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Report No. 4-11

Population Viability Analysis for the Quebec Pilot Study Area in Support of NAESI Habitat-Based Biodiversity Standards

Technical Series 2008

Photos:
Bottom Left- clockwise

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Crop spraying: Corel CD photo # 95C2840
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POPULATION VIABILITY ANALYSIS FOR THE QUEBEC PILOT STUDY AREA IN SUPPORT OF NAESI HABITAT-BASED BIODIVERSITY STANDARDS

REPORT NO. 4-11

NOTE TO READERS

The National Agri-Environmental Standards Initiative (NAESI) is a four-year (2004-2008) project between Environment Canada (EC) and Agriculture and Agri-Food Canada (AAFC) and is one of many initiatives under AAFC's Agriculture Policy Framework (APF). The goals of the National Agri-Environmental Standards Initiative include:

- Establishing non-regulatory national environmental performance standards (with regional application) that support common EC and AAFC goals for the environment
- Evaluating standards attainable by environmentally-beneficial agricultural production and management practices; and
- Increasing understanding of relationships between agriculture and the environment.

Under NAESI, agri-environmental performance standards (i.e., outcome-based standards) will be established that identify both desired levels of environmental condition and levels considered achievable based on available technology and practice. These standards will be integrated by AAFC into beneficial agricultural management systems and practices to help reduce environmental risks. Additionally, these will provide benefits to the health and supply of water, health of soils, health of air and the atmosphere; and ensure compatibility between biodiversity and agriculture. Standards are being developed in four thematic areas: Air, Biodiversity, Pesticides, and Water. Outcomes from NAESI will contribute to the APF goals of improved stewardship by agricultural producers of land, water, air and biodiversity and increased Canadian and international confidence that food from the Canadian agriculture and food sector is being produced in a safe and environmentally sound manner.

The development of agri-environmental performance standards involves science-based assessments of relative risk and the determination of desired environmental quality. As such, the National Agri-Environmental Standards Initiative (NAESI) Technical Series is dedicated to the consolidation and dissemination of the scientific knowledge, information, and tools produced through this program that will be used by Environment Canada as the scientific basis for the development and delivery of environmental performance standards. Reports in the Technical Series are available in the language (English or French) in which they were originally prepared and represent theme-specific deliverables. As the intention of this series is to provide an easily navigable and consolidated means of reporting on NAESI's yearly activities and progress, the detailed findings summarized in this series may, in fact, be published elsewhere, for example, as scientific papers in peer-reviewed journals.

This report provides scientific information to partially fulfill deliverables under the Biodiversity Theme of NAESI. This report was written by J. Tews of Noreca Consulting. The report was edited and formatted by Denise Davy to meet the criteria of the NAESI Technical Series. The information in this document is current as of when the document was originally prepared. For additional information regarding this publication, please contact:

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NOTE À L’INTENTION DES LECTEURS

L’Initiative nationale d’élaboration de normes agroenvironnementales (INENA) est un projet de quatre ans (2004-2008) mené conjointement par Environnement Canada (EC) et Agriculture et Agroalimentaire Canada (AAC) et l’une des nombreuses initiatives qui s’inscrit dans le Cadre stratégique pour l’agriculture (CSA) d’AAC. Elle a notamment comme objectifs :

- d’établir des normes nationales de rendement environnemental non réglementaires (applicables dans les régions) qui soutiennent les objectifs communs d’EC et d’AAC en ce qui concerne l’environnement;
- d’évaluer des normes qui sont réalisables par des pratiques de production et de gestion agricoles avantageuses pour l’environnement;
- de faire mieux comprendre les liens entre l’agriculture et l’environnement.

Dans le cadre de l’INENA, des normes de rendement agroenvironnementales (c.-à-d. des normes axées sur les résultats) seront établies pour déterminer les niveaux de qualité environnementale souhaités et les niveaux considérés comme réalisables au moyen des meilleures technologies et pratiques disponibles. AAC intégrera ces normes dans des systèmes et pratiques de gestion bénéfiques en agriculture afin d’aider à réduire les risques pour l’environnement. De plus, elles amélioreront l’approvisionnement en eau et la qualité de celle-ci, la qualité des sols et celle de l’air et de l’atmosphère, et assureront la compatibilité entre la biodiversité et l’agriculture. Des normes sont en voie d’être élaborées dans quatre domaines thématiques : l’air, la biodiversité, les pesticides et l’eau. Les résultats de l’INENA contribueront aux objectifs du CSA, soit d’améliorer la gérance des terres, de l’eau, de l’air et de la biodiversité par les producteurs agricoles et d’accroître la confiance du Canada et d’autres pays dans le fait que les aliments produits par les agriculteurs et le secteur de l’alimentation du Canada le sont d’une manière sécuritaire et soucieuse de l’environnement.

L’élaboration de normes de rendement agroenvironnementales comporte des évaluations scientifiques des risques relatifs et la détermination de la qualité environnementale souhaitée. Comme telle, la Série technique de l’INENA vise à regrouper et diffuser les connaissances, les informations et les outils scientifiques qui sont produits grâce à ce programme et dont Environnement Canada se servira comme fondement scientifique afin d’élaborer et de transmettre des normes de rendement environnemental. Les rapports compris dans la Série technique sont disponibles dans la langue (français ou anglais) dans laquelle ils ont été rédigés au départ et constituent des réalisations attendues propres à un thème en particulier. Comme cette série a pour objectif de fournir un moyen intégré et facile à consulter de faire rapport sur les activités et les progrès réalisés durant l’année dans le cadre de l’INENA, les conclusions détaillées qui sont résumées dans la série peuvent, en fait, être publiées ailleurs comme sous forme d’articles scientifiques de journaux soumis à l’évaluation par les pairs.

Le présent rapport fournit des données scientifiques afin de produire en partie les réalisations attendues pour le thème de la biodiversité dans le cadre de l’INENA. Ce rapport a été rédigé par J. Tews de Noreca Consulting. De plus, il a été révisé et formaté par Denise Davy selon les critères établis pour la Série technique de l’INENA. L’information contenue dans ce document était à jour au moment de sa rédaction. Pour plus de renseignements sur cette publication, veuillez communiquer avec l’organisme suivant :

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EXECUTIVE SUMMARY

For the population viability analysis (PVA) component of the ‘Biodiversity Theme’ of the National Agri-Environmental Standards Initiative (NAESI) we conducted a review of completed population analyses for the eastern Ontario pilot study area. Based on the analyses we propose and discuss a standardized approach for population viability analysis and the development of habitat-based biodiversity performance standards under NAESI. We then apply this standardized PVA approach for the NAESI Québec pilot study area located in the St. Lawrence Lowlands eco-region using a sub-set of the surrogate species previously selected for the eastern Ontario study area.

By developing and linking demographic population models, habitat suitability models and spatial PVAs using the software package RAMAS©GIS the overall analysis is tailored towards developing habitat-based standards for each surrogate species. Habitat-based standards are developed by assessing spatial and non-spatial simulation model scenarios and their output with respect to desired ‘targets’ of specific model performance ‘measures’. We defined three performance measures and their respective targets for a simulation time frame of 50 years where population dynamics of a metapopulation are considered, (i) viable if the extinction risk is <5%, (ii) stable if the average population abundance declines by no more than 10% over the simulation trajectory, and (iii) ‘functional’ or ‘functionally present’ if the risk of decline to 50% of initial population size in any year is less than 5%.

For each species habitat-based standards are based on a simulation trajectory of 50 years, a 95% confidence for 1000 simulation replicates, and current landscape conditions on the NAESI Québec study area scale (4869 km^2), unless otherwise stated. The recommended habitat-based standards were developed as broad guidelines to ensure a sufficient habitat supply so that these

populations are viable and near stable and that their ecological functions and processes are maintained at appropriate spatial and temporal scales. Our level of confidence for each species varies depending on the availability and quality of empirical data and the feasibility of each habitat and population model. For example, low levels of confidence were achieved for species with high uncertainties in demographic rates (American mink, Belted kingfisher) or with strong matrix effects (Northern leopard frog).

The recommended habitat-based standards are subject to varying degrees of uncertainty and may vary depending on patch size distribution, initial population size, study area size as well as demographic rates. Any changes in the model assumptions may lead to variations in the recommended standards. Based on the results of the habitat and population models we suggest the following set of habitat-based standards:

Marsh Wren: (i) a minimum patch size of 2 - 10 ha to avoid patches being a strong population sink (depending on habitat quality), (ii) a minimum patch size of 65 ha of suitable habitat (based on an average population density of 0.25 ha per male) to support a single, viable population, (iii) a maximum inter-patch distance of 2 km to allow sufficient natal and breeding dispersal, and (iv) a minimum amount of 0.9% suitable marsh habitat to support a viable, and stable metapopulation.

Ovenbird: (i) a minimum patch size of 200 ha of highly suitable forest habitat to avoid patches being a population sink (based on the assumed stage matrix and a minimum of 87% pairing success resulting in a minimum intrinsic rate of increase of 1.0), (ii) a minimum patch size of 850 ha of suitable habitat (based on an average population density of 0.24 individuals per ha) to support a single, viable population, (iii) a minimum amount of 20% - 40% suitable forest habitat at a spatial scale of 250 km^2 to support a viable metapopulation, (iv) a minimum of 80-90% of the total population abundance distributed across large, self-sustainable forest patches (lambda>1.0, >

approx. 200 ha) to support near stable population trends.

Red-shouldered Hawk: (i) a minimum patch size of 26 km^2 of suitable habitat (based on an average population density of 1.7 breeding individuals per km^2) to support a single, viable population, (ii) a minimum amount of 6.6% of suitable habitat to support a viable and stable metapopulation under optimal patch size distribution; if the metapopulation contains a significant proportion of smaller patches with low connectivity (with the total area below the minimum viable patch size) the recommended habitat amount may be significantly higher.

American Bittern: (i) a minimum patch size of 30 km^2 of suitable habitat (based on an average population density of 127 ha per male or 1.57 breeding individuals per km^2) to support a single, viable population, (ii) a minimum amount of 1% suitable habitat to support a viable metapopulation, (iii) a minimum amount of 1.8% suitable habitat (with a minimum patch size that supports at least 12 breeding pairs) to support a viable, stable and functional metapopulation; if patches are smaller minimum habitat amount may be significantly larger.

Pileated Woodpecker: (i) a minimum patch size of 100 ha (equivalent to supporting a minimum of 2-4 breeding pairs) to avoid patches being a strong population sink, (ii) a minimum patch size of 22 km^2 of suitable habitat (based on an average population density of 5 breeding individuals per km^2) to support a single, viable population, (iii) a minimum amount of 11.5% of suitable habitat to support a viable, stable and functional metapopulation.

Northern Leopard Frog: (i) a maximum inter-patch distance of 500 m between breeding locations to facilitate movement and re-colonization, (ii) high quality matrix habitat including low road densities and low traffic volume to avoid high dispersal mortality, (iii) a minimum patch size of 0.1 ha of suitable breeding habitat to allow longer term patch occupancy (or an equivalent amount of habitat to support a minimum of 600 adult males).

American Mink: (i) a minimum patch size of 14-18 km^2 of suitable habitat to support a single, viable population (low confidence due to uncertain estimates in vital rates and frequency of drought events).

Belted Kingfisher: (i) a minimum patch area of approximately 180 km of suitable shoreline habitat to support a single viable population (assuming an average population density of 1 km shoreline habitat per adult male bird) (low confidence due to modifications in demographic rates), equivalent to 18 km^2 of suitable shoreline habitat assuming a habitat corridor width of 100 m.

Northern Flying Squirrel: (i) a minimum patch size of 10-20 ha for patch occupancy, (ii) a minimum patch size of 160 ha (based on an average population density of 0.5 individuals per ha) to support a single, viable population, (ii) a maximum inter-patch distance of 6 km (for inter-patch distances larger than 1 km forested corridors or stepping-stone forest habitats need to be present), (iii) a minimum amount of 1.8% of suitable habitat to support a viable, stable and functional metapopulation.

Bobolink: (i) a minimum patch size of 20 ha for patch occupancy, (ii) a minimum patch size of 135 ha (based on an average population density of 1.5 individuals per ha) to support a single, viable population, (iii) a maximum inter-patch distance of 15 km, (iv) a minimum amount of 0.75% of high quality habitat to support a viable, stable and functional metapopulation, (v) no hayfield harvesting prior to the first week in July.

