentage of females breeding has increased by 4%, mean fledged young is increased to 4 young/brood, and mortality of fledged young is 30%. See Table 1 for baseline demographic rates. Census data for autumn (odd-numbered) timesteps omitted for clarity.

What is the impact of population size on population viability?

Smaller populations are expected to experience greater fluctuations due to various stochastic processes. If random processes are strong determinants of population dynamics, then smaller populations can decline faster and become extinct sooner than larger populations. A series of scenarios was developed to explore the impact of population size on extinction risk for loggerhead shrike. Nine scenarios were run for the Carden population, in which the initial population size was varied from N= 5 to N=150, with carrying capacity increased to K=750 for all scenarios. Results will provide guidance on the vulnerability of the currently small populations to stochastic events and help to set population targets.

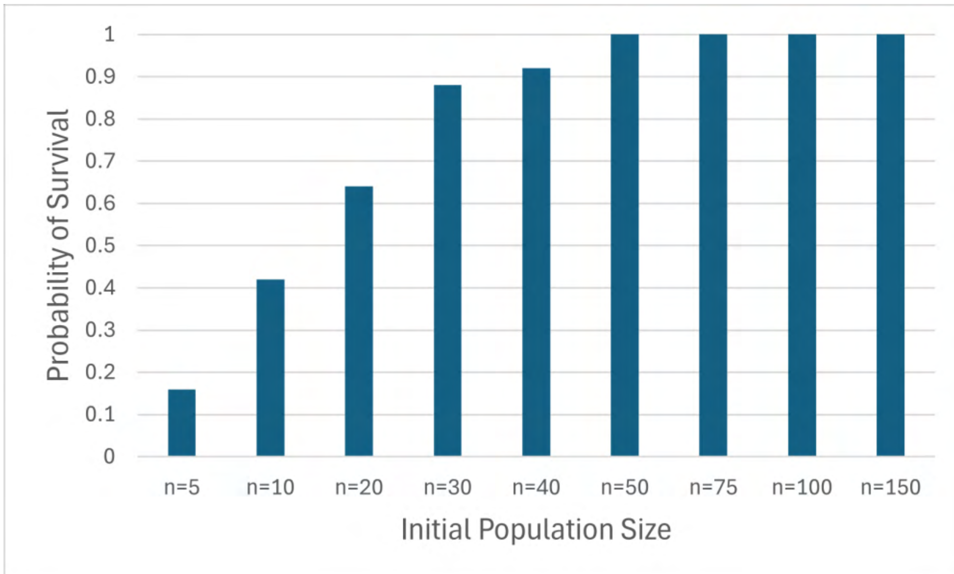

Figure 7. Probability of survival for the Carden population in relation to initial population size over 40 years in stochastic simulations of population growth using a carrying capacity of K=750 and demographic rates that, based on additional modelling, should yield a stable population growth rate (see text for further details).

Results indicated for populations with stable population trend, the average probability of survival over a 40-year time period was low for populations with initial population size less than 30, which is near to that currently in all four of the remaining areas in Ontario. However, probability of survival increases to 100% for populations of at least 50 individuals (Figure 7).

Important knowledge gaps

Given the results of this PVA, and after interpreting those results in the context of small population biology, the following factors were identified as the most important knowledge gaps for assessing the viability of loggerhead shrike. Addressing the following knowledge gaps will be important to identify threats, guide effective management strategies for conservation of this taxon and to improve the existing population viability model.

Population size: Estimates of population abundance and trends are important to both ensure simulation models accurately reflect a species status, but also, as presented in Miller (2023), to help validate models. In Ontario, an annual breeding population census is conducted for loggerhead shrike, but with a focus on the two areas (Napanee and Carden) where breeding birds can reliably still be found. In the USA, currently, breeding population estimates for loggerhead shrike can only be derived from the Breeding Bird Survey (BBS) at this time. BBS methods are likely not suitable for monitoring trends in this species as they are short, point-count auditory based surveys in randomly selected habitat. For Full Annual Cycle models, population abundance estimates would ideally be available for both the breeding and non-breeding season. While Christmas Bird Count (CBD) data can be used to help track trends in time during the non-breeding season, abundance estimates are hard to derive from this data set. Further, for any census method, estimates must account for detectability of a species – loggerhead shrike are known for being cryptic during certain periods in their breeding cycle (e.g. when females are incubating eggs). The existing colour-banded program can be used to address this gap, provided there is adequate banding and subsequent monitoring efforts, both of sites where birds were banded and surrounding habitat. Ideally this research should extend to included the breeding and non-breeding seasons where loggerhead shrike can be found year-round. Further, methods to quantify detectability need to be developed by which more accurate population estimates can be derived.

Demographic rates, especially mortality: Better understanding of loggerhead shrike age- and sex-specific mortality rates are required to improve viability projections and to inform management decisions. The colour-banding program can also be used to address this knowledge gap, given adequate monitoring over time, and ideally with improved detectability estimates.

Migration and Dispersal: The existing colour banding program has proven useful in identifying dispersing individuals and dispersal rates, and movements within and between the breeding and non-breeding grounds wintering grounds of banded shrike. However, return rates are inadequate to robustly determine the degree of dispersal among breeding populations and of migratory connectivity. Stable isotopes have proven useful to quantifying migratory connectivity in avian species and, to a lesser degree, estimates of connectivity among breeding populations, but working with small population sizes pose a challenge. A better understanding is needed regarding how shrike population size is regulated by dispersal of shrike of varying sex and age. This information will also help to quantify regional metapopulation structure and demographic rates.

Population and region-specific threats: Threats such as road mortality may differ among different habitats and shrike populations. It is important, both for viability projections and especially for improving the efficacy of management actions, to understand the type and level of threat for each population and region (i.e. metapopulation).

Conclusions

Conclusions from model results are as follows:

- Despite the uncertainty in demographic rates, population size, and the impact of various threats to loggerhead shrike, there is sufficient information available for PVA methods to provide useful information to help guide future research and potential management. Additional research to address key knowledge gaps will improve model utility.
- Sensitivity testing indicates that female hatch year mortality, adult female mortality, the percentage of females reproducing, and clutch size are the parameters to which the model is most sensitive, and thus likely where management actions would be most effective.
- Population augmentation can significantly improve population trends. However, until vital rates are improved through additional management actions, the long-term sustainability and viability of Ontario populations is at risk.
- Populations of 50 or more individuals will demonstrate greater resilience from environmental and demographic stochasticity.
- Management actions focused on improving carrying capacity will increase the likelihood of viability for populations.

The results of the simulation models have identified key demographic parameters that should be the focus of future research and monitoring, and to better identify threats and gauge the impact of conservation actions, including habitat management. Model results indicate that even small improvements to key demographic rates will significantly improve the sustainability and viability of loggerhead Shrike populations in eastern Canada and the United States.

Acknowledgements

This PVA model was developed in consultation with members of the North American Loggerhead Shrike Working Group, Wildlife Preservation Canada and the conservation breeding program partners (African Lion Safari, Nashville Zoo, National Aviary, Parc Omega, Smithsonian Conservation Biology Institute, Toronto Zoo). These PVA models and results will serve as a basis to evaluate potential management actions to increase loggerhead shrike viability and to evaluate recovery goals for this species in eastern Canada and the United States, and informed species conservation planning discussions in January 2024.

References

Lacy, R.C., Pollak, J.P. 2023. VORTEX: A Stochastic Simulation of the Extinction Process.

Miller, P.S. 2023. A Population Viability Analysis of the Loggerhead Shrike in Eastern Canada and the United States. Apple Valley, MN: IUCN SSC Conservation Planning Specialist Group.

Appendix E. Final SCP Workshop: Original Draft Agenda

Note: Exact schedule was revised as required to meet the needs of the workshop as it progressed.

Day 1: Tuesday, January 23

Aim: By end of day, we intend to have reviewed all previous Species Conservation Planning (SCP) work to date, presented additional information to inform action planning, prioritized where in the system to act, and drafted short-to mid-term goals (2024-2034).