1 GENERAL INTRODUCTION

As part of the Biodiversity Theme of the National Agri-Environmental Standards Initiative (NAESI) several pilot projects have been established across agricultural regions in Canada to develop and test a decision support process for the development of habitat-based biodiversity performance standards. One goal of this process is to determine the quantity and pattern of habitat required to meet the habitat requirements for a set of selected surrogate species that represent a desired level of biodiversity. The selected tool for assessing these requirements is population viability analysis (PVA). PVA is a widely used management and conservation tool to evaluate the threats of extinction or decline for species of concern. Due to their stochastic nature population viability models produce estimates of the probability of extinction and expected population sizes based on species' life histories, vital rates and dispersal characteristics. Such analyses can be non-spatial, spatial-implicit or spatial-explicit. RAMAS©GIS (Akçakaya and Root, 2005) is a software tool that allows spatial-implicit analysis linking habitat data with demography and will be used for all population analyses conducted for this report.

This report contains two major parts. The first part provides a review of 11 population viability analyses completed for a pilot study area established in the St. Lawrence Lowlands eco-region in eastern Ontario (Section 2). Based on these analyses and their habitat-based recommendation we propose and discuss a standardized approach for the application of population modeling analyses and the development of habitat-based standards under NAESI (Section 3). In the second part this PVA approach is then subsequently applied for the pilot study area in the St. Lawrence Lowlands eco-region of Québec using a sub-set of the surrogate species previously selected for the eastern Ontario study area (Sections 5-14). For each surrogate species we finally recommend a revised set of habitat-based standards.

2 SUMMARY OF PVAS COMPLETED FOR THE NAESI EASTERN ONTARIO PILOT STUDY AREA

2.1 Summary of PVA results

In this section of the report we present a review of the 11 PVA studies conducted for the NAESI Eastern Ontario pilot study area in the united counties of Stormont, Dundas, and Glengarry. We reviewed four reports including a total set of 11 species: Marsh Wren, Ovenbird, Red-shouldered Hawk, American Bittern, Pileated Woodpecker, Northern Leopard Frog, American Mink, Belted Kingfisher, Northern Flying Squirrel, Bobolink, and Painted Turtle. Each PVA study was reviewed based on:

- the methodological approach
- model parameterization
- recommendations for habitat-based standards
- whether each study provides the information required for the NAESI objectives and
- the overall feasibility of each species to be used as a surrogate species for habitat modeling and population viability analysis

The 11 reviewed PVA case studies showed a considerable amount of variation with respect to methodological approaches (Tables 1 and 2). For example, across the range of studies:

- different "habitat suitability threshold" parameters where chosen (which determine whether a cell is suitable or unsuitable)
- 'quasi-extinction' thresholds varied among studies (which determine the population abundance at which the metapopulation is considered to be extinct)
- simulation time was not uniform (varied between 50 or 100 years)

- different correlation-distance functions were applied and most importantly
- different performance measures where used to assess metapopulation viability (e.g., extinction risk, expected metapopulation abundance, population trend, etc)

Table 1 and 2 summarize the essential demographic and spatial model parameters of each population viability analysis.

Due to the high variation in methodological approaches risk assessments and predictions are therefore difficult to compare among the four study reports. However, general trends indicate positive to neutral trends for 7 of the 12 species (see Table 3 for details). Based on the demographic models *and* current habitat supply in the eastern Ontario pilot study area the studies indicate more or less viable populations for: (a) Northern leopard frog, (b) Mink, (c) Northern flying squirrel, (d) Bobolink, (e) Midland painted turtle, (f) Marsh wren, and (g) Pileated woodpecker. Negative trends or non viable populations were found for: (a) Belted kingfisher, (b) Ovenbird, and (c) American bittern. No significant trends could be found for the Red-shouldered hawk. A detailed summary of the main results of each PVA study is provided in Table 3.

Table 1: Summary of parameterizations and model variables for intermediate or base scenarios in each PVA study. NLFro=Northern Leopard Frog, BeKifi=Belted Kingfisher, Mink, Ovbi=Ovenbird, Wren=Marsh Wren, Ceil=Ceiling density dependence type.

Demographic parameters (base scenario)	**NLFro**	**BeKifi**	**Mink**	**Ovbi**	**Wren**
# of stage/age classes	4	2	5	2	4
Sex ratio (proportion of females)	0.5	0.5	0.5	0.5	0.62
Polygyny	No	No	No	No	Yes
Fecundity rate	38.0	1.53	0.6	0.7-1.4	1.64
Juvenile survival rate	0.09	0.13	0.86	0.31	0.3
Adult survival rate	0.4	0.56	.9-.33	0.623	0.68
CV in stage matrix	<=100%	<=30%	<=50%	<=30%	<=50%

Table 1: Summary of parameterizations and model variables for intermediate or base scenarios in each PVA study. NLFro=Northern Leopard Frog, BeKifi=Belted Kingfisher, Mink, Ovbi=Ovenbird, Wren=Marsh Wren, Ceil=Ceiling density dependence type.

Demographic parameters (base scenario)	**NLFro**	**BeKifi**	**Mink**	**Ovbi**	**Wren**
Carrying cap. K (adult/ha)[1] (pairs/shoreline m)[2]	26800[1]	1.25[2]	0.04[1]	.0-1.0[1]	9.43[1]
CV of carrying capacity	0%	0%	0%	10%	10%
Initial abundance	K*0.66	K*0.66	K*0.66	=K	=K
Density Dependence type	Ceil	Ceil	Ceil	Ceil	Ceil
Environmental stochasticity	Yes	Yes	Yes	Yes	Yes
Demographic stochasticity	Yes	Yes	Yes	Yes	Yes
Disturbance/Catastrophe	Yes	Yes	Yes	No	No
Model parameters					
Simulation time (yrs)	100	100	100	50/100	50/100
Extinction threshold for metapopulation	11000	0	0	0	0
Spatial parameters (base scenario)					
Study area size (km^2)	3250	3250	3250	200	200
Neighborhood distance (m)	500	8500	6500	100	50
HSI threshold	0.5	0.5	0.5	0.51	0.5
Max. dispersal distance (km)	2	66	45	5.0	3
Max. dispersal rate	0.15	1.0	1.0	0.1	0.25
Distance correlation function	(?)	(?)	(?)	1.0-0.0	1.0-0.0
Reported model output					
Extinction risk / persistence	Yes	Yes	Yes	Yes	Yes
Expected minimum abundance (EMA)	No	No	No	Yes	Yes
Stability (ratio final to initial abundance)	No	No	No	Yes	Yes
Functional Presence (risk of decline to <50% of initial population in any yr)	No	No	No	No	No

Table 2: Summary of parameterizations and model variables for intermediate or base scenarios in each PVA study. NFlSq=Northern Flying Squirrel, Boli=Bobolink, Turtle=Painted Turtle, RSHa=Red-shouldered Hawk, AmBi=American Bittern, PiWoPe=Pileated Woodpecker, ScrAlle=Scramble Allee competition, Cont=Contest competition, Scr=Scramble competition.

Demographic parameters (base scenario)	**NFlSq**	**Boli**	**Turtle**	**RSHa**	**AmBi**	**PiWoPe**
# of stage/age classes	4	2	5	2	2	2
Sex ratio (proportion of females)	0.5	0.55	0.5	0.5	0.5	0.5
Polygyny	Yes	Yes	No	No	No	No
Fecundity rate	1.35	1.74	.53-1.04	0.36	0.25	0.44
Juvenile survival rate	0.54	0.34	0.27	0.75	0.78	0.61
Adult survival rate	.18-.58	0.49	0.98	0.75	0.78	0.61
CV in stage matrix	10%	10%	10%	<60%	<12%	<10%
Carrying cap. K (adult/ha)	1.3[1]	2.4[1]	800[1]	0.036[1]	0.052[1]	0.06[1]
CV of carrying capacity	10%	10%	10%	-(?)	-(?)	-(?)
Initial abundance	=K	=K	K/4	=K	=K	=K
Density Dependence type	ScrAlle	Cont	Scr	Cont	Cont	Cont
Environmental stochasticity	Yes	Yes	Yes	Yes	Yes	Yes
Demographic stochasticity	Yes	Yes	Yes	Yes	Yes	Yes
Disturbance/Catastrophe	No	Yes	Yes	No	No	No
Model parameters						
Simulation time (yrs)	50	50	50	50	50	50
Extinction threshold for metapopulation	30	30	0	250	50	250
Spatial parameters (base scenario)						
Study area size (km^2)	500/3250	3250	3250	3250	3250	3250
Neighborhood distance (m)	1000	500	1000	1200	1300	1300
HSI threshold	0.5	0.15	0.6	0.2	0.2	0.2
Max. dispersal distance (km)	6.08	14.2	3.3	21.6	10	0.5
Max. dispersal rate	1.0	1.0	0.3	0.34	0.2	0.2
Distance correlation function	1.0-0.0	1.0-0.0	1.0-0.4	1.0-.0	1.0-.4	1.0-.4
Reported model output						
Extinction risk / persistence	Yes	Yes	Yes	Yes	Yes	Yes
Expected minimum abundance (EMA)	Yes	Yes	Yes	Yes	Yes	Yes
Stability (ratio final to initial abundance)	No	No	No	Yes	Yes	Yes
Functional Presence (risk of decline to <50% of initial population in any yr)	No	No	No	Yes	Yes	Yes

Table 3: Main results from population viability analyses of 11 surrogate species in the eastern Ontario pilot study area.

Species	Results	Comments
Marsh Wren	Extinction risk of the Marsh wren metapopulation was 25.4% and 0% in two 200 km^2 sub-study areas with different marsh densities. Expected minimum abundance (EMA) was 40 and 2579 individuals and the population trend (average abundance at time step 100 divided by abundance in the first year) was 0.6 (negative) and 0.95 (nearly neutral), respectively.	A future refinement of the fecundity rate should incorporate fledgling rates based on 3-female harems (see Schriml 1993) as polygyny in the model allows males to have a maximum of 3 females per breeding season.
Ovenbird	Extinction risk was high and population trends strongly negative for all sampled sub-populations in the eastern Ontario pilot region. A sub-area with the highest average deciduous and mixed forest cover in the NAESI pilot project area exhibited an extinction risk of 69% after 50 years of simulation time.	A thorough review revealed that the Larsen et al. study (2004), upon which the stage matrix was based, contained an error. The fecundity rates in this study did not include survival rates from the juvenile to the adult stage (this is a common mistake in many PVA studies). Thus, a re-analysis should change the stage matrix accordingly.
Red-shouldered hawk	Three performance measures were used to assess population viability in the eastern Ontario pilot region: viability, stability, functionality. For the base scenario (medium values for all demographic parameters) 2 habitat patches were identified with an extinction risk of 1.4% for a threshold of 250 individuals and a simulation time of 50 years. Median growth rate as a measure of population stability (ratio of median final abundance to initial abundance) was 0.7224, indicating a decline from initial abundance. Overall, the medium model resulted in a declining population, albeit one which appears to be stabilizing eventually at approximately 80% of its initial abundance.	-
American Bittern	For the base (i.e., medium) scenario with 9 identified habitat patches extinction risk (i.e., viability) was 1.7% for a threshold of 100 individuals (simulation time was 50 years). Median growth rate (i.e., stability) was 0.55 indicating a substantial decline from initial abundance. Functional presence (measured as one minus risk of interval decline to a threshold of 167 individuals) was 0.42.	-
Pileated Woodpecker	For the medium scenario extinction risk was only 0.1% for a threshold of 250 individuals. Stability was 0.79 indicating a decline from the initial population abundance. Functionality was 0.88. In the medium scenario 6 habitat patches were identified based on a neighborhood distance of 1.3 km.	-
Northern Leopard Frog	For a neighborhood distance of 500 m (20m*20m cell size) and a HSI cut-off value of 0.5 (for the identification of patches) a total of 215 habitat patches were found (base scenario). Metapopulation extinction risk over a time frame of 100 years was 1.2% and 1.8% with and without	-

Table 3: Main results from population viability analyses of 11 surrogate species in the eastern Ontario pilot study area.