Time (EST / CST)	Activity	Details	Lead
08:40 / 07:40	**Arrival period**	We will start promptly at 09:00 EST/8:00 CST – please arrive on time to help us get the most out of the day. Please make sure you check-in and pick-up a name tag when you arrive.	
09:00 / 08:00	**Presentation:** Welcome	Welcome Land Acknowledgement (for TZ), and introduction of Workshop Facilitation Team.	Jim Jessica
09:15 / 08:15	**Presentation:** Workshop process	Introduce a working agreement and explain workshop logistics.	Stephanie
09:35 / 08:35	**Presentation:** Review of planning work to this point	This presentation will provide a brief summary of planning work accomplished as part of the LOSH Species Conservation Planning process to date, i.e. key outcomes from previous CPSG steps including Vision and threat assessment. An overview of the 3 day workshop process and required outputs will be given, as well as an introduction to working group structure and responsibilities.	Jessica
09:55 / 08:55	**Presentation:** PVA results and implications for action planning	This presentation will summarize the key points emerging from the Population Viability Analysis (PVA) and model sensitivity testing.	Amy
10:15 / 09:15	**Open Discussion**	Questions and comments from presentations. *We will also seek volunteers to work with the Organizing Team in the evening to develop draft indicators of success for the Vision, and briefly describe the required task*	Jessica
10:30 / 09:30	**BREAK**		
10:50 / 09:50	**Presentation:** Species Distribution Modeling and available suitable habitat (Canada/US)	This presentation will summarize key points emerging from Species Distribution Modeling (SDM) work completed in recent years	Hazel/Amy
11:10 / 10:10	**Open Discussion**	Questions and comments from presentations.	Jessica

11:30 / 10:30	**Presentation: Where should we intervene?**	**Plenary presentation** to explain the process for prioritizing where to intervene and explain working group roles and responsibilities.	Jessica
12:00 / 13:00	**Developing our understanding of the system: Where should we intervene?**	**Working groups** will review available information and begin to assess where to intervene.	ALL
12:30 / 11:30	**LUNCH**		
13:30 / 12:30	**Developing our understanding of the system:** Where should we intervene?	**Working groups** will work on prioritizing where they want to intervene and prepare their presentation back to plenary.	ALL
14:45 / 13:45	**Presentation of working group results:** Where should we intervene?	**Plenary** presentations by each working group on the results of their discussion, followed by open discussion for questions and comments to be made by all groups.	Jessica/ Working Group (WG) reps
15:30 / 14:30	**BREAK**		
15:50 / 14:50	**Deciding where to intervene:** What are our goals?	**Plenary presentation** introducing the concept of goal development	Stephanie
16:05 / 15:05	**Deciding where to intervene:** What are our goals?	**Working groups** will spend time developing draft 2024-2034 goal statements, each composed of the change they want to affect and how they hypothesize this change will positively change the situation on the ground. How much change is required? Prepare presentations back to plenary	ALL
16:35 / 15:35	**Presentation of working group results:** What are we proposing as goals?	**Plenary** presentations by each working group on their draft goals. Participants can add their own ideas to the goals being developed by other groups and make recommendations as to what the priority goals should be.	Stephanie/ WG reps
17:20 / 16:20	**Summary and explanation of next steps**	Summary of the day's work, reflecting on priority areas for intervention and resulting draft goals. We will review the task of the "Vision indicators of success" development group (working tonight for ~1-1.5 hrs) and indicate what the focus will be tomorrow.	Jessica/Phil
17:30 / 16:30	**END OF DAY 1**		
Evening, Time TBD	**Indicators of success development group**	The volunteers will convene together online at an agreed time, with the Organizing Team to develop draft indicators of success to be shared on Day 2.	Phil

Day 2: Wednesday, January 24

Aim: By end of day, we intend to have agreed on the short- to mid-term goals (2024-2034) and identified how goals will be achieved.

Time (EST / CST)	Activity	Details	Lead
09:00 / 08:00	Process for today	Official start time – please arrive on time to help us get the most out of the day. After a summary of progress made on Day 1, the process and aim for today will be introduced.	Jessica
09:15 / 08:15	**Presentation of working group results:** draft indicators of success	A member of the group will present back the draft indicators of success with time given for comments from the broader group. The draft(s) will also be made available throughout the day for all participants to add any further thoughts to.	Vision indicators of success WG rep
09:45 / 08:45	**Deciding where to intervene, continued…**	**Plenary discussion** to identify any additional cross-cutting goals and assign to WGs to develop.	Stephanie
10:00 / 09:00	**Deciding where to intervene, continued…**	**Working groups** will finalize their clear goal statements for the interventions selected, including the desired change and how the change is predicted to positively impact the system and the species.	ALL
10:30 / 09:30	**BREAK**		
10: 50 / 9:50	**Presentation:** Goal ordering	**Plenary:** Discuss chronological ordering of goals for development during this workshop.	Stephanie
11:05 / 10:05	**Goals**	**Working groups** will organize goals into chronological order.	ALL
11:45 / 10:45	**A review of conservation interventions for LOSH:** What has been done to date and what can we learn?	This **Plenary presentation** will summarize the different approaches that have been used to date to reduce threats to LOSH in Ontario, including review of their performance and what can be learned. Insights from the new USGS publication on the effects of management practices on LOSH will be considered. There will be time for participants to add any additional experience with employed strategies. Brief explanation of the afternoon task will be given.	Hazel Jessica

12:30 / 11:30	**LUNCH**		
12:00 / 13:00	**Deciding how to intervene:** What approaches can we take to achieve your goals?	**Working groups** will map out the different approaches that could be taken to realize each goal and come up with their preferred strategy. Prepare presentation back to plenary. *Note: working groups may be re-organized into goal-based groups*	ALL
15:00 / 14:00	**Presentation of working group results:** What approaches could we take?	**Working groups** will present the results of their discussion on approaches to realize the goals, their preferred strategy with their reasoning behind this choice, followed by open discussion for questions and comments to be made by all groups.	Jessica/ WG reps
15:30 / 14:30	**BREAK**		
15:50 / 14:50	**Presentation:** Development of action statements	Explanation of SMART actions and review of action statement template	Stephanie
16:10 / 15:10	**Deciding how to intervene, continued…**	**Working groups** will continue to develop conservation approaches, incorporating feedback from other groups. Groups can begin to identify the most immediate actions that need to be taken, and the most significant actions, identifying other actions if time allows.	ALL
17:20 / 16:20	**Summary and explanation of next steps**	Summary of today's work and indication of focus for Day 3.	Jessica
17:30 / 16:30	**END OF DAY 2**		
		Potential optional visit to shrike facilities and/or other host zoo area	

Day 3: Thursday, January 25

Aim: By end of day, we intend to have produced a draft action plan, outlining the vision, indicators of success, goals, approaches and actions, identify what the next steps are in completing the action plan, and determine a leadership structure for moving implementation ahead.

Time (EST / CST)	Activity	Details	
09:00 / 08:00	Process for today	Official start time – please arrive on time to help us get the most out of the day. After a summary of progress made on Day 2, the process and aim for today will be introduced.	Jessica
09:15 / 08:15	**Specifying what is to be done:** What actions should we take, by whom and when?	**Working groups** will add detail under the approaches as necessary to achieve each goal. In addition to identifying and prioritizing actions, they will agree on responsibilities, create timelines, and identify means of verification for each key action using the provided action statement template.	ALL
10:30 / 09:30	**BREAK**		
10:50 / 09:50	**Presentation of working group results:** What are the specific actions to be undertaken?	**Working groups** present back the initial results of the actions they've identified to contribute to goal completion, followed by open discussion for questions and comments to be made by all groups.	Jessica/ WG reps
11:30 / 10:30	**Prepare to implement:** How do we move forward together?	**Plenary** discussion to agree on framework for how key individuals and organizations will communicate, coordinate, make decisions, and track and report on progress as they move forward together to implement the plan, and develop a schedule for progress reviews, and adaptation/revision of the strategy.	Jessica
12:30 / 11:30	**LUNCH - GROUP PHOTOS**		
13:30 / 12:30	**Specifying what is to be done, continued**	**Working groups** continue to work on the detailed actions they've identified to contribute to goal completion. Discuss and agree how group will complete this work/carry it forward.	ALL

14:45 / 13:45	**Draft action plan presentation preparation….**	WGs will prepare a draft PowerPoint presentation of the action plan, including vision, draft indicators of success, goals, strategies and actions, plus an overview of the proposed leadership structure to oversee implementation.	ALL
15:30 / 14:30	**BREAK**		
15:50 / 14:50	**Presentation: Draft Action Plan**	Working group representatives will work together to deliver a **plenary presentation** providing a full overview of the action plan so far	WG reps
16:35 / 15:35	**Celebrate! & Next Steps to Completion**	Celebrate our achievements over the last 3 days! Explain process for completing, commenting on and editing the plan and a timeline to publication. This will include explaining how participants can input into the draft plan as it is compiled.	Jessica
16:50 / 15:50	**Closing remarks & Post-workshop survey**		TBD
17:00 / 16:00	**END OF DAY 3**		

Appendix F. Threat Summary Tables for Canada and the United States

WHERE TO INTERVENE – CANADA

Threats	Manitoulin	Carden	Napanee	Smiths Falls	
Population Status (from PVA Report Table 2, Figures 4 & 5)	Tiny & inconsistent	Very small, declining	Very small, declining	Tiny & inconsistent	**Obstacles/challenges to implementation**
Threat Score Rank (from PVA Report Table 1; out of 14). *Represents relative aggregate threat score between ALL 14 LOSH populations.*	14	8	4	5	
Habitat loss					
Housing/cottage development					• Lack of awareness and/or interest (farmers, private landowners); • Variable landowner priorities; • Loosening of MBTA regulations
Recreational development (shooting range, golf, others?)					
Agricultural intensification (cash crops)					
Aggregate development					
Renewable energy development (solar, wind)					
Loss of active "rough" pasture					
Habitat degradation					
Conversion to suburban housing					• Lack of awareness and/or interest (farmers, private landowners); • Variable landowner priorities; • Persecution due to restrictions related to endangered species legislation; • Negative 'butcher bird' perception; • Research needed to develop habitat management techniques that consider trophic cascades, i.e. benefit shrike prey (e.g. grasshoppers); • Need for and effectiveness of supplemental feeding around nest sites is unknown
Reduction in / removal of nest shrubs					
Reduction in/removal of nest shrubs due to human persecution					
Native shrub encroachment	U				
Non-native shrub encroachment				U	
Incompatible management with other grassland bird species					
Catastrophic events					
Summer Natural weather event (storms, etc.)					
Interactions with motor vehicles					
Car/truck collisions					• Lack of awareness and/or interest (farmers, landowners, general public)