Species	Results	Comments
	dispersal among patches, respectively. A worst-case habitat scenario with a 30% reduction in the quality and quantity of breeding habitat (129 habitat patches) resulted in an extinction risk of 11.7%.	
Mink	With minimum habitat suitability necessary for breeding set to 0.4, 32 m x 32 m landscape pixel size, and a neighborhood distance of 1.5 km (three patches) and 6.5 km (one patch) extinction risk for 100 years of simulation was 0% in both scenarios. Metapopulation models forecasted very low extinction risks for management purposes, even with the addition of harvesting. Local extinction risks of the mink remain low until a harvest of 40% juveniles and 20% adults, upon which regional populations may become vulnerable to local extinction. Results from sensitivity analyses show that even with 20% reductions in the estimates of most demographic parameters, mink populations remain stable. Overall, current landscape conditions seem to support viable mink populations over a wide range of scenarios.	The overall results suggest that the current stage matrix with a finite rate of increase of 1.35 (i.e., 35% annual population growth in the absence of demographic and environmental stochasticity and density dependence) might overestimate population growth unless other so far unaccounted effects would have detrimental impacts on mink population dynamics.
Belted Kingfisher	For a neighborhood distance of 8 km (equivalent to maximum daily range of nesting adults), a cell size of 32m*32m, and a cut of HSI value of 0.5 a total of 3 sub-populations/habitat patches were found. For this baseline scenario simulations indicated a rapidly declining metapopulation with a median time to local extinction of 37 years (extinction risk = 100%). For 50 simulated years extinction risk was 86.1%. A watershed restoration simulation with 50% increase in habitat suitability for shorelines within 3 km of non-urban sandy soils resulted also in near certain probability of extinction with a median time to extinction at 45 years.	Overall, the high extinction risk was largely due to a low finite rate of increase of lambda = 0.91, i.e., populations may not be viable irrespective of habitat supply (without additional immigration). For future work the stage matrix might need to be modified.
Northern Flying Squirrel	In total, 275 habitat patches greater than 20 ha in size were identified, resulting in a total area of suitable habitat of 134.23 km^2 or approximately 4% of the landscape. However, most of these patches were located in the northeastern half of the study area, where squirrel habitat comprised approximately 7% of the landscape. The study concludes that if the habitat model is at least 50% correct the squirrel population is both viable (0% probability of extirpation within 50 years) and stable over the next 50 years.	An in-depth review of the demographic parameters revealed that the stage matrix did not represent a correct Leslie stage matrix; both fecundity and survival rates need to be modified accordingly.
Bobolink	Study found that there is approximately 535 km^2 of bobolink habitat evenly spread across the study area - evenly distributed between medium (45% patches) and optimal (55% of patches) size classes. The current population appears viable, stable and ecologically functional irrespective of estimates of habitat amount and quality, although population size would be lower if habitat model was substantially incorrect. However, the	An in-depth review of the demographic parameters revealed that the stage matrix did not represent a correct Leslie stage matrix; both fecundity and survival rates need to be modified accordingly.

Table 3: Main results from population viability analyses of 11 surrogate species in the eastern Ontario pilot study area.

Species	Results	Comments
	bobolink population cannot withstand more than a 20% reduction in fledging rates annually; consequently widespread annual disturbance because of haying during the nesting season would reduce the viability of this population.	
Midland Painted Turtle	Extinction risks were low for a wider range of scenarios. The simulated painted turtle population also appeared stable and robust to higher rates of nest predation. Adult female turtles also seemed robust to small changes in survival rates. However, a 20% or more reduction in adult female survival rates over a prolonged period of time would result in painted turtle decline. Overall, the study suggests a sufficient supply of suitable habitat for longer term persistence in the eastern Ontario pilot region.	The authors suggest that the painted turtle may not be a useful surrogate species for developing habitat-based standards, because of the difficulties associated with defining habitat using remotely sensed data.

2.2 Summary of Habitat-Based Recommendations

The reports responded differently in terms identification of habitat-based standards as outlined in the ‘Request for Proposal’ document. In two of the reviewed reports (Noreca Consulting and Elutis Modeling and Consulting Inc. (2007) and Pearce et al. (2007)) habitat-based standards were suggested (Table 4). For the remaining species habitat-based standards were not identified. Based on the consultant’s reports and the feasibility of each species for the purpose of the NAESI objectives we were able to synthesize habitat-based standards for 5 of the 11 surrogate species. For 6 species the analyses in the reports did not allow to draw any conclusions or the species was deemed as unsuitable for the purpose of NAESI (i.e., midland painted turtle).

Table 4: Summary of recommendations for habitat-based standards

Species	Recommendations for habitat-based standard
Marsh Wren	Suggested standards are: (1) a minimum viable patch size of ~114 ha assuming that all individuals reside in one patch/population, (2) a minimum (metapopulation) patch size of ~1.7 ha to avoid patches being a strong population sink, (3) a minimum of 0.2% - 1.2% marsh habitat on a 200 km^2 landscape scale (depending on the patch size distribution), and (4) a maximum distance of 2-3 km to the nearest patch to allow sufficient natal and breeding dispersal.
Ovenbird	Suggested standards are: (1) a minimum viable patch size of ~742 ha assuming that all

Table 4: Summary of recommendations for habitat-based standards

Species	Recommendations for habitat-based standard
	individuals reside in one patch/population, (2) a minimum (metapopulation) patch size of 100 ha allowing a minimum intrinsic growth rate of 1.0, (3) a minimum of 30-40% suitable forest cover on a 200 km^2 landscape scale (depending on the patch size distribution), and (4) for near stable population trends a minimum proportion of ~50% source patches with a minimum source patch size that facilitates 100% pairing success (250 ha in this study).
Red-shouldered Hawk	Study did not explore how much habitat is needed to facilitate near stable population trends and low extinction risks.
American Bittern	Study did not explore how much habitat is needed to facilitate near stable population trends and viability. However, overall it appears that current habitat availability may not be sufficient to support longer term viability.
Pileated Woodpecker	Study did not suggest habitat-based standards. However, based on the analysis it appears that current habitat quantity and quality may be sufficient to support longer term viability.
Northern Leopard Frog	Based on the results and the assumptions of the model it appears that 0.1% of suitable marsh habitat is needed to ensure longer term persistence. For the base scenario amount of suitable habitat in the study area (325,000 ha) was approximately 350 ha. As a comparison, marshes cover approximately 0.84% of the eastern Ontario pilot area. Thus, based on the assumptions of the habitat suitability model approx. 8.4% of all marsh habitat in the eastern Ontario pilot area appears to be suitable for the NLF.
Belted Kingfisher	All scenarios resulted in near extinction. Study did not explore how much habitat may be needed to ensure longer term persistence. (note, that finite rate of increases was < 1.0)
Mink	Mink populations were viable over a wide range of scenarios. However, the population analysis did not explicitly explore at which point changes in habitat availability might reduce population persistence and stability.
Northern Flying Squirrel	Suggested standards: (1) a minimum patch size of 20 ha is required for patch occupancy, (2) a minimum viable patch size of 108-318 ha (density 0.22-0.65 females/ha) assuming that all individuals reside in one patch/population, (3) patches need to be separated by a maximum distance of 6 km to ensure dispersal, (4) forested corridors or stepping-stone forested habitat to ensure safe dispersal over distances greater than ~1 km and (5) approximately 7% mature forested habitat per 500 km^2 (depending on patch size distribution).
Bobolink	Suggested standards: (1) a minimum patch size of 10 ha, (2) a minimum viable patch size for old hayfields of approximately 37 ha assuming that all individuals reside in a single patch/population, (3) a maximum inter-patch distance of 14 km, and (4) a minimum of 6% high quality hayfields on the landscape or 12-18% younger hayfields and lightly grazed pasture (depending on the patch size distribution and spatial arrangement of patches). If hayfields are harvested prior to the first week in July, then they can be considered habitat sinks, causing population decline unless sufficient additional habitat is available to produce sufficient offspring each year to offset these losses.
Painted Turtle	Suggested standards: (1) road density less than 1.5 km roads/km^2, (2) the existence of pond complexes, defined as ponds located within 1km of each other, (3) at least one permanent pond within a pond complex, and (4) pond complexes located within a maximum distance of 3-4 km of each other to ensure sufficient exchange of individuals. Despite these suggestions it is noted that the painted turtle may not be a useful indicator species because of the difficulties associated with defining habitat using remotely sensed data.

3 A STANDARDIZED PVA APPROACH FOR THE DEVELOPMENT OF HABITAT-BASED STANDARDS UNDER NAESI

The large numbers of PVA studies that are and will be conducted under NAESI require a standardized approach that is tailored towards the objectives of the overall NAESI biodiversity theme framework. In a first step we tried to identify specific categories of standards that are (i) applicable for the NAESI objectives, and (b) feasible to obtain if a habitat and population modeling analysis is conducted. In our synthesis we grouped the standards into five major classes of which the first four classes describe a multi-tier approach to define minimum patch sizes required for different patch states:

- Minimum patch size required for occurrence (MPS-O)
- Minimum patch size required for being a population source (lambda >1.0) (MPS-S)
- Minimum patch size for providing a viable (single) population (MPS-V)
- Minimum inter-patch distance to allow sufficient dispersal (MIPD)
- Minimum habitat amount required for different population performance measures (MHA)

Note that the standards MIPD and, in particular, MPS-O are primarily based on empirical data and do not necessarily require a population modeling analysis and the standard MPS-V does not require a spatial PVA. Each model-based standard is subject to specific model conditions. For example, the standard MPS-V is associated with the simulated time (50 years for the NAESI PVA standardization), the extinction risk threshold below which a population is considered viable (e.g. 5%), and the assumed population density (based on empirical data). Additional conditions apply to minimum habitat amount (MHA). For example, a MHA standard is only of value if information is provided with respect to the spatial scale of the analysis and the target of the performance measure.

We generally distinguish between a performance ‘measure’ and a performance ‘target’ where a ‘measure’ is a quantifiable model output and a ‘target’ a desired value or threshold of this measure. For the standardized NAESI PVA approach we defined three performance measures and their respective targets for a simulation trajectory of 50 years:

- Viable population (target: <5% extinction risk)
- Stable population (target: <10% population decline from initial to final abundance)
- Functionally present or functional population (target: <5% risk of decline to 50% of initial population size in any year)

‘Viability’ is measured as the risk or probability of extinction for the given time frame. ‘Stability’ is measured as a numerical change in the abundance from the initial to the final population size. ‘Functionality’ is measured as the probability that, in any year during the simulation, the total metapopulation size is more than a fixed threshold, which is set at 50% of the initial total metapopulation size. The latter three measures and targets apply primarily to the standard of minimum habitat amount. That is, a minimum habitat amount may be present on a current landscape to provide viability, stability, and/or functionality (or a combination) for a focal metapopulation. The ultimate goal in each PVA will be to find the amount of habitat supply required to achieve all three performance targets. However, under certain circumstances this may be either not practical or may depend on certain initializations of the population model.

Firstly, a species may be demographically limited and even an unlimited increase in habitat amount may not be sufficient enough to achieve any of the three performance targets. For example, some species are at their northern range margin in southern Canada and rely on immigration from southern core populations. In this case (without considering the additional provision of immigrants) ‘local’ demographic rates may result in intrinsic rates of increase of <1.0, i.e., the population is practically a population sink.

Secondly, stability of a model population may often not be achieved if initial population size equals the carrying capacity (depending on the type of density dependence and carrying capacity). We therefore decided to initialize all populations with 50% of the carrying capacity which we consider a realistic assumption of the relationship between average and maximum population density. As initial population abundance in the model may or may not be consistent with current abundances in the study region ‘stability’ only refers to changes in abundance of a hypothetical model population and not projected changes in real abundances on the landscape. Otherwise initial population abundance would need to be based upon actual occupancy data (which were not available).

Thirdly, the 50% threshold of functional presence ought to represent an abundance level present at any given time so that ecological functions of that species are provided. However, it is important to denote that this measure is highly sensitive to the type of population dynamics underlying each model species. Species with strong population cycles or which are subject to frequent density-independent catastrophes may provide their full ecological function even though this performance target may never be achieved. Thus, the measure of ‘functionality’ or ‘functional presence’ needs to be dealt with caution. Overall, we conclude that further research is needed to (i) find a quantitative, science-based method for assessing the degree to which a species provides its ecological functions at the species, community and ecosystem level, and (ii) develop policy guideline scenarios to assess at which population level species are able to fulfill a desired level of ecological functions.

For assessing minimum habitat requirements (MHA standard) landscape scenarios need to be tested until the desired performance targets are achieved. For example, for non-viable populations (hypothetical) habitat patches my need to be added or for viable populations patches may need to be removed or reduced in size. Assessing minimum requirements in terms of habitat amount can be achieved through different technical steps which depend upon the species and its habitat requirements. For example Akcakaya et al. (2007) either removed smaller patches or reduced the amount of edge habitat. Another method would be to change the habitat suitability threshold for the calculation of population patches or to modify the carrying capacity of patches.

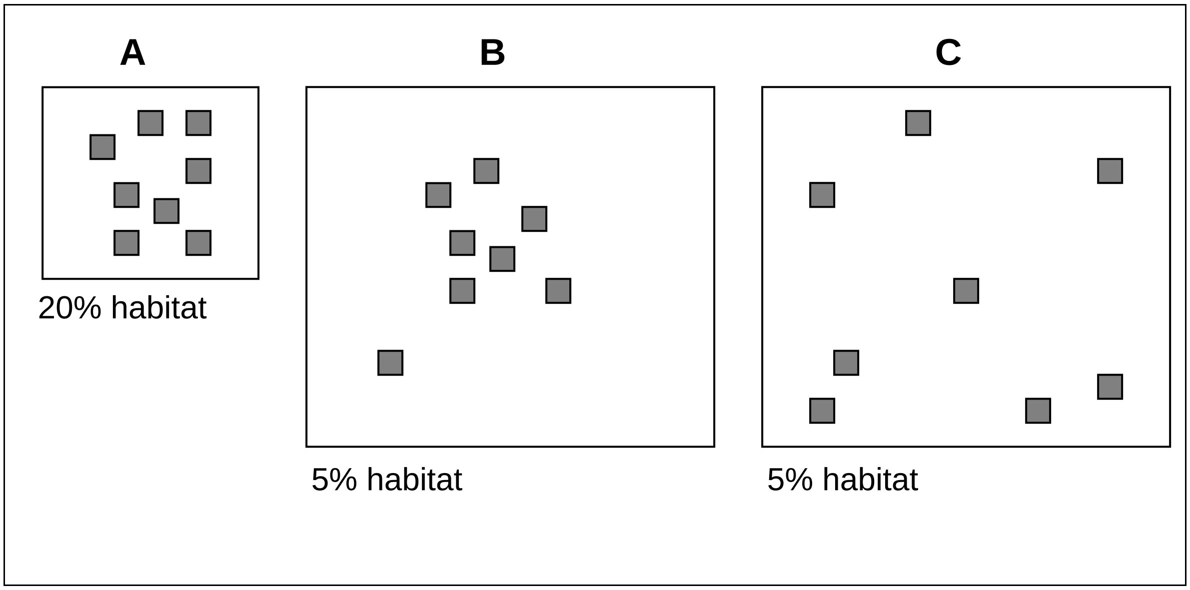
Depending on the species we applied different methods to modify habitat amount on the current landscape. In some case it is particularly useful to vary the patch size distribution in a spatial model by, for example, re-distributing the carrying capacity in the landscape among some of the population patches. This will often show that even smaller habitat amounts with optimal patch size distributions (with less population sinks) can lead to similar population performances compared to landscapes with significantly larger habitat amounts.

The amount of habitat on a landscape required for persistence, stability and/or functional presence is, as previously noted, a function of the spatial extent of the study area, inter-patch distances as well as the respective size of each patch (relative to minimum viable population size). To illustrate this, consider the following three examples shown in Figure 1. Landscape A has 8 population patches comprising a total habitat amount of 20%. The metapopulation in landscape A has an extinction risk of less than 5% (i.e., it is viable) over a time frame of 50 years and an average inter-patch distance of less than 1 km. In contrast, the population in landscape B with a similar average inter-patch distance covers only 5% of the landscape (on a larger spatial scale), yet is still viable. In landscape C average inter-patch distance has decreased to below a critical threshold. Even though the metapopulation in landscape C has a total of 5% habitat available the population may not be viable. However, if abundances in the majority of patches in landscape C would be above the minimum viable population size, the metapopulation would be still viable (and inter-patch distances could be largely neglected).

Based on the above considerations it is evident that MHA is associated with a specific spatial scale. To provide consistency across all surrogate species of the Québec analysis we therefore decided to apply the MHA standard for the entire NAESI pilot study area scale, i.e., for each surrogate species we conducted each metapopulation analysis on the same spatial scale. Even though we are aware of the drawbacks of using a single scale (due to the fact that species have different operational scales and requirements), varying the spatial scale in each analysis would require to decide on the appropriate scale in each analysis, increase the parameter space, and introduce uncertainty as to where spatial boundaries need to be set and which habitat patches need to be included in the analysis.

A moving window analysis where a certain spatial area is sub-sampled (if the chosen metapopulation scale is smaller than the NAESI study area scale) might circumnavigate the issue of setting artificial, non-data driven metapopulation boundaries. However, it would also increase the labor intensity in each analysis dramatically as many sub-areas would need to be sampled in order to test the full range of possible patch size distributions and spatial patch configurations. Due to software limitations of RAMAS©GIS that do not allow more than 500 populations to be simulated and the high degree of habitat fragmentation this kind of spatial analysis was chosen for the ovenbird (see Section 6).

Figure 1: Relationship between habitat amount, inter-patch distance, spatial scale and population viability. Each gray square represents a habitat patch occupied by a population (see further explanations in the text).



As the standard ‘MHA’ is based on the total area of suitable habitat, MHA would increase if the total habitat area required for persistence is re-distributed in a smaller area. For example, 5% habitat on a larger spatial scale could be equivalent to 20% on a smaller scale resulting in similar population viability. Even though inter-patch distance would be significantly smaller (and smaller inter-patch distances are likely to decrease extinction risk if the majority of patches are below the minimum viable population size), re-calculating this standard for a smaller scale is still useful as it represents a more conservative estimate.

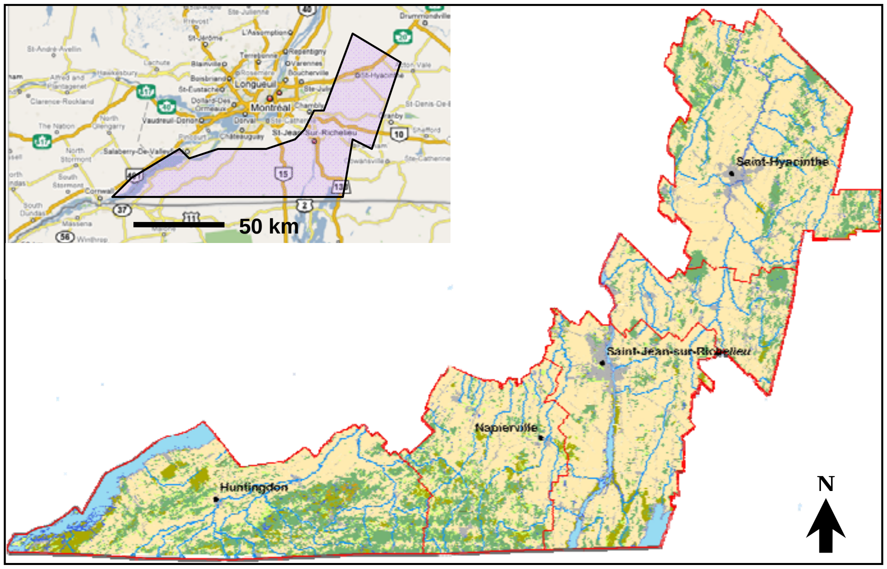
4 QUÉBEC PVA PILOT STUDY

The NAESI Québec pilot study area is located in the St. Lawrence Lowlands ecoregion in southern Québec (Figure 2). The ecoregion includes the lowlands centered on the Ottawa and St. Lawrence rivers stretching from Québec City to the Frontenac Axis near Brockville in Ontario. Most of the Québec pilot study area is intensively cultivated farmland with scattered mixedwood and deciduous forests.

For the Québec pilot study we conducted PVA re-analyses for 10 surrogate species, previously selected for the eastern Ontario pilot study area. We deemed all eastern Ontario surrogate species as feasible, except the painted turtle. The painted turtle may not be a useful indicator species for developing habitat-based standards, because of the difficulties associated with defining habitat using remotely sensed data (see Pearce et al., 2007).

In collaboration with the project team and based on a thorough review of available HS models from the Québec study area (Maheu-Giroux, 2007) and the eastern Ontario study area (Akçakaya et al., 2007, Pearce et al., 2007, Noreca Consulting and Elutis Modeling and Consulting Inc., 2007; Golder Associates, 2007) each species was assigned a habitat suitability index (HSI) model. Based on the chosen HSI model David Baldwin from Spatialworks provided HS maps for all 10 surrogate species.

Figure 2: Location of the NAESI Québec pilot study area south of Montreal, Québec, Canada. The study area is approximately 4869 km^2 in size.



5 MARSH WREN (CISTHOTORUS PALUSTRIS)

The Marsh wren (*Cistothorus palustris*) is a small songbird of the wren family and inhabits fresh to brackish fens, seasonal, semi-permanent, or permanent wetlands with dense, mixed, or monotypic stands of emergent aquatic vegetation (Zimmerman et al., 2002). The Marsh wren was chosen as a surrogate species as it is a frequent inhabitant of cattail marshes in the St. Laurence Lowlands Ecoregion (see Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). A population viability analysis (PVA) conducted for the eastern Ontario pilot area showed that extinction risk in the base scenario was 25.4% and 0% in two 200 km^2 sub-study areas with different marsh densities (Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). Expected minimum abundance (EMA) was 40 and 2579 individuals and the population trend (average abundance at time step 100 divided by abundance in the first year) was 0.6 (negative) and 0.95 (nearly neutral), respectively.

5.1 Non-spatial Demographic Model

A demographic population model was developed and tested as part of a PVA study for the eastern Ontario pilot study area (see Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). We slightly modified the previous model based on a thorough analysis of the empirical study by Schriml (1993). We included fledgling rate data from 3-female harems and also took into account sample size in each of the study years. Based on this study, we assumed an average number of 2.22 fledglings per female and brood, a pre-breeding census and that juvenile from the previous year (i.e., 0-year olds) are able to breed. Thus, assuming a female-skewed sex ratio of 1:1.53 fecundity of juvenile male per female in the Leslie matrix is calculated by:

> *1.5 (# of broods per year) * 2.22 (fledging rate) * 0.38 (male sex ratio) * 0.3 (survival rate from juvenile to adult stage) = 0.379*

and

> *1.5 (# of broods per year) * 2.22 (fledging rate) * 0.62 (female sex ratio) * 0.3 (survival rate from juvenile to adult stage) = 0.619*

for female juveniles (see Table 6 for stage matrix). This translates to a finite rate of increase of 1.0815 based on a stable age distribution. In the base scenario the coefficient of variation (CV) for fecundity and survival rates was 50% and 25%, respectively (see Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). For this base scenario we found an initial minimum viable population size (MVP) of 265 males (152 juveniles and 113 adults) for a simulation time of 50 years (with an extinction risk of less than 5%). Assuming an average population density of 0.25 ha per male for cattail marshes (see Noreca Consulting and Elutis Modeling and Consulting Inc., 2007) a minimum ‘viable’ patch size of 66 ha can be calculated. However, taking into account the high variability in fecundity rates and annual territory size this estimate is subject to a high degree of uncertainty.

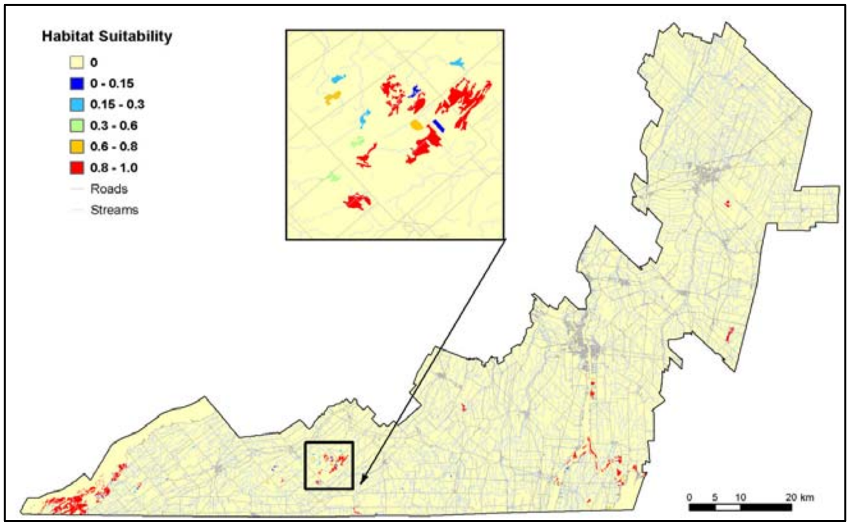
Table 5: Stage matrix for the Marsh wren demographic model.