Predation of hatch year					
Free-roaming cats					• Lack of awareness and/or interest (farmers, landowners, general public); • LOSH difficult to detect: Quantifiable detection probability/survey methodology needed
Terrestrial wildlife (native) -- snakes, mammals					
Raptors / corvids (native)				U	
Depredation of nests/Nest Interference/Nestling mortality					
Free-roaming cats					• Lack of awareness and/or interest (farmers, landowners, general public)
Terrestrial wildlife (native) -- snakes, mammals					
Raptors / corvids (native)				U	
Presence of birders / photographers					
Anthropogenic debris (plastic baling twine, netwrap etc. - entangled nestlings)					• Lack of awareness and/or interest (farmers, landowners, general public)
Allee effect/Small populations					
Single birds can't find a mate; small populations more vulnerable to demographic stochasticity					• LOSH difficult to detect: • Quantifiable detection probability/survey methodology needed; • Female overwinter survival is research need; • Identifying proportion of males breeding is research need
Unknown threat level/knowledge gap					
Migration interference (migration mortality)					Drivers unknown; need to increase understanding of migration routes and causes of migration mortality; technology limitations
Dispersal mortality					Difficulty differentiating dispersal vs death; Poor understanding of individual movements & lack of suitable technology; local dispersal post-breeding (research need)
Inbreeding depression					Risk and impact unknown
Climate Change					Climate change impacts unknown (research need)
Disease epidemic					Population level impact of WNV unknown (research need)
Fire suppression (habitat loss/degradation)					Importance as driver unknown

Legend

	Severe -- contributes to very rapid population decline
	Moderate - contributes to rapid poplation decline
	Minimal - contributes to slow/negligible population decline
U	Indicated an unknown threat level in an empty cell, or some uncertainty in characterization if in red/yellow/green
na	Threat not applicable to this population

Additional challenges previously noted:

Difficult to distinguish migrants vs residents	Lack of field research funding
Difficult to reliably sex birds in hand	Lack of understanding of LOSH ecosystem services
Unable to access habitat-Land tenure/Breadth, etc	Knowledge gaps on threats at various scales

WHERE TO INTERVENE – US

Threats and mechanistic drivers	Coastal	VA Piedmont	Virginia Valleys	Appalachian Plat.	IL - IN	KY	Central TN	West KY - TN	MO-AR	North IL	Obstacles/challenges to implementation
Population Status (from PVA Report Table 2, Figures 4 & 5) <u>**ALL POPULATIONS ARE DECLINING</u>	Very Large	Small	Small	Small	Small	Small	Med	Med	Very Large	Med	
Threat Score Rank (from PVA Report Table 1; out of 14). *Represents relative aggregate threat score between <u>ALL 14</u> LOSH populations.*	13	12	7	11	**1**	9	6	10	**3**	**2**	
Habitat loss											
Housing/cottage development											• Lack of awareness and/or interest (farmers, private landowners); • Variable landowner priorities; • Loosening of MBTA regulations.
Recreational development (shooting range, golf, others?)											
Agricultural intensification (cash crops)		na									
Aggregate development											
Renewable energy development (solar, wind)											
Loss of active "rough" pasture (breeding season)		na									
Loss of active "rough" pasture (winter)		U								na	
Habitat degradation											
Conversion to suburban housing											• Lack of awareness and/or interest (farmers, private landowners); • Variable landowner priorities; • Persecution due to restrictions related to endangered species legislation; • Negative 'butcher bird' perception; • Research needed to develop habitat management techniques that consider trophic cascades, i.e. benefit shrike prey (e.g. grasshoppers); • Need for and effectiveness of supplemental feeding around nest sites is unknown
Incompatible grazing rotation			U		U						
Reduction in / removal of nest shrubs											
Road improvements (widening, ditch cleaning)										U	
Native shrub encroachment										U	
Non-native shrub encroachment										U	
Incompatible management with other grassland bird species		U	U	U							

WHERE TO INTERVENE – US

Fluctuating / declining prey abundance limiting food availability											
Climate change impacting timing and abundance of invertebrate prey / Natural and anthropogenic climate change resulting in fluctuations / Direct effect on prey abundance due to climate change	U	U	U		U						• Climate change impacts on invertebrates and its importance to LOSH unknown (research need)
Interspecific competition (e.g., American kestrels)								U		na	
Catastrophic events											
Summer Natural weather event (storms, etc.)		U	U								
Winter Natural weather event (storms, etc.)										na	
Disease epidemic	U	U		U	U		U	U			• Population level impact of WNV unknown (research need)
Interactions with motor vehicles											
Car/truck collisions											• Lack of awareness and/or interest (farmers, landowners, general public)
Predation of adults/overwintering											
Free-roaming cats		U	U	U	U	U	U	U		U	• Lack of awareness and/or interest (farmers, landowners, general public); • LOSH difficult to detect: Quantifiable detection probability/survey methodology needed; • Female winter survival (research need) • Predation risk in US largely unknown (what species & magnitude of problem) (research need)
Terrestrial wildlife (native) -- snakes, mammals		U	U	U							
Raptors / corvids (native)		U	U	U				U			
Predation of hatch year											
Free-roaming cats					U					U	• Lack of awareness and/or interest (farmers, landowners, general public); • LOSH difficult to detect: Quantifiable detection probability/survey methodology needed • Predation risk in US largely unknown (what species & magnitude of problem) (research need)
Terrestrial wildlife (native) -- snakes, mammals				U		U	U	U			
Raptors / corvids (native)											

WHERE TO INTERVENE – US

Depredation of nests/Nest Interference/Nestling mortality											
Free-roaming cats					U						• Lack of awareness and/or interest (farmers, landowners, general public)
Terrestrial wildlife (native) -- snakes, mammals											
Raptors / corvids (native)								U			
Presence of birders / photographers											
Anthropogenic debris (plastic baling twine, netwrap etc. - entangled nestlings)					U					na	• Lack of awareness and/or interest (farmers, landowners, general public)
Interactions with industrial chemicals											
Herbicide application along fencerows	U	U	U	U	U	U	U	U		U	• Lack of knowledge of impact of insecticides (research need)
Pesticide application to limit agricultural pests	U				U						
Direct effect on prey abundance due to pesticide application					U						
Allee effect/Small populations											
Single birds can't find a mate; small populations more vulnerable to demographic stochasticity						U					• LOSH difficult to detect: Quantifiable detection probability/survey methodology needed; • Female overwinter survival is research need; • Identifying proportion of males breeding is research need
Unknown threat level/knowledge gap											
Inbreeding depression											Risk and impact unknown
Migration interference (migratory populations)											Drivers unknown; need to increase understanding of migration routes and causes of migration mortality; technology limitations
Dispersal mortality											Difficulty differentiating dispersal vs death; Poor understanding of individual movements; Lack of suitable technology to track individual movements; local dispersal post-breeding is research need

Legend

	Severe -- contributes to very rapid population decline
	Moderate - contributes to rapid poplation decline
	Minimal - contributes to slow/negligible population decline
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Additional challenges previously noted:

Difficult to distinguish migrants vs residents	Lack of field research funding
Difficult to reliably sex birds in hand	Lack of understanding of LOSH ecosystem services
Unable to access habitat-Land tenure/Breadth, etc	Knowledge gaps on threats at various scales

Appendix G. Action Plans for Canada and the United States

Acronyms

ACC	Animal Care Committee
ALS	African Lion Safari
AR	Anthelmintic Resistance
AZAPMC	Association of Zoos and Aquariums Population Management Center
BECO	Bird Ecology and Conservation Ontario
BTR	Breeding and Transfer Recommendations
C-SWG	U.S. Fish and Wildlife Service's Competitive State Wildlife Grant Program
CSC	Captive Subcommittee
CWS	Canadian Wildlife Service
DVM	Doctor of Veterinary Medicine
ECCC	Environment and Climate Change Canada
ENGOs	Environmental Non-governmental Organizations
FEC	Fecal Egg Count
HY	Hatch Year
MECP	Ministry of the Environment, Conservation and Parks
MNRF	Ministry of Northern Development, Mines, Natural Resources and Forestry
NCC	Nature Conservancy of Canada
NHIC	Natural Heritage Information Centre
NRCS	Natural Resources Conservation Service (United States Department of Agriculture)
OFO	Ontario Field Ornithologists
OSSGA	Ontario Stone, Sand and Gravel Association
WHISPer	Wildlife Health Information Sharing Partnership-event reporting system
WMI	Wildlife Management Institute
WPC	Wildlife Preservation Canada

Canada

Working group members:

- *In situ* (Strategies 1, 3-6): Mike Burrell (OFO), Drew Suave (UQAM/ALS), Hazel Wheeler (WPC), Helmi Hess (WPC), Jordan Howard (NCC)
- *Ex situ* (Strategy 2): Jane Spero (WPC), Jon Spero (Toronto Zoo), Vicky Carriere (Parc Omega), Audrey Pilon (Parc Omega), Andrea Morgan (ALS), Gareth Morgan (ALS), Joe deGraauw (Nashville Zoo)

Table G1. The 10-year Action Plan for eastern loggerhead shrike (*L. l. migrans*) in Canada including goals, recommended strategies, medium-term objectives, and required actions.