	Female Juvenile	**Female Adult**	**Male Juvenile**	**Male Adult**
Female Juvenile	0.619	0.619	0	0
Female Adult	0.3	0.68	0	0
Male Juvenile	0.379	0.379	0	0
Male Adult	0	0	0.3	0.68

5.2 Habitat suitability model

The habitat suitability model (HSM) was based on the HS model by Maheu-Giroux (2007) with increasing suitability from 10-25 ha marsh size. In the previous HSM for the eastern Ontario pilot study area area-sensitivity was not considered although patches smaller than 0.4 ha were excluded from the spatial model analysis (see Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). The suitability of cells for the marsh wren in the Québec analysis ranged from 0.0 (unsuitable) to 1.0 for patches larger than 25 ha (highly suitable) (Figure 3). For the following PVA re-analysis we chose the Québec pilot study area HSM as it can be considered a more conservative assessment of available and suitable habitat due to the consideration of area-sensitivity.

Figure 3: HSI map for the Marsh wren in the Québec pilot study area based on the HS model by Maheu-Giroux (2007). HSI values range from 0.0 (no suitability) to 1.0 (highest suitability). Map source: Maheu-Giroux (2007).



5.3 Spatial population viability analysis

For a habitat suitability threshold of 0.5 we identified a total of 42.85 km^2 suitable marsh wren habitat distributed across 37 population patches. This total habitat amount is equivalent to approximately 0.88% of the Québec pilot study area (4,869 km^2 in size). Initial abundance was 20,149 individuals which is equivalent to 50% of the estimated carrying capacity, based on an assumed maximum population density of 10 individuals (both male and female) per ha of highly suitable marsh habitat. Other spatial model parameters were the same as in the base scenario of the eastern Ontario pilot study PVA (Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). We also assumed a coefficient of variation (CV) for K of 10% taking into account annual variations in the habitat quality (e.g., imposed through changes in water levels) (see Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). Parameters for the dispersal function were the same as in the initial PVA. However, since the spatial model was applied to the entire study area, the distance-correlation function was set so that adjacent cells exhibit 100% correlation and approximately 0% was assumed among cells with the longest distance within the study area.

The base scenario of the spatial model showed an extinction risk of 0%. Expected minimum abundance (EMA) was 10,732 individuals (EMA is the minimum abundance for each simulation run averaged over all runs). Average marsh wren abundance decreased from 20,149 adults in the initial year to 18,379 in the final year (Figure 4b). This negative change in abundance is equivalent to a population trend with an effective growth rate of 0.91 over 50 simulated years. The interval percent decline risk curve (Figure 4c) shows that approximately 40% of all simulation runs had at least one year where the metapopulation decreased to at least 50% of the initial population size. Average metapopulation occupancy rates show that approximately 31 of the 38 population patches were occupied after 50 years of simulation time. The results also show that the majority of patches were unoccupied for not more than 10 (Figure 5). Only smaller and more isolated patches such as patch 22, 32, and 35 were unoccupied for longer periods of time.

Based on the model assumptions the PVA re-analysis indicates a viable metapopulation for the NAESI Québec pilot study area. A total of 42.85 km^2 of suitable marsh wren habitat distributed across the study region provides sufficient habitat in order to allow population viability *and* near stability over 50 years. The performance target 'functionality' was not met as more than 40% of the simulation runs resulted in the metapopulation declining to at least 50% of the initial population size (functionality was not met by any scenario with a HS threshold < 0.5). The total amount of all suitable habitat patches combined is equivalent to 0.88% of the Québec study area. If the total habitat amount was decreased below this threshold (by randomly removing population patches) the performance target population stability was not met. A habitat amount of 0.88% lies within the range reported for the eastern Ontario pilot study area (0.2% - 1.2%). However, the Ontario study was based on two smaller, 200 km^2 sub-study areas and a stage matrix with a larger finite rate of increase.

Figure 4: (a) Typical simulation run for the spatial model; (b) average population trajectory for 1000 replications over 50 years; (c) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time; (d) metapopulation occupancy over 50 years showing the average number of patches occupied. Extinction risk for the base scenario was 0%, expected minimum abundance (EMA) 10,732; average population abundance decreased from 20,149 adults in the initial year to 18,379 in the final year.

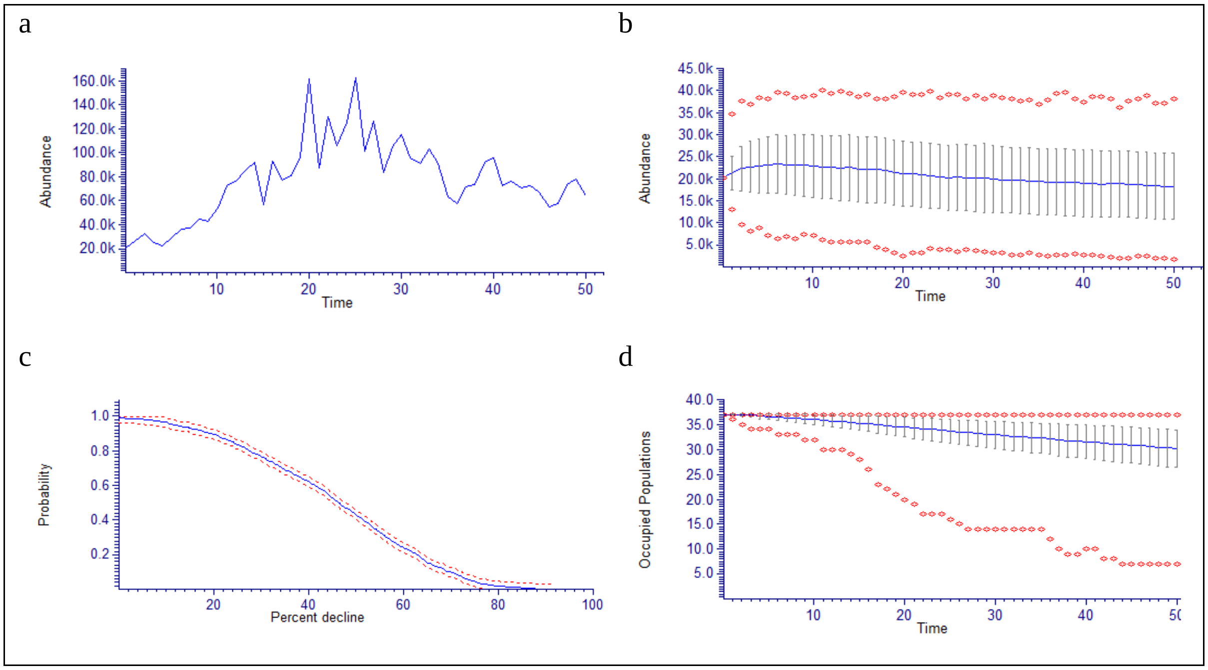
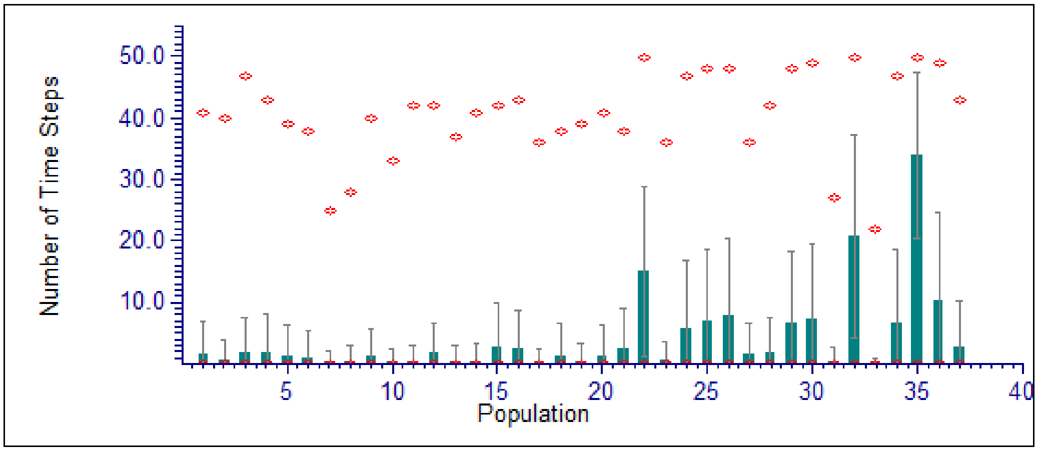


Figure 5: Local extinction duration for all populations. The bars show the average number of time steps that a patch is unoccupied.



5.4 Recommendations for habitat-based standards

Based on empirical data and the updated PVA study for the Québec pilot study area we suggest the following set of habitat-based standards:

- a minimum patch size of 2 - 10 ha to avoid patches being a strong population sink (depending on habitat quality)
- a minimum patch size of approx. 65 ha of suitable habitat (based on an average population density of 0.25 ha per male) to support a single, viable population over 50 years with 95% confidence
- a minimum amount of 0.9% suitable marsh habitat to support a viable and stable metapopulation on the NAESI Québec study area scale (4869 km^2) (subject to patch size distribution)
- a maximum inter-patch distance of 2 km to allow sufficient natal and breeding dispersal

6 OVENBIRD (SEIURUS AUROCAPILLUS)

The ovenbird (*Seiurus aurocapillus* L.) is a common long-distance neotropical migratory passerine that breeds across Canada from northeast British Columbia to Newfoundland and south to North Carolina in the United States. Ovenbirds typically breed in large, mature deciduous forests where they build a domed nest of leaves and grass on the ground. Due to current fragmentation and loss of habitat in the eastern Ontario pilot study area a previous PVA showed relatively high risks of extinctions for a wide range of model scenarios (Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). Extinction risk was high and population trends strongly negative for all sampled sub-populations in the eastern Ontario pilot region. The base scenario for a sub-area with the highest average deciduous and mixed forest cover in the NAESI pilot project area exhibited an extinction risk of 69% after 50 years of simulation time.

6.1 Non-spatial demographic model

A demographic population model was developed and tested as part of a PVA study for the eastern Ontario pilot study area (see Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). However, a re-analysis revealed that the Larsen et al. study (2004), upon which the stage matrix was based, did not fully represent a Leslie stage matrix. The fecundity rates did not include survival rates from the juvenile to the adult stage. This is a common mistake in many PVA studies. We therefore did a re-analysis using an average fecundity of 2.8 fledglings per female per year based on the original study and multiplying this by a juvenile survival rate of 0.31 and a sex ratio of 0.5. Using the same adult survival rate as in Larsen et al. (2004) (i.e., 0.623) this translates to a pre-breeding census stage matrix with a lambda of 1.0570 and a fecundity of the juvenile and adult stage class of 0.434 (see Table 6).

Table 6: Ovenbird stage matrix comprised of fecundity (first row) and survival rates for the two stages (with standard deviations).

	juvenile	**adult**
juvenile	0.434 (±0.13)	0.434 (±0.13)
adult	0.623 (±0.093)	0.623 (±0.093)

The coefficients of variation for fecundity and survival were 30% and 15% as in the original study, respectively. Based on this scenario we found an initial MVP size of 102 females (female juveniles and adults) for a time frame of 50 years (less than 5% extinction risk), i.e., a total of 204 adult ovenbirds assuming an equal sex ratio. For eastern Ontario in the vicinity of the NAESI pilot project study area, average densities for occupied patches are reported at 0.12 male/ha (SD=0.14) or 8.3 ha/male (Lee et al., 2002) (i.e., 0.24 individuals/ha or 4.16 ha/individual) which is within the reported range for other breeding areas (see Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). Based on these estimates we calculated a minimum viable patch size of 850 ha for an ovenbird population to be persistent over 50 years with a confidence of 95%.

6.2 Habitat Suitability Model

The HSM for the PVA re-analysis was based on the model for the eastern Ontario pilot study area (Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). We decided to use the eastern Ontario model version as in the Québec model patch size is already built into the HS index. However, in the ovenbird PVA pairing success and, thus, fecundity needs to be calculated based on the size of a patch. The HSI value for each cell in the spatial ovenbird model is determined by multiplying the HSI value of forest type (NAESI classes Q2001-2008 mixed forest = 0.75; Q3001-3007 deciduous forest = 1.0) by forest age (Table 7) and reducing this value by 50% if a habitat cell is located within 50 m of an edge to an open or near-open habitat (non-forested NAESI classes: Q4011-Q5005, Q6101-Q9008) (see Lee et al., 2002 for edge effects). The resulting HS map for the Québec pilot study area is shown in Figure 7. Due to computational constraints with RAMAS©GIS three case study areas were selected (Figure 6 – 9) (see next section for details).

Table 7: Index values for forest age classes in the ovenbird HIS model.

Uneven-aged stands	**HSI**
Young (< 80 yrs)	0.6667
Old (> 80 yrs)	1.0
Even-aged stands and stands with two distinct canopies (midpoints)	
Age 10	0.166667
Age 30	0.5
Age 50	0.833333
Age 70	1
Age 90	1
Age 120	1

Figure 6: **HSI map for the ovenbird in the Québec pilot study area based on the eastern Ontario HS model (Noreca Consulting and Elutis Modeling and Consulting Inc., 2007). HSI values range from 0.0 (pink; no suitability) to 1.0 (brown; highest suitability). Three case study areas were selected, each 250 km^2 in size (from bottom to top: 1-3).**

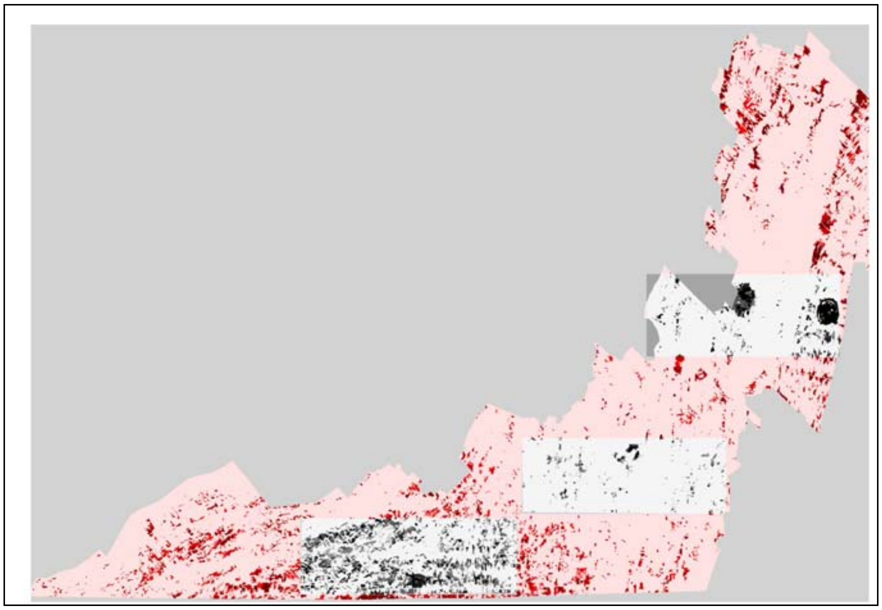


Figure 7: **HSI map for case study area 1 (250 km^2 in size). HSI values range from 0 (light gray) to 1.0 (black).**

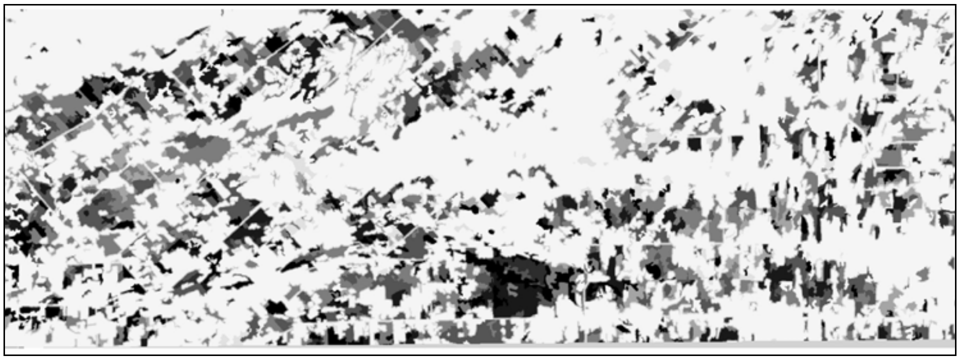


Figure 8: HSI map for case study area 2 (250 km^2 in size). HSI values range from 0 (light gray) to 1.0 (black).

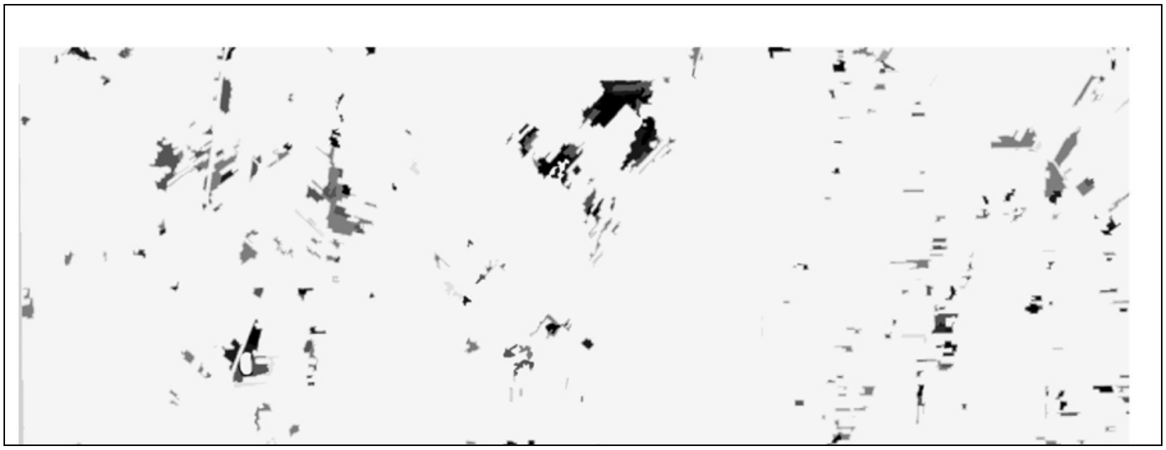


Figure 9: HSI map for case study area 3 (250 km^2 in size). HSI values range from 0 (light gray) to 1.0 (black).

6.3 Spatial Population Viability Analysis

Based on average territory sizes from Ontario (0.61 – 1.6 ha; Stenger, 1958) we estimated a neighborhood distance of 2 cells (i.e., 60 m). The habitat suitability threshold was set at 0.5. Due to the high degree of fragmentation in the Québec study area this parameterization exceeds the number of maximum populations RAMAS©GIS can handle (>500). We therefore decided to run the spatial model on three case study areas with different forest cover values (Figures 6-8). Each case study area is approximately 250 km^2 in size and differs in terms of forest cover, number of populations, and carrying capacity (Table 8). The carrying capacity K is based on maximum reported population densities of 1 female per ha (see references in Noreca Consulting and Elutis Modeling and Consulting Inc., 2007) and is calculated by multiplying total habitat suitability in a patch times K. We furthermore applied a threshold of 5 females (i.e., 5 breeding pairs) that a population patch needs to support, otherwise the model might overestimate carrying capacity in the landscape and include patches that are too small in size. Finally, as in the original model, pairing success is calculated as a function of patch size: pairing success increases linearly from 0.5 to 1.0 until a threshold of 250 ha (see Noreca Consulting and Elutis Modeling and Consulting Inc., 2007 including the original empirical studies herein). In other words, fecundity is reduced to a maximum of 50% for very small patches with a carrying capacity of ~5-10 females and larger patches with a minimum size of 250 ha will have the same fecundity as in the stage matrix. Thus, the intrinsic rate of increase in the stage matrix is reduced to a lambda as low as 0.8748 and therefore a large proportion of sink patches is expected to be present (due to the high number of small, fragmented habitat patches). All other parameters including the dispersal function are the same as in the initial PVA. The distance-correlation function was set so that adjacent cells exhibit 100% correlation and cells with the longest distance apart approximately 50%.

Table 8: Amount of suitable habitat, number of populations, carrying capacity K and initial abundance for three ovenbird case study areas in the Québec pilot study area. Initial abundance is 50% of the carrying capacity.

Study area	Suitable habitat (km^2)	Amount (%)	# of populations	K	Initial abundance
1	113.3 km^2	45.3	180	7627	3813
2	11.7 km^2	4.7	37	822	409
3	46.1 km^2	18.4	62	3784	1891

Figure 10: (a) Average population trajectory for 1000 replications over 50 years; (b) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time; (c) metapopulation occupancy over 50 years showing the average number of patches occupied. Extinction risk for case study area 1 was 0%, expected minimum abundance (EMA) 391; average population abundance decreased from 3,813 adults in the initial year to 581 in the final year.

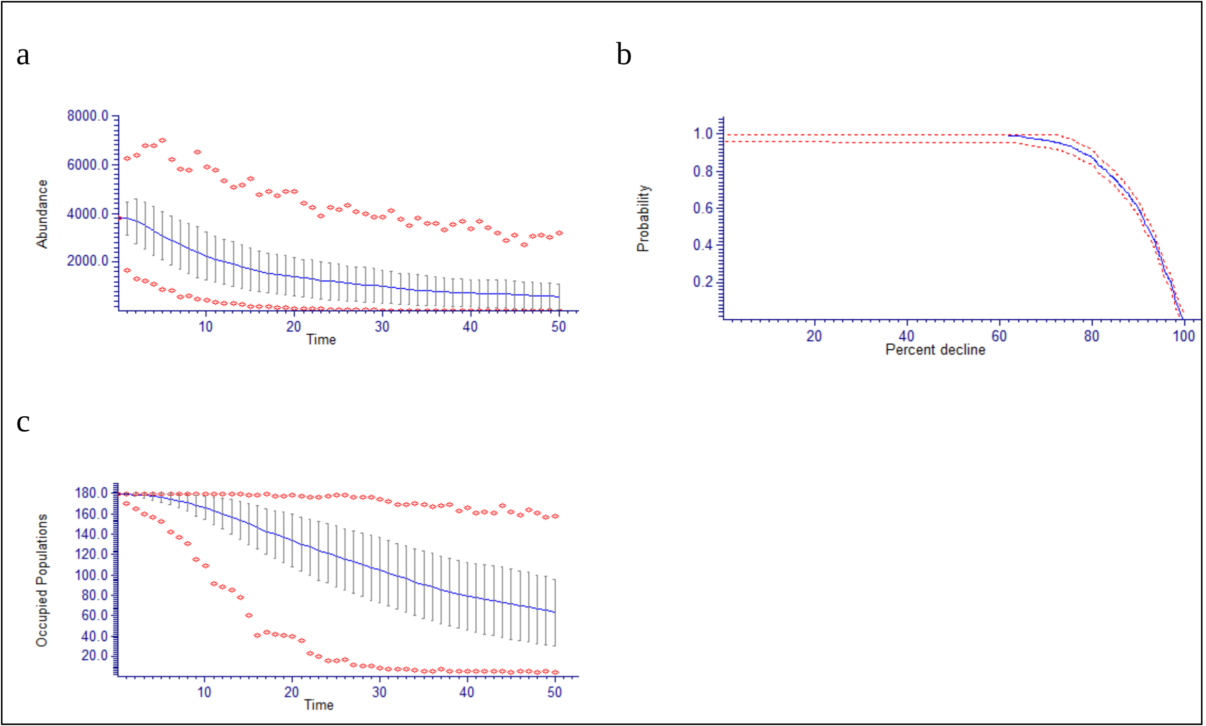
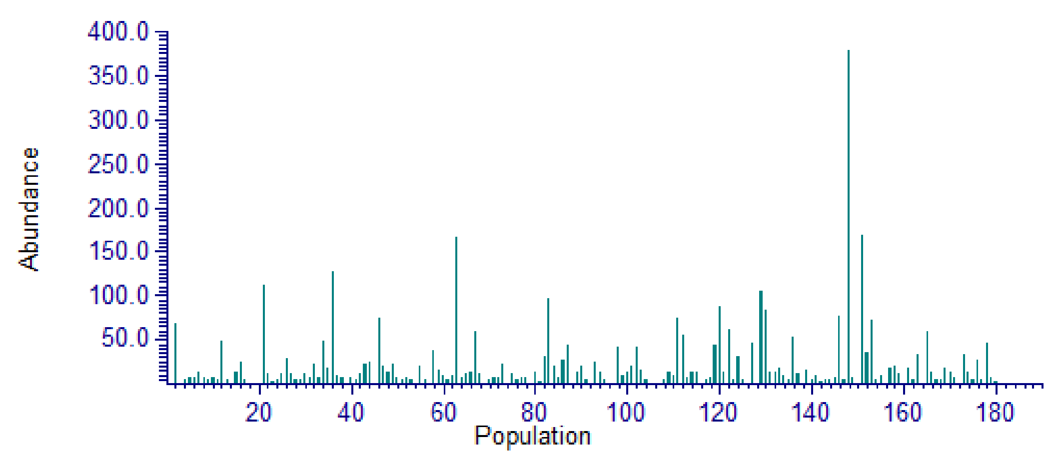


Figure 11: Population structure (average abundance after 50 years) for case study area 1 (1000 replicates).