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
Goal: Increase population size to 25 pairs in both Carden and Napanee in order to decrease vulnerability to demographic stochasticity and minimize Allee effect.										
Strategy 1: Improve *in situ* loggerhead shrike population demographics										
Objective 1.1: Develop effective nest protection methods to increase the number of fledged young per nest										
a) Research nest protection methods that have been used for bird species and assess their effectiveness.	WPC (Helmi Hess)	0-6 months	Understandin g nest protection methods available for piloting with shrikes nests	LOSH WG	Compiled information in nest protection methods document	n/a	-	Staff time	Email to LOSH Recovery Team, LOSH WG	
b) Solicit feedback on identified methods from loggerhead shrike networks	WPC	Year 1	Agreement on which nest protection method(s) to pilot	LOSH Captive Sub-Committee, LOSH WG, researchers of other LOSH subspecies (western Canada?)	Meeting minutes or email agreement	No consensus on best method(s)	Effective methods exist from *Action Statement 1*	Staff time	Email or possible virtual meeting	
c) Implementing best option as a pilot project	WPC, other organizations undertaking	Breeding season 2025/ annually	Known LOSH nests receive protection;	Landowners, MECP (Joe Crowley),	Reduction in nest failures in situ	Permit acquisition, cost, nest suitability/	Success of *Action Statements 1* and *2*	Unknown until best method is determined	LOSH Working Group meeting,	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
	LOSH field research		possible manuscript	ECCC, CWS (John Brett)		accessibility, staffing			possible publication of results	
d) Adapt methods based on results of pilot	WPC, other organizations undertaking LOSH field research	Annually (once program implemented)	Improvements to nest protection pilot program, permanent program implementation	LOSH WG	Incorporation into relevant field protocols	Permit acquisition, cost, nest suitability/ accessibility, staffing	Success of *Action Statements 1-3*	Unknown, staff time	LOSH Working Group meeting, possible publication of results	
Objective 1.2: Deliver education and outreach to mitigate direct threats to survival and reproduction, e.g. nest predation, nest disturbance, road mortality, anthropogenic waste										
a) Compile resources available through organizations related to loggerhead shrikes (breeding range, habitat requirements, threats to survival), and note how they're currently distributed.	WPC	Year 1	Creation of a library of existing outreach resources	NCC, Couchiching Conservancy, breeding facilities	See Outcome	n/a	n/a	Staff time	Email/directly in drive	Resources will need updates with current info
b) Identify new streams for dispersal of information to potentially new audiences.	WPC, NCC, OFO	Year 1	Compiled list of new places/ways to educate the public about LOSH	Breeding facilities, local community groups, nature/interpretive centers, schools, businesses	See Outcome	n/a	n/a	Staff time, travel expenses, printing costs	Email	Social media? Outreach events (not shrike specific)? Interpretive signs in high traffic areas? QR codes? Flyers/brochures at local businesses /libraries/ community centers/farm cooperatives?
c) Implement outreach/education plan to capitalize on identified streams.	WPC, NCC, OFO	Year 2	Prepared outreach package to disperse educational information to new audiences.	Breeding facilities, local community groups, nature/interpretive centers, schools, businesses	Compiled education/outreach package	Unwillingness of potential collaborators	n/a	Staff time, travel expenses, printing costs	Email	-

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
Objective 1.3: Develop contingency plans to mitigate effects of catastrophic events, integrated across *in situ* and *ex situ* populations										
a) Identify potential catastrophes that could affect shrike populations (e.g. extreme heat, tornadoes, economic uncertainty, etc.).	WPC	0-3 months	Full understanding of possible catastrophes to include in contingency planning	Ex situ breeding facilities, LOSH Working Group	Compiled list/table of catastrophes that affect LOSH *(migrans)*	n/a	n/a	Staff time	Email to LOSH Working Group/Captive Sub-committee meetings	
b) Research catastrophe mitigation techniques used by other researchers/programs.	WPC (Jane Spero, Helmi Hess)	Year 1	Understanding of which catastrophes can be mitigated and how	*Ex situ* breeding facilities, LOSH Working Group, other SAR bird researchers	Compiled list/table of catastrophe mitigation techniques	Lack of communication/response	Existence of previous catastrophe mitigation techniques	Staff time	LOSH Working Group/Captive Sub-committee meetings	
c) Write a contingency plan, including details on necessary permits for proposed actions.	WPC, Breeding facilities	Year 2	Written methods for catastrophe mitigation	LOSH Working Group, MECP, ECCC CWS	Written contingency plan	Permit requirements, cost, feasibility of implementation	n/a	Staff time/ Unknown	LOSH Working Group/ Captive Sub-Committee meetings	
d) Disseminate plan to appropriate parties.	WPC	Year 2	Integration of contingency plan in appropriate protocols	LOSH Working Group, *Ex-situ* breeding facilities	n/a	n/a	n/a	Staff time	Email	
e) Implement contingency plans as necessary and adapt methods based on results	*In Situ* and *Ex Situ* Research/Breeding Teams	Year 2, annually	Mitigation of catastrophes *in situ* and *ex situ*	n/a	Season/Year End Reports for WPC, breeding facilities, other researchers	Permit requirements, cost, feasibility of implementation	n/a	Unknown	LOSH Working Group/ Captive Sub-Committee meetings, email	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
Objective 1.4: Use effective conservation breeding and release methods to maximize hatch-year survival and recruitment										
a) Periodic review of existing research on best practices for conservation breeding and release.	WPC, Captive Sub - Committee	Annual	Updated knowledge to integrate into protocols	Other LOSH researchers and conservation breeding program organizations (e.g. San Clemente LOSH Program)	Compiled information on most current conservation breeding and release practices	n/a	n/a	Staff time	Captive Sub-Committee meeting, email	
b) Incorporate research into protocols	WPC, Captive Sub - Committee	Year 1, as updates are required	Best practices are utilized	Breeding facilities, Couchiching Conservancy, NCC	Season/Year End Reports for WPC, breeding facilities, other researchers	Cost, staffing, catastrophes, feasibility, unforeseen circumstances, permit requirements	n/a	Unknown	Email, Meeting with relevant parties	
Objective 1.5: Collaborate with U.S. researchers to maintain knowledge transfer and further full annual cycle conservation measures (NOTE: refer to Strategy 6)										
a) Maintain active Canadian participation in the Loggerhead Shrike Working Group	WPC, Amy Chabot, Drew Sauve, Alisa Samuelson	Monthly meetings	Awareness of and collaboration across all eastern LOSH research and conservation efforts	LOSH WG	Canadian presence at meetings	Individual availability (especially during field season)	Continuity of Working Group meetings	Staff time	Email/LOSH WG meetings	
b) Identify other working groups that could be beneficial to LOSH conservation, and ensure Canadian representation as appropriate	WPC, Drew Sauve	Year 1, annually or as needed	Involvement in new working groups or research networks	LOSH WG (esp. Amy Chabot and Alisa Samuelson)	Participation in meetings, contact by email	No appropriate groups to join, lack of interest in LOSH participants	n/a	Staff time	Email	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
Strategy 2: Improve *ex situ* release numbers										
Objective 2.1: Fill available holding spaces at existing partner facilities to increase number of birds in *ex situ* population										
a) Contact existing conservation breeding facilities to confirm number and quality of available holding spaces	WPC	0-6 months	Current and accurate list of available spaces at existing facilities; indications of any spaces that are in need of repair	Ex situ partner facilities	Compiled list	n/a	n/a	n/a	Email, holding status of captive population in annual report	
b) Increase retention numbers of HY birds at current conservation breeding facilities to fill available spaces	WPC (Jane Spero), AZAPMC (Colleen Lynch)	Year 1; annually	Current breeding facilities are filled to capacity	*Ex situ* partner facilities	Regular annual reports on status of population (Recovery Team report)	Age/experience of current *ex-situ* population affecting successful clutches and number of birds reared	No change in number/quality of holding spaces at existing facilities, no changes to staffing/ resources needed to house birds at existing facilities	$3 dollars CAN/day/bird (calculation made by Parc Omega)	Regular annual reports on status of population (Recovery Team report)	
Objective 2.2: Increase holding capacity at current facilities to allow for greater retention of hatch-year birds										
a) Compile current cost estimates for the construction of a breeding/ overwintering shrike 'pod'	Parc Omega	0-6 months	Updated price and materials list for the construction of one pod for distribution to existing (and new) partner breeding facilities	Jane Spero (WPC; to facilitate distribution of materials)	Document available for distribution	Staff time, changing material prices	n/a	Staff time	Email; Captive Subcommittee (CSC) Meeting; file made available in shared Google Drive	
b) Identify and contract draftsperson to develop breeding/ overwintering	WPC (Jane Spero), Parc Omega	Year 1	'Pod' blueprints made available for distribution to	Ex situ partner facilities	'Pod' blueprints made available for distribution to existing/new	Funding	Finding draftsperson interested in providing in-kind work	Staff time, cost for work if not provided in-kind	Email; CSC Meeting; file made available in shared	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
shrike 'pod' blueprints			existing/new partner facilities		partner facilities				Google Drive	
c) Identify and secure funding sources for the construction of additional breeding/ overwintering shrike 'pods'	*Ex situ* partner facilities	Year 2-3	Funding secured by at least one facility for the construction of 1+ 'pod'	WPC	Annual report	Limited funding sources available, grant applications denied	Funding sources can be found	Staff time	Email, CSC meeting, annual RT report	
d) Construct breeding/ overwintering 'pods' at existing facilities	*Ex situ* partner facilities	Year 4-5	Construction of 1+ 'pod' completed at least one existing conservation breeding facility	WPC	Annual report	Action 3 is completed (funding secured); limited staffing and contractor time	*Ex-situ* population robust enough to fill new spaces once available (adequate numbers of fledglings produced to retention)	Staff time	Email, CSC meeting	
Objective 2.3: Recruit new conservation breeding facilities to increase available breeding spaces and number of birds in *ex situ* population										
a) Create welcome package with necessary materials for onboarding a facility	WPC (Jane Spero)	Year 1	Welcome package completed and made available to future breeding partners/ interested breeding partners	Parc Omega	Document available for distribution	Staff time; timeline for completion of 'pod' cost estimates and blueprints (see actions 2.1, 2.2)	n/a	Staff time	Email, CSC meeting; document to be made available in Google Drive	
b) Establish regular communication and involvement with Granby Zoo (potential future breeding facility)	WPC	Year 2-ongoing	Increased involvement from Granby Zoo in LOSH Recovery Program	Parc Omega	Granby Zoo attendance at Captive Subcommittee meetings, Recovery Team meetings	Timeline for onboarding unclear	Sustained interest in the program from Granby Zoo	Staff time	Email, CSC meetings	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
c) Contact interested facilities (Carolina Raptor Centre, Safari Niagara) to determine feasibility of joining conservation breeding program	WPC	Year 2	Strengthened understanding of the suitability of interested facilities	n/a	Annual report	Staff time	n/a	Staff time	CSC meeting, annual report distribution	
d) Onboard new facilities with 'welcome package' (required materials for 'pod' construction, housing birds, and active involvement in CSC activities)	WPC	Year 3-4	New facilities are briefed for joining program	n/a	Annual report	Staff time; timeline for completion of actions 2.1, 2.2	n/a	Staff time	CSC meeting, annual report distribution	
e) Onboard new facilities with established breeding pairs	WPC	Year 5	New facilities house successfully established pairs and contribute to annual release numbers	Existing facilities transferring birds	Annual report	Staff time; timeline for enclosure completion at new facilities	No major change in facility funding for the program, *ex-situ* population is robust enough for new facility to acquire birds	Staff time, cost of program (food for species, 'pod' hydro, etc.)	CSC meeting, annual report distribution	
Objective 2.4: Identify and implement effective mate pairing methods to increase *ex situ* pair success and number of fledged young per nest										
a) Research parameters and criteria involved in keeping established pairs together (weighing against mean kinship) in other conservation breeding and release programs	WPC	0-6 months	Better understanding of parameters involved to take mate choice into consideration in similar conservation breeding and release programs	n/a	Literature review completed	Staff time	n/a	Staff time	Findings discussed at fall CSC meeting	Discussed at SCP meeting: - Keeping pairs together for 3 or more years to gain experience - Do pairs get kept together after one or two unsuccessful years?

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
b) Discuss findings and solicit feedback on how established pairs should be prioritized in annual breeding and transfer recommendations (BTRs) during fall CSC meeting	WPC, AZAPMC (Colleen Lynch), Captive Subcommittee members	Year 1	Agreement on parameters involved in prioritizing established pairs	n/a	CSC minutes; annual report/BTRs/ studbook report	Staff time to complete action 1	Action 1 is completed; time in meeting to devote to subject	n/a	CSC minutes	-
c) Implement new criteria for keeping established pairs together; adapt methods based on results	WPC; *Ex situ* partner facilities	Year 2-ongoing	Established pairs are prioritized; fewer annual re-pairings necessary, fewer spring transfers	AZAPMC (Colleen Lynch)	Incorporation into annual BTRs/studbook reports	Inbreeding in captive population affected	Mean kinship/ inbreeding coefficients not affected	n/a	Annual BTRs/studbook report	-
d) Research extended breeding windows (early introductions, later breeding cut-offs) that have been used in similar conservation breeding and release programs and assess effectiveness.	WPC	Year 1	Better understanding of feasibility of extended windows; proposed plan for implementation if feasible	WPC	Literature review completed; evidence gathered on effectiveness of extended breeding windows	Staff time	n/a	Staff time	CSC meeting	Discussed at SCP workshop: - Possible pro: young/ inexperienced pairs have more practice with nest construction, re-nesting - Could use dummy eggs at tail end of season if necessary
e) Discuss findings and solicit feedback on extended breeding windows during spring CSC meeting	WPC	Year 1-2	Agreement on next steps for extending breeding windows	WPC	CSC minutes; annual report/ incorporation into husbandry manual	Staff time	Action 4 is completed; time in meeting to devote to subject	Staff time	CSC minutes	-
f) Implement extended breeding window	WPC, *Ex situ* partner facilities	Year 2-ongoing	Younger/ inexperienced pairs have	n/a	Annual report; incorporation	BTRs are not distributed in time	Transfers have taken place by early spring; all	n/a	CSC meetings,	-

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
methods; adapt methods based on results			more practice with nest construction, re-nesting, greater production of young		into husbandry manual	for spring transfers to take place	birds able to be introduced on time; spring treatments have taken place in time for introductions		annual report	
g) Research clutch swapping methods and assess effectiveness for LOSH conservation breeding and release program	WPC (Jane Spero)	Year 2	Better understanding of feasibility of clutch swaps; proposed plan for implementation if feasible to discuss at CSC meeting	n/a	Literature review completed	n/a	n/a	Staff time	Annual report, CSC meeting	Discussed at SCP meeting: - Switching eggs from less experienced pairs for more experienced pairs to foster - *In situ*/*Ex situ* clutch swapping to strengthen genetics in captive flock
h) Discuss findings and solicit feedback from CSC members on feasibility of implementing clutch swapping methods	WPC, *Ex situ* partner facilities	Year 2	Agreement on clutch swap methods to implement	*Ex situ* partner facilities/CSC	CSC minutes; annual report/ incorporation into husbandry manual	Staff time	Action 8 is completed; time in meeting to devote to subject	Staff time	CSC minutes	-
i) Implement clutch swapping methods; adapt methods based on results	WPC, *Ex situ* partner facilities	Year 3-ongoing	Reduction in fledgling mortality; higher annual fledgling production	n/a	Annual report; incorporation into husbandry manual	Staff time/increased workload	-	Staff time	CSC meetings; annual report	-
j) Revisit and discuss the feasibility of initiating a pairing centre facility (African Lion Safari) to reduce number of annual interfacility and international	ALS, *Ex situ* partner facilities	Year 3-4	Increased understanding of feasibility of designating an established dating centre; plan in place for next steps (if any)	WPC	CSC minutes; annual report	- Transfer timeline of established pairs to breeding facilities would truncate breeding window/post-pairing transfer disrupts breeding - Limited available space at ALS	Established pairs remain together (established females/males are not re-paired when considering mean kinship/other)	Staff time	CSC minutes, annual report	Discussed in SCP meeting: - Established pairing centre would ensure Conservation Breeding Facilities have fewer spring transfers to contend with