The base scenario of the spatial model for study area 1 with 45.3% suitable habitat showed an extinction risk of 0% (Figure 10). Expected minimum abundance (EMA) was 391 individuals. Average ovenbird abundance increased from 3,813 adults in the initial year to 581 in the final year (Figure 10a). This change in abundance is equivalent to a negative population trend with an effective growth rate of 0.15 over 50 simulated years. The interval percent decline risk curve (Figure 10b) shows that approximately 100% of all simulation runs had at least one year where the metapopulation decreased to more than 50% of the initial population size. Average metapopulation occupancy rates show that approximately two thirds of all population patches went extinct after 50 years of simulation time. The strong decline in abundance (despite a 0% risk of extinction) was largely due to small populations acting as population sinks (Figure 10). Such sink populations have a patch size of less than 200 ha (equivalent to a pairing success of 87% and an intrinsic rate of increase of ~1.0) and a carrying capacity of less than 200 females (depending on the suitability of that patch). Only one population with an average population abundance of more than 350 females after 50 years can be considered as sustainable (Figure 10).

For study area 2 and 3 the model generated different results and furthermore highlights the importance of area sensitivity and source-sink dynamics in ovenbirds. For area 2 with 4.7% of suitable habitat extinction risk was 26.4% and EMA was 17 females. The metapopulation declined from an initial 409 individuals to 31 in the final year (effective growth rate of 0.075) (Figure 12a). All patches in this case study area are below 200 ha in size and thus have a negative intrinsic rate of increase due to low pairing success. This model result changed dramatically when the same analysis was conducted for case study area with 18.4% of suitable habitat. This area provides less than 50% of the habitat amount provided in case study area 1. However, it contains two very large patches of continuous forest that are self-sustainable and which represent nearly

80% of the total metapopulation carrying capacity in this area (see also average population structure in Figure 13). For this study area extinction risk was 0%, EMA 987 females and population abundance declined from 1891 in the first year to 1544 in the final year (effective growth rate of 0.81). Thus, even though total habitat amount in this area is significantly lower than in area 1 (18.4% compared to 45.3%) this case study area generated the best model performance (i.e., 0% extinction risk and 0.81 effective population growth).

By applying these three different case study areas with significant variations in patch size distributions we have shown that abundance loss via population sinks (considering no immigration from outside the case study areas) can be a major driver for population stability. Thus, minimum patch size need to be explicitly considered for recommending any habitat standards related to population stability. Overall, ovenbird populations appear viable (in the Québec study area) if at least a few large and sustainable patches of continuous forest habitat are available. The performance goal of functionality was not met by any of the modeling scenarios. If more than 10-15% of the total population abundance in an area is distributed across smaller, fragmented forest patches it is very unlikely that the metapopulation will be near stable (i.e., <10% population decline) over longer periods of time (without any immigration from outside).

Figure 12: Simulation results for case study area 2 (a and b) and 3 (c and d); (a) and (c) show average population trajectory for 1000 replications over 50 years; (b) and (d) metapopulation occupancy over 50 years showing the average number of patches occupied. Extinction risk was 26.4% (area 2) and 0% (area 3), expected minimum abundance (EMA) 17 (area 2) and 987 (area 3); average population abundance decreased from 409 adults in the initial year to 31 in the final year (area 2) and from 1891 to 1544 females (area 3).

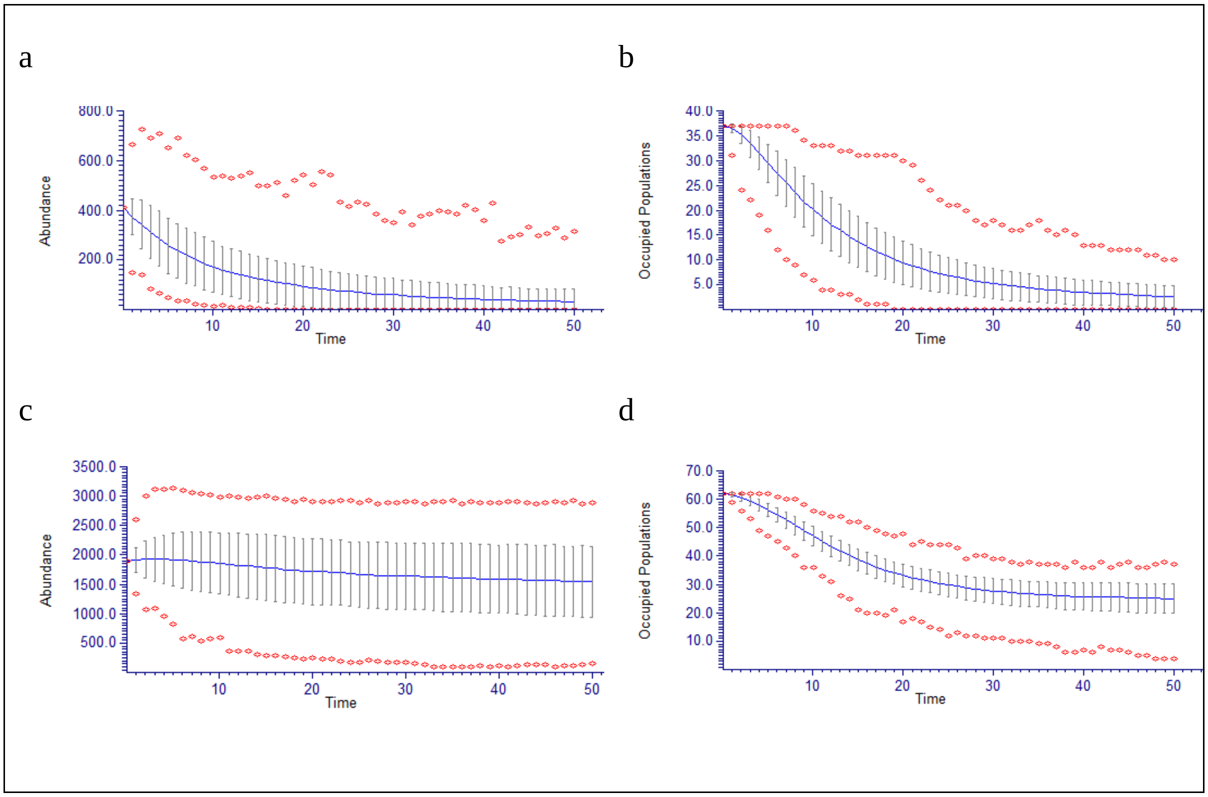


Figure 13: Population structure (average abundance after 50 years) for case study area 3 (1000 replicates).

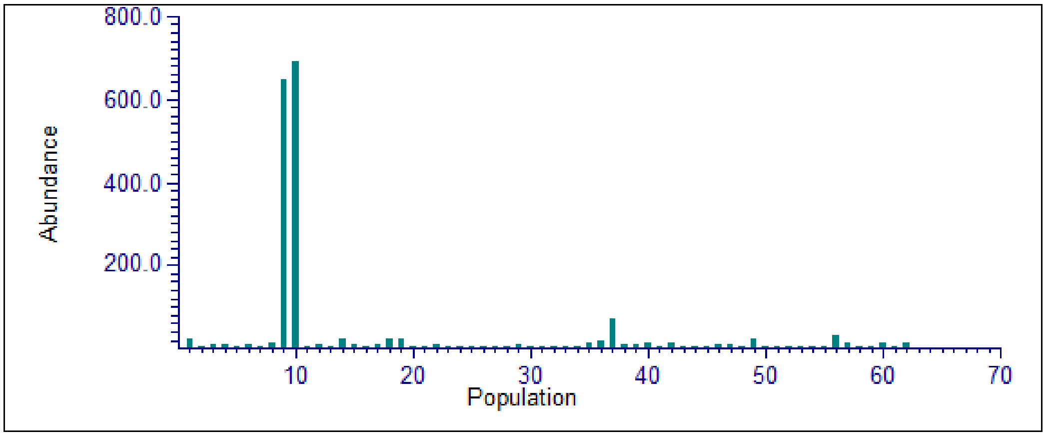
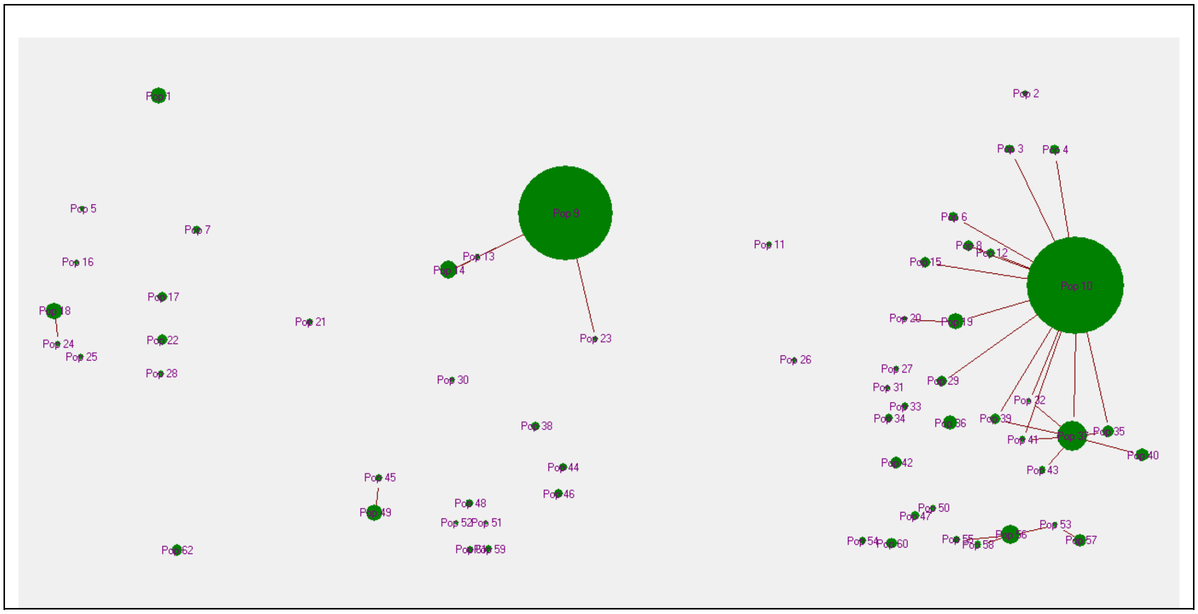


Figure 14: Spatial metapopulation structure for case study area 3. Note the two large population patches that contain nearly 80% of the total carrying capacity.



6.4 Recommendations for Habitat-Based Standards

Based on the PVA study for the eastern Ontario (Noreca Consulting and Elutis Modeling and Consulting Inc., 2007) and the Québec pilot study area (this report) we suggest the following re-defined set of habitat-based standards:

- a minimum patch size of 200 ha of highly suitable forest habitat to avoid patches being a population sink (based on the assumed stage matrix and a minimum of 87% pairing success resulting in a minimum intrinsic rate of increase of 1.0)
- a minimum patch size of 850 ha of suitable habitat (based on an average population density of 0.24 individuals/ha) to support a single, viable population over 50 years with 95% confidence
- a minimum amount of 20% - 40% suitable forest habitat at a spatial scale of 250 km^2 to support a viable metapopulation over 50 years (depending on the patch size

distribution)

- a minimum of 80-90% of the total population abundance distributed across large, self-sustainable forest patches (lambda>1.0, ~200 ha) to support near stable population trends

7 RED-SHOULDERED HAWK (*BUTEO LINEATUS*)

The Red-shouldered Hawk (*Buteo lineatus*) is a raptor species that nests in mature forest stands, but depends on riparian areas, woody swamps, and wetland margins for foraging activities The Red-shouldered Hawk was selected as a surrogate species in the eastern Ontario pilot study area due to its habitat area requirements, large home range, and dependence on forest interiors. For the base scenario (i.e., medium values for all demographic parameters) in the eastern Ontario pilot study area PVA 2 habitat patches were identified with an extinction risk of 1.4% for a threshold of 250 individuals and a simulation time of 50 years (Akçakaya et al., 2007). Median growth rate as a measure of population stability (ratio of median final abundance to initial abundance) was 0.7224, indicating a decline from initial abundance. Overall, the medium model resulted in a declining population, albeit one which appears to be stabilizing eventually at approximately 80% of its initial abundance.