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
transfers at CSC meeting						- Not enough established pairs to remain at facilities - Age/experience of *ex situ* population				
Objective 2.5: Identify and implement effective husbandry methods to decrease mortality events in the *ex situ* population										
a) Investigate methods for assessing anthelmintic resistance (AR) and alternative Capillaria treatment in *ex-situ* population	Christina Tschritter (ALS), Jane Spero (WPC)	0-6 months	Work plan in place to identify any AR in captive pop; draft plan to trial proposed alternative treatment methods	Toronto Zoo (Nic Masters, Jon Spero), African Lion Safari (Amy Chabot, Gareth Morgan)	Draft recommended work plan for fecal collection and AR assessment trial, Animal Care Committee applications completed	Staff time	Animal Care Committee (ACC) approves applications at Toronto Zoo and African Lion Safari for trial in fall	Staff time, cost and acquisition of Mini-FLOTAC FEC kits	Email, ACC application completed	Discussed in SCP workshop: - Investigate how substrate types affect Capillaria levels
b) Conduct retrospective analysis on mortality events in *ex situ* population to gain a better understanding of trends related to Capillaria, Vitamin A deficiency	Christina Tschritter (ALS), Jane Spero (WPC), Drew Sauve (Queen's), Amy Chabot (ALS)	0-6 months	Increased knowledge of mortality trends seen in Captive population	Jordan Whitaker (DVM)	Draft manuscript in-hand for publication; increased knowledge of mortality trends seen in Captive population	Staff time/ workload	Staff workload allows for manuscript to be completed within proposed timeline	Staff time	Email, Annual report	-
Objective 2.6: Improve existing field enclosures and expand release capacity of existing release sites to maximize number of juveniles released										
a) Repair existing release enclosures at field sites	WPC (Jane Spero, Helmi Hess)	0-6 months, ongoing	Existing release enclosures are sound and fit for large release groups and inclement weather	Nature Conservancy of Canada, Couchiching Conservancy	Annual report	Staff time, limited budget for materials	Sufficient time in staff workload to devote to enclosure repair	Staff time, cost of materials needed for repairs	Details included in annual reports	
b) Identify appropriate	WPC	Year 4+	1+ locations are identified	Nature Conservancy	Annual report	Staff time	n/a	Staff time, mileage	Details included in	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
locations (level ground, 1-2 mid-sized hawthorn/cedar bushes, etc.) for new release enclosures on existing field release sites			in each release site	of Canada, Couchiching Conservancy					annual reports	
c) Identify and secure funding sources for the construction of additional release enclosures	WPC	Year 4+	Funding secured for 1+ triple-unit release enclosure at both release sites	Nature Conservancy of Canada, Couchiching Conservancy	Annual report	Limited funding sources available, grant applications denied	Funding sources can be found	Staff time	Email, CSC meeting	
d) Construct triple-unit release enclosures at existing breeding sites	WPC	Year 4+	Construction of 1+ triple-unit release enclosure completed at one-both release sites	Nature Conservancy of Canada, Couchiching Conservancy	Annual report	Action 3 is completed (funding secured); limited staffing and contractor time	*Ex-situ* population robust enough to fill new spaces once available (adequate numbers of fledglings produced to release)	Staff time	-	
Objective 2.7: Recruit birds from the wild population to improve *ex situ* population demographics										
a) Discuss with Captive Subcommittee and Colleen Lynch to produce plan for wild recruitment (evaluate possible scenarios, decide which is feasible)	WPC, AZAPMC (Colleen Lynch), Captive Subcommittee members	Year 3+	Plan for wild recruitment proposed	Environment and Climate Change Canada	Details included in annual reports	Staff time, wild recruitment priority is unclear	Timeline for action is appropriate (should be higher priority?)	Staff time	Details included in annual reports; CSC meeting	
b) Develop updated protocol for wild recruitment	WPC	Year 3+	Protocol for wild recruitment is developed	Captive Subcommittee , Environment and Climate	Details included in annual reports; documents made available	Staff time, wild recruitment priority is unclear	Timeline for action is appropriate (should be	Staff time	Details included in annual reports;	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
			and distributed	Change Canada	in Shared Drive for review		higher priority?)		CSC meeting	
c) Execute protocol for wild recruitment in Napanee ON	WPC	Year 4+	Young are recruited to the *ex-situ* population successfully, *ex situ* genetic diversity increases	Captive Subcommittee, Environment and Climate Change Canada	Details included in annual reports	Staff time, wild recruitment priority is unclear; dependent on timeline for action 1, 2	Timeline for action is appropriate (should be higher priority?)	Staff time, facility time	Details included in annual reports; CSC meeting	
Objective 2.8: Incorporate genomics into population management strategies to improve *ex situ* population demographics										
a) Revisit and reinstate genomics subcommittee	African Lion Safari (Amy Chabot)	-	Next genomics subcommittee meeting scheduled	WPC	Email, agenda distributed	Staff time/workload	Staff available for meeting within the year	Staff time	Email	
Objective 2.9: Address knowledge gaps pertaining to husbandry/management of *ex situ* population to improve population demographics										
a) Investigate potential for multi-species holdings to increase capacity at existing *ex-situ* facilities	National Aviary	Year 2	Greater understanding of multi-species holdings as it pertains to LOSH	Captive Subcommittee members	Draft document compiled for holding LOSH with other species; details included in annual reports	Staff time, little information available on subject	-	Staff time/workload	Details included in husbandry manual; CSC meeting	
b) Review and update current maintenance and breeding diet recommendations	Toronto Zoo, WPC	Year 2	Updated diet protocol/ recommendations for *ex-situ* population	Captive Subcommittee members	Updated diet protocol	Limited staff time	Toronto Zoo nutritionists have time to devote to investigating and updating current diet recommendations	Staff time/workload	Details included in updated husbandry manual	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
Goal: Reduce habitat degradation in order to improve quality of existing habitat										
Strategy 3: Engage rights holders and stakeholders in restoration and enhancement of existing habitat.										
Objective 3.1: Work with communities and partner organizations to plan vegetation management activities in sensitive habitat										
a) Contact municipalities to determine where vegetation management is permitted (e.g. roadside)	WPC (Helmi Hess), NCC (Jordan Howard)	April 2024	Understanding of permissible activities and required permits	Municipalities	Information collected on potential permits	Bureaucratic hurdles/lack of communication	n/a	In-kind staff time	Email/meeting?	
b) Identify properties/landowners for potential management events.	WPC (Helmi Hess), NCC (Jordan Howard)	April - September, repeating annually	List of landowners/ contact details for properties	Landowners/ managers/rights holders	Compiled list	Lack of interested parties	n/a	Staff time	Email/meeting?	
c) Research liability requirements for management events on private properties	NCC (Jordan Howard), OFO (Mike Burrell)	April 2024	Compiled information	Ontario Field Ornithologists, Couchiching Conservancy	Liability Requirements summary document	n/a	n/a	Staff time	Email/meeting?	
d) Plan/implement community events	WPC, NCC, OFO	July? - April, repeating annually	Public involvement in shrike conservation, improvement of shrike habitat	Couchiching Conservancy, OFO, Ontario Nature, local conservation groups, rightsholders, landowners	Number of events, number of participants	Land access (municipal), lack of interest, cost	n/a	Staff time, volunteer time, tools/materials, cost of outreach materials/ marketing	Reports of event success in social media, newsletters, blogs, websites etc.	
Objective 3.2: Provide incentives to landowners for implementing habitat stewardship measures										
a) Research/compile list of possible incentive programs	WPC (Helmi Hess)	Year 1, review/update in Y5 and Y10	Compiled list of incentive programs	NCC, Beef Farmers of Ontario, OSSGA, MNRF, ECCC,	Summary document of available conservation incentives	Finding the right contacts	n/a	In-kind staff time	Email/meeting?	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
available to landowners.				MECP, other land trusts?						
b) Secure funding for implementation of habitat stewardship projects with private landowners.	WPC	Year 1, annually	Involvement of landowners in shrike habitat improvement	Funding organizations, donors, landowners	WPC Annual Reports	Applications denied, no interest from landowners	Interest from landowners	Staff time	LOSH Working Group meeting/email	
Objective 3.3: Develop an outreach program to educate landowners on loggerhead shrike habitat requirements.										
a) Compile resources available through organizations related to loggerhead shrikes and their habitat and note how they're currently distributed.	WPC	Year 1	Creation of a library of existing outreach resources	NCC, Couchiching Conservancy, breeding facilities	A shared drive of resource library	n/a	n/a	Staff time	Email/directly in drive	Resources will need updates with current info
b) Identify new streams for dispersal of information to potentially new audiences.	WPC, NCC, OFO	Year 1	Collection of new places/ways to educate the public about LOSH	Breeding facilities, local community groups, nature/ interpretive centers, schools, businesses	Compiled list	n/a	n/a	Staff time, travel expenses, printing costs	Email	Social media? Outreach events (not shrike specific)? Interpretive signs in high traffic areas? QR codes? Flyers/brochures at local businesses/libraries/community centers/farm cooperatives?
c) Create a communication plan to capitalize on identified streams.	WPC, NCC, OFO	Year 1	Prepared mode of communication to disperse educational information to new audiences.	Breeding facilities, local community groups, nature/interpretive centers, schools, businesses	Written communication plan	Unwillingness of potential collaborators	n/a	Staff time, travel expenses, printing costs	Email	-

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
Objective 3.4: Ensure existing broader grassland management plans (e.g. provincial government, other conservation plans) incorporate Loggerhead Shrike habitat requirements.										
a) Identify and determine land ownership of target habitat parcels for management activities.	WPC, NCC	Year 1	Ability to move forward with contacting landowners for habitat stewardship	Couchiching Conservancy, municipalities, other land trusts?	Compiled list	Inaccessible ownership records, landowner information is a PO Box or Ontario LTD address	n/a	Staff time, travel expenses	Email	Keep list of landowners that reach out directly to WPC for habitat management collaboration
b) Identify existing management initiatives and opportunities for integration of loggerhead shrike requirements and implement as appropriate.	WPC, NCC	Year 1	LOSH habitat requirements considered in grassland management plans implemented by organizations/ govts in Ontario.	Couchiching Conservancy, MNRF, ECCC	LOSH habitat requirements incorporated into management plans, copies of plans compiled	Lack of compatible management programs, lack of interest in collaboration, permit requirements, cost, lack of appropriate contacts	n/a	Unknown	Email	-
c) Reach out to industry (aggregates/cattle producers) to explore possibility of opening aggregate buffer lands to grazers	WPC	Year 1	Maintenance of suitable grasslands for LOSH, improved relationships with industry officials through facilitation of win-win situation	Beef Farmers of Ontario, Cindy McCarthy, OSSGA	Written confirmation of participation	Lack of interest, lack of good contacts	Aggregates will see land leases to ranchers as beneficial	Staff time, travel expenses, any funding from WPC?	Email, written agreements	-
Goal: Manage/decrease land development or conversion in order to reduce habitat loss across potentially suitable shrike range in Ontario as determined by the SDM.										
Strategy 4: Protect and conserve suitable habitat to ensure amount is sufficient for recruitment, survival, and other species needs.										
Objective 4.1: Maintain and/or develop 1:1 relationships with key stakeholders and rights-holders to promote engagement in habitat protection.										
a) Stake/rights-holder analysis within identified loggerhead shrike	WPC, NCC	Year 1, as needed when land ownership	Understandin g of important groups to involve in	Couchiching Conservancy, other land trusts, Cindy	Compiled list of contacts for stake-/rights holders	Lack of interest, incompatible interests, lack of contact information	-	Staff time, travel expenses	Email	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
habitat areas, including identification of key contacts.		changes or new areas are investigated	habitat protection decision making	McCarthy, Beef Farmers of Ontario, OSSGA, Indigenous groups						
b) Create communication plan for key contacts	WPC	Year 1	A schedule of important dates annually to reach out key contacts	Couchiching Conservancy, NCC, other land trusts, Cindy McCarthy, Beef Farmers of Ontario, OSSGA, Indigenous groups	Annual communication schedule	n/a	n/a	Staff time	Email	
Objective 4.2: Secure new parcels of land to the program with habitat suitable for shrikes										
a) Connect with land trusts in key shrike habitat areas to identify priority parcels/overlapping interests.	WPC, NCC	Year 2/as necessary	Prioritization of land parcels to target for habitat protection	Couchiching Conservancy, NCC, other land trusts	Compiled list and associated mapping	Prioritization of parcels for other species where habitat management requirements may be incompatible with LOSH	n/a	Staff time	Email, meetings	NCC in Grey Bruce/Manitoulin
b) Identify land for sale or targeted acquisition that contains suitable habitat.	NCC, WPC	Annually	Knowledge of possible land to acquire	Couchiching Conservancy, other land trusts, NHIC (Wasyl Bakowsky)	Running List	Price, none for sale	n/a	Staff time	Email	-
c) Develop/support acquisition projects.	NCC, WPC	Year 2, as necessary	Structure in place for multi-organizational collaboration on land acquisition	Couchiching Conservancy, other land trusts, other avian conservation organizations, other habitat protection organizations	Written plan	Funding	n/a	Staff time, Unknown	Email, meetings	-

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
Objective 4.3: Lobby for policy changes (e.g. industry, municipalities) to improve habitat protections.										
a) Research/compile existing industry and/or government policies that apply to grassland habitats.	WPC, Drew Sauve	Year 1	Compilation of applicable policies	All levels of government, industry, Cindy McCarthy, Joe Crowley (MECP), John Brett (ECCC CWS)	Summary document on applicable policies	Lack of/slow communication	n/a	In-kind staff time	Email/meeting?	-
b) Identify policies that could be modified to improve outcomes for loggerhead shrike, and draft policy changes.	WPC, Drew Sauve	Year 2	Draft of policy changes	Policy experts (government, industry)	Draft document of proposed policy changes	Feasibility of modifications	n/a	Staff time	Email/meeting?	Roadside activities identified as a priority
c) Propose policy changes to appropriate audiences.	WPC	Year 3	Initiating process for policy changes	NCC, OFO, other land trusts, other potential partners: Environmental Defense, CPAWS, Ontario Nature	Summary document of contact with policy makers	Bureaucracy, impacts on other industries/ stakeholders, lack of interest from policy makers, access to policy to makers, appropriate contacts/level of government	Willingness for change from policy makers	Staff time, travel expenses	Email/meeting?	-
Goal: Assess potential for re-establishment at additional sites to expand distribution in Ontario.										
Strategy 5: Identify additional sites for population re-introduction/re-establishment outside of existing core areas and promote maintenance of those habitat areas.										
Objective 5.1: Assess availability of existing habitat in areas identified as containing suitable habitat in the refined loggerhead shrike species distribution model.										
a) Ground-truth SDM results for Manitoulin Island and Cornwall.	WPC	Year 2-5	Confirmation of suitable habitat as determined by SDM	NCC (Manitoulin), Wikwemikong First Nation, Eastern Ontario Model Forest	Report ground-truthing results on SDM map	Land access, travel costs	n/a	Staff time, travel expenses	Email	

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
				(Cornwall), other parties identified in the SDM stake- and rights-holder analysis (included in the 2023 report by WPC)						
Objective 5.2: Develop relationships with key stakeholders and rights-holders to promote engagement in habitat protection and awareness of loggerhead shrikes.* (* New stakeholders/rights-holders identified in these actions should be included in actions implemented in Strategies 3 and/or 4, as appropriate)										
a) Stake/rights-holder analysis within identified loggerhead shrike habitat areas, including identification of key contacts in Manitoulin and Cornwall (if ground-truthing work confirms habitat).	WPC, NCC	Year 2-5, continuing as needed when land ownership changes or new areas are investigated	Understanding of important groups to involve in habitat protection decision making	Land trusts, industry, First Nations	Compiled list of contacts for stake-/rights holders	Lack of interest, incompatible interests, lack of contact information	n/a	Staff time, travel expenses	Email	A draft stake- and rights-holder analysis was completed by WPC in 2023 that can serve as a base for this work
b) Create communication plan for key contacts	WPC	Year 2	A schedule of important dates annually to reach out key contacts	Land trusts, industry, Indigenous groups	Annual communication schedule	n/a	n/a	Staff time	Email	-
c) Identify new streams for dispersal of information to potentially new audiences.	WPC, NCC, OFO	Year 2-5	Collection of new places/ways to educate the public about LOSH	Local community groups, nature/ interpretive centers, schools, businesses	Compiled list	n/a	n/a	Staff time, travel expenses, printing costs	Email	Social media? Outreach events (not shrike specific)? Interpretive signs in high traffic areas? QR codes? Flyers/brochures at local businesses/libraries/community centers/farm cooperatives?

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
Goal: Improve our understanding of loggerhead shrike population demographics and habitat use across the full annual cycle.										
Strategy 6: Support and/or conduct research to address existing knowledge gaps on loggerhead shrike population demographics and habitat use across the full annual cycle.										
Objective 6.1: Develop research plans for priority knowledge gaps										
a) Reinvigorate the research subcommittee of the LOSH Recovery Team (or comparable body).	WPC	Year 1	An organized group with a dedicated focus on long-term research questions.	Amy Chabot, Drew Sauve, Alisa Samuelson, Mike Burrell, breeding facilities, other LOSH researchers, other bird-focused organizations (e.g. Birds Canada? BECO?), Ontario Parks (Jenn Hoare?), MECP (Joe Crowley?), MNRF (Richard Feldman?), ECCC (John Brett, Kevin Hannah?)	Scheduled meetings for subcommittee	Lack of participants, lack of time, incompatible schedules	n/a	Staff time	Meetings	-
b) Prioritize knowledge gaps.	Research Subcommittee (formed in Action Statement 1)	Year 1	Understanding of the extent of knowledge gaps and which research questions to start with	Loggerhead Shrike Working Group, academic contacts	Prioritized list of research questions	n/a	n/a	Staff time	Email/meetings	**List of knowledge gaps (for reference):** **1.** Mortality risk from dispersal/ migration **2.** Climate change - Phenological mismatch with prey? **3.** Loss of insect prey **4.** Disease **5.** Identify U.S. breeding/wintering grounds and migration routes of *migrans* subspecies in order to

Action	Responsible Party	Timeline/ Frequency	Outcome	Key Collaborators	Indicator	Obstacles/ Limitations	Assumptions	Cost Estimates	Communi-cation	Other Important Considerations
										better target conservation actions
c) Identify potential research partners (existing and new connections; academics, ENGOs, etc.).	Research Subcommittee	Year 2	Creation of an avenue to begin answering research questions	U.S. shrike researchers	Compiled list	Lack of interest, lack of time, incompatible schedules	n/a	Staff time	Email	-
d) Develop research plans to address knowledge gaps, as possible.	Research Subcommittee, research partners identified above	Year 2-3	Timeline identified for work on the prioritized research questions to occur	U.S. shrike researchers	Written research plans	Funding, lack of interest, lack of time, incompatible schedules	n/a	Unknown	Email, LOSH WG meetings	-

United States

Working group members:

Alisa Solecki (Queen's University), Amy Chabot (ALS), Allisyn Gillet (Indiana Department of Natural Resources), Richard Bailey (West Virginia Division of Natural Resources), Sergio Harding (Virginia Department of Wildlife Resources), David Hanni (Tennessee Wildlife Resources Agency), Steve Latta (National Aviary), Scott Rush (Mississippi State University), Carola Haas (Virginia Tech), Cyndi Routledge (Southeastern Avian Research), Emily Donahue (Arkansas State University), Eric Soehren (Alabama Game and Fish Commission), Jim Giocomo (American Bird Conservancy/Oaks and Prairies Joint Venture), John Carpenter (North Carolina Wildlife Resources), Michael Patton (Kentucky Department of Fish and Wildlife Resources), Bob Mulvihill (National Aviary).