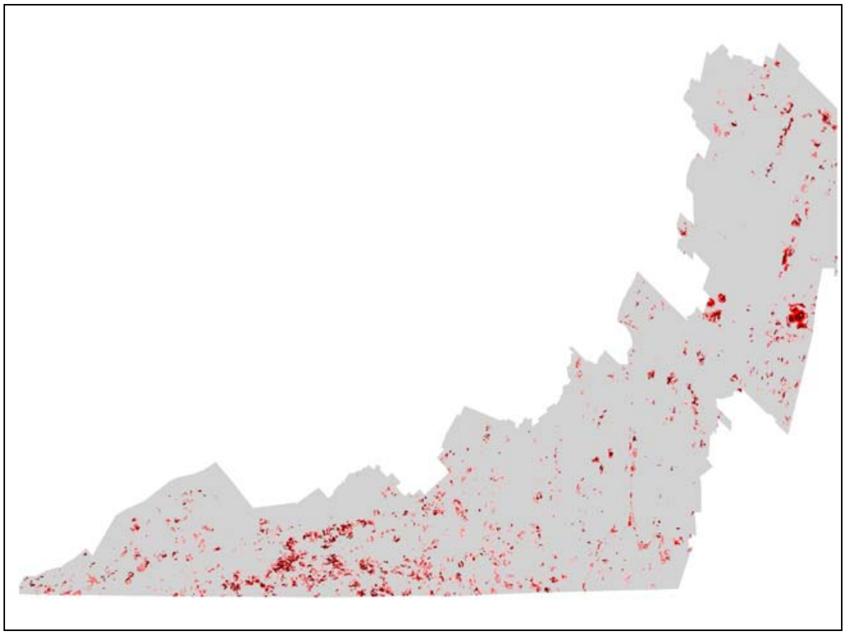
7.1 Non-Spatial Demographic Model

A demographic population model was developed as part of a PVA study for the eastern Ontario pilot study area (see Akçakaya et al., 2007). The intermediate scenario was based on a medium parameterization for the stage matrix and variability in vital rates and a contest competition density dependence function with a maximum growth rate of 1.1 (Akçakaya et al., 2007). For this base scenario an initial MVP size of 60 individuals is needed to ensure an extinction risk of less than 5% over a time frame of 50 years (assuming that initial population size is equivalent to the carrying capacity). Based on a stable age distribution, 73.8% of the individuals are breeding adults and therefore initial MVP corresponds to approximately 44 breeding adults of Red-shouldered hawk. Average population density in six studies was 0.85 nests per km^2 (see references in Akçakaya et al., 2007) which corresponds to 1.7 breeding individuals per km^2. Thus, based on this information we can calculate a minimum viable patch size of 25.9 km^2 of suitable habitat such as mature hardwood and mixed forests with closed canopies and proximity to water and wetlands.

7.2 Habitat Suitability Model

Akçakaya et al. (2007) developed a HS model for the eastern Ontario pilot study area that we utilized for the Québec study area. However, this model overestimates the area of suitable habitat as it gives all deciduous and mixed forest and swamp types an equal habitat suitability value of 1.0. In collaboration with the project team we improved these estimates by using the Bouvier and Howes Eastern Ontario Habitat Suitability Matrices (Bouvier and Howes, 1997) and adjusted the HS scores by giving the following NAESI land cover classes a score of 0.5: Q2001 – Q2002, Q2005 – Q2006, Q2008, Q3002, Q3006, and Q4006 – Q4010. A HS score of 1.0 was given for: Q2003, Q3001, Q3003-3005, and Q3007. The overall habitat suitability scores for the Red-shouldered hawk ranged from 0.0 (unsuitable) to 1.0 for cells with highest suitability.

Figure 15: HSI map for the Red-shouldered hawk in the Québec pilot study area based on the modified eastern Ontario HS model. HSI values range from 0.0 (no suitability, pink) to 1.0 (highest suitability, brown).



7.3 Spatial Population Viability Analysis

For a habitat suitability threshold of 0.2 (intermediate scenario in Akçakaya et al., 2007) and a neighborhood distance of 1.7 km (intermediate value, based on empirical estimates of average breeding home ranges, see Akçakaya et al., 2007) we identified a total of 287.2 km^2 suitable habitat distributed across 12 population patches (Table 9). This amount of suitable habitat is equivalent to approximately 5.89% of the Québec pilot study area (4,868.91 km^2). To avoid overestimations of the carrying capacity and the inclusion of small habitat fragments this result is also based on a local patch threshold of 4 individuals above which a population will only be considered (see Akçakaya et al., 2007). This is consistent with the suggestion that this species prefers patches >100 ha. But, it is also consistent with the suggestion that it may utilize patches as small as 10 ha. Carrying capacity was estimated at 3.79 individuals per km^2 (including non-breeding individuals from the juvenile stage) based on maximum reported population densities (see Akçakaya et al., 2007). Increasing the HS to 0.3 resulted in 11 population patches with an area of 221.4 km^2 (equivalent to 4.54% habitat amount) and a carrying capacity of 462 individuals (note that abundance includes both males and females) (Table 9).

Table 9: Habitat suitability thresholds scenarios for the Red-shouldered Hawk model and their effects on area, habitat amount, number of patches, carrying capacity (K), and initial abundance.

HS threshold	Area (km^2)	Amount (%)	# of pop.	K	Initial abundance
0.1	319.6	6.56	14	544	274
0.2	287.2	5.89	12	521	260
0.3	221.4	4.54	11	462	232
0.4	200.3	4.11	11	437	217

For the interpretation of our model results we did not use a quasi-extinction threshold (as in the original study) where persistence probability is defined as the probability that the population will remain above a certain threshold for the entire duration of a simulation. Other spatial model parameters such as dispersal and the correlation-distance function were the same as in the base scenario of the eastern Ontario pilot study PVA (Akçakaya et al., 2007).

For a habitat suitability threshold of 0.2 and a starting population of 260 individuals (both sexes and all stages included) extinction risk was 0% over a simulation time of 50 years (Figure 16b). The population trend was negative with a 55% decline in abundance (effective growth rate = 0.45). Metapopulation occupancy rates were high due to relatively large dispersal distances of Red-shouldered hawk (Figure 16d, 17a). However, even though populations in the Québec pilot study area appear to be viable (based on the model assumptions) they were neither stable nor functional over the simulated trajectory. This is partly a result of several populations being smaller and below the minimum viable population size of 44 breeding adults (Figure 22).

We then assessed at which amount of habitat supply (assuming the intermediate demographic model provided in Akçakaya et al., 2007) metapopulations may become stable and/or functional. Decreasing the habitat suitability threshold to 0.1 (i.e., increasing the amount of suitable habitat) resulted in 319.6 km^2 of habitat (6.56% habitat amount) distributed across 14 populations with a total carrying capacity of 544 individuals (Table 9). Extinction risk for this scenario was 0%, EMA 152 individuals with the population declining from 274 in the initial year to 233 in the final year (Figure 18a). Thus, the metapopulation was still unstable (effective growth rate = 0.85) and showed no functional presence. In the case of Red-shouldered hawk the high risk of interval percent decline (Figure 18b) is primarily due to its low population size with a considerable degree of demographic stochasticity.

Figure 16: Simulation results for a habitat suitability threshold of 0.2: (a) typical simulation run for the spatial model; (b) average population trajectory for 1000 replications over 50 years; (c) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time; (d) metapopulation occupancy over 50 years showing the average number of patches occupied. Extinction risk was 0.1%, expected minimum abundance (EMA) 92.7; average population abundance decreased from 260 adults in the initial year to 119 in the final year.

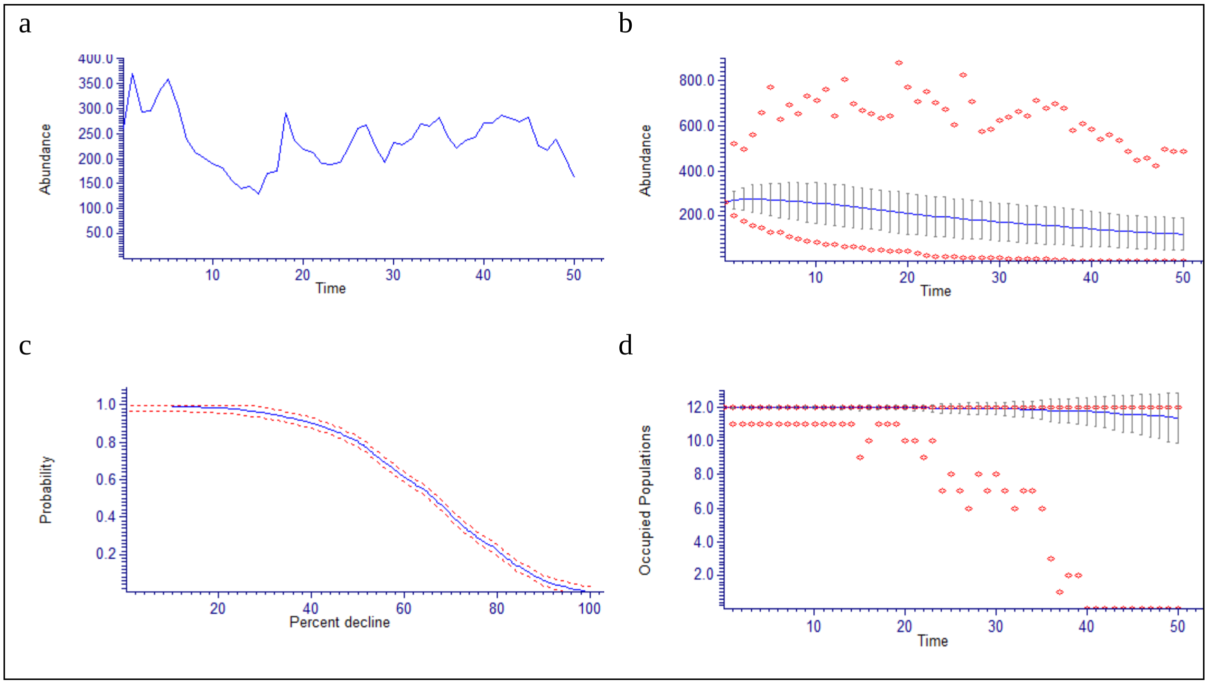


Figure 17: (a) Metapopulation structure for the base scenario with a suitability threshold of 0.2 and a neighborhood distance of 1.7 km; (b) average population structure (abundance) after 50 years of simulation.

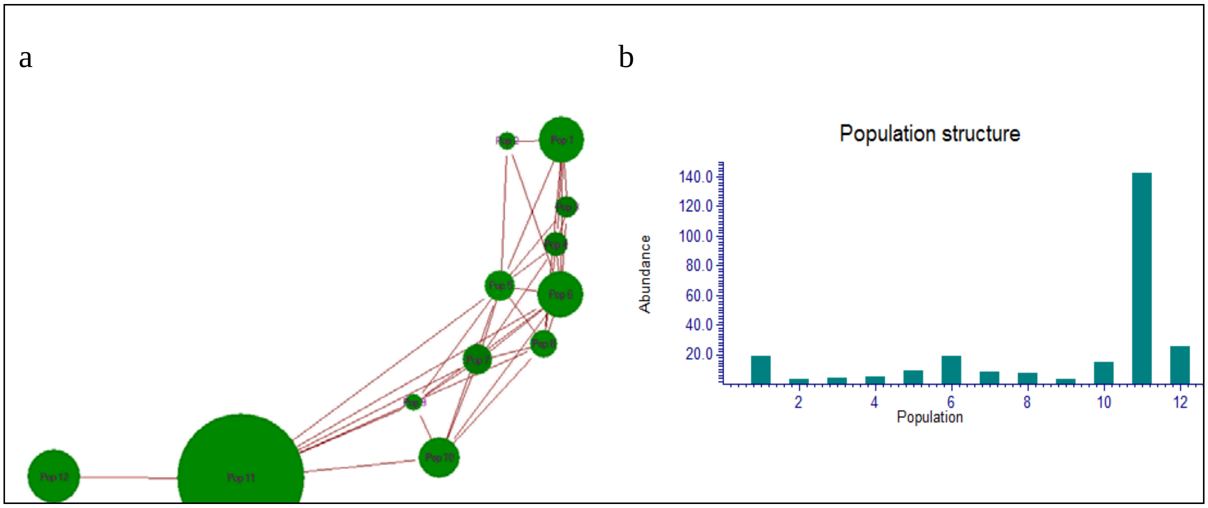