Table G2. Draft 10-year Action Plan for loggerhead shrike in the United States, within the geographic scope of *L. l. migrans*. Goals and strategies have been finalized, while objectives and actions are preliminary based on discussions during the January 2024 workshop. Work to finalize the action plan(s) will be continued by a LOSH WG coordinator and state representatives.

Goal: Protect and conserve suitable habitat to ensure sufficient habitat for recruitment, survival and other species needs
Strategy 1: Protect existing habitat and conserve lands through purchases and other financial incentives
Objective 1.1: Identify and prioritize core stable habitat areas to focus protection (SDM)
Strategy 2: Improve engagement/create awareness among farmers, private landowners, land managers, and industry on the importance of sufficient suitable habitat for shrike conservation
Objective 2.1: Tailor messaging to be compatible with landowner values and objectives
Objective 2.2: Elevate species as priority with land managers
Strategy 3: Incentivize landowners to maintain existing habitat
Goal: Restore and enhance habitat quality at local and landscape scales to support shrike
Strategy 4: Develop shrike specific habitat management practices (i.e. BMPs) and deliver/communicate to land managers and landowners

Objective 4.1: Build relationships with landowners and managers (e.g. NRCS, land trusts) to address multiple threats to habitat	
Action	**Additional Details**
a) Develop team for contacting NRCS and messaging strategies - Multiscale outreach plan with NRCS	**Key Collaborators:** NRCS **Indicator:** Hire a coordinator that facilitates the meetings between shrike state specialists and NRCS/other contacts
b) Determine who other potential partners are for land easements/trusts or monitoring	**Key Collaborators:** Regional and state-level organizations
c) Determine other high-level methods to provide funding for implementing shrike-based plans than NRCS	**Comments:** WMI/WHISPer/C-SWG could be utilized to hire coordinator with multi-state funding (Conservation Delivery Specialist)
d) Determine who other potential partners are for land easements/trusts or monitoring	**Key Collaborators:** Regional and state-level organizations
Objective 4.2: Manage habitat quality using farm bill programs, conservation easements, grazing leases, financial incentives	
Objective 4.3: Deliver effective communication to landowners on known BMPs for LOSH	
Action	**Additional Details**
a) Determine if there are existing western plans for other species that can be adapted for shrike management in the east	
b) Develop communication plan to implement and share BMPs	**Key Collaborators:** Regional and state-level NRCS biologists (to determine priorities of local landowners); Existing contact with Bridget Costanzo(?) at Working Lands for Wildlife in the Eastern Region through Carola Haas **Indicator:** Hire on-the-ground staff for implementation and broader outreach **Comments:** State-by-state approach - *understand/identify and incorporate considerations of landowner values and priorities in management planning*
c) Develop tools to improve communication between land managers and scientists	

d) Reconvene habitat committee to work on communication products	**Indicator:** Short one-pager geared towards practitioners (land managers, NRCS) (similar to GWWA) - State-specific, habitat specific variations (provide more options for landowners to assist wildlife); Larger shrike booklet (similar to the Ontario Landowner's Guide); Comprehensive BMP Guide (similar to Cerulean Warbler) **Comments:** Start with synthesis of what we know now; Update products as new research comes out
Objective 4.4: Develop comprehensive BMPs, that address priority threats, are inclusive of regional differences and landowner values/priorities	
Action	**Additional Details**
a) Synthesis of what we know now, identify Knowledge Gaps relevant to BMPs, update as new research comes out	
b) Fill Knowledge Gaps relevant to BMPs at three scales: landscape, within habitat patch, within nesting territory (relates to research priorities under Strategy 7)	**Outcome:** fill knowledge gaps at the landscape level to identify the regions that are and are not worth targeting for restoration/preservation and identify core areas that are at low risk of development/destruction in order to preserve and improve these areas as required for Objectives 1.1 and 5.1 (Concerted effort with a sub-group) **Important considerations:** four essential habitat elements (within habitat patch), specific micro-climates, nest shrub density, perching/hunting needs, conspecific attraction and associated considerations
c) Survey methods, ground truthing	
d) Develop region specific approaches for habitat management	
e) Conduct human dimensions study/survey in different regions	**Indicators:** Understand/identify and incorporate considerations of landowner values and priorities in management planning
f) Reconvene habitat committee to work on comprehensive BMP guide	**Indicators:** Guidelines provided to landowners for managing their lands to address threats (contents of BMP guide to be determined but relate to objectives under Strategy 10)

Strategy 5: Facilitate and support implementation of BMPs on priority lands	
Objective 5.1: Identify and prioritize core stable habitat areas to focus management/research	
Objective 5.2: Facilitate uptake and application of BMP by landowners/managers	
Action	**Additional Details**
a) Relationship-building with local communities to facilitate buy-in and input/collaboration	**Outcome:** -Education and outreach as a portion of the private lands biologists' responsibilities -Encourage engagement from the public through education and outreach -Foster private landowner collaboration and opportunities to participate in working group activities and monitoring/banding **Key Collaborators:** -State personnel / private lands biologists - NRCS -"Shrike Watch" team of private lands biologists/technicians/ "partner biologists" to monitor shrikes **Indicator:** -Create one-pager for brief facts and information geared towards the public and increasing detection -Loggerhead shrike website -News articles and media presentations
Objective 5.3: Identify additional tools and delivery methods to meet goals	
Action	**Additional Details**
a) Training for landowners for prescribed burns	**Outcome:** Build capacity and facilitate restoration on private lands
b) Explore alternatives to cattle grazing (e.g. prescribed burns, mowing, goats)	**Outcome:** Build capacity and facilitate restoration on private lands
c) Insert shrike needs into certification programs/create bird friendly certification programs/synergies with other species (e.g. grazing certification, heritage farming certification)	**Outcome:** Build capacity and facilitate restoration on private lands

Strategy 6: Incentivize landowners to create new habitat	
Goal: Work in partnership to address knowledge gaps and threats, including those relating to habitat, demographics, and Allee effect/conspecific attraction in a strategic/coordinated fashion, to improve *in situ* population demographics and support other goals and strategies.	
Strategy 7: Pursue research to address knowledge gaps and identify threats	
Objective 7.1: Identify specific priority knowledge gaps	
Action	
a) Identify funding opportunities	
b) Conduct literature review	
c) Additional research on habitat requirements for shrikes	
d) Dedicated study on Allee effect/conspecific attraction	
Strategy 8: Pursue funding to facilitate research, coordination of efforts and dissemination of results	
Strategy 9: Create mechanisms for developing collaborations and sharing results of research	
Objective 9.1: Develop standardized and coordinated monitoring protocol (for both breeding and winter)	
Action	**Additional Details**
a) Increase amount of tracking	
b) Investigate permits for movement tracking of wild shrike (adults or juveniles) in the U.S. and Canada	**Timeline/Frequency:** initiate tracking in 2026
c) Determine sources of adult mortality and provide insights into demographic parameters (dispersal, migration, territory size, etc.)	**Key Collaborators:** Dedicated staff covering several states for monitoring and tagging

Strategy 10: Identify actions and, as necessary, undertake actions to address threats to improve *in situ* population demographics (e.g. directly reduce mortality/increase reproduction vs more indirectly via habitat restoration/management)
Objective 10.1: Improve demographics rates, adult/HY/SY survival, prey availability
Action
a) Investigate methods for increasing wild populations that do not include supplementation/ translocations (i.e., increasing local breeding success, decreasing mortality, increasing foraging success (e.g., provide heterogeneous heights of vegetation (mosaic), bare ground/rock; increase grazing), etc.)
Objective 10.2: Reduce depredation of nests/predation of nestlings
Action
a) Remove predator attractants
b) Cats indoors
c) Reduce edge effect through habitat management measures (e.g. interspersion)
d) Add more suitable nest substrate (e.g. trees, shrubs)
e) Address plastic entanglement/mortality
Objective 10.3: Ensure shrike can survive catastrophic weather events
Action
a) "Shrike bunkers" (e.g. brush piles, evergreens, windbreaks)
b) Flood control measures (e.g. agricultural fields in spring or ice/snow in winter reducing prey availability)
c) Planting riparian buffers
Goal: For small populations, increase population size to a level that is resilient to stochasticity (e.g. catastrophic weather events)
Strategy 11: Investigate *ex situ* methods to augment small populations to above 50 birds (25 breeding pairs) in combination with habitat restoration and management (research/adaptive management approach) [small population, vulnerable to stochastic events]

Strategy 12: Reintroduce shrike in areas of local extirpation (research/adaptive management approach) [local loss of natural population]
Goal: Improve LOSH WG sustainability to ensure implementation of conservation action plan
Strategy 13: Increase membership/capacity
Strategy 14: Build a dedicated team to coordinate and lead action plan development and implementation e.g. A Working Group Coordinator and 6 state/province level staff
Objective 14.1: Develop a business plan for fundraising for this purpose (e.g. "Shrike Watch" proposal by Jim Giocomo)
Objective 14.2: Build a team to address all the strategies except for the research (unknowns/gaps) and the *ex situ* programs (e.g., outreach, meeting with landowners/private biologists, land management)
Action
a) Hire a WG coordinator, hire 6 state level "shrike people"
b) Finalize conservation action plan
c) Identify which strategies are being addressed
Strategy 15: Identify allocation path for salaries and funding avenues in common with other species at risk that may benefit from conservation actions for LOSH.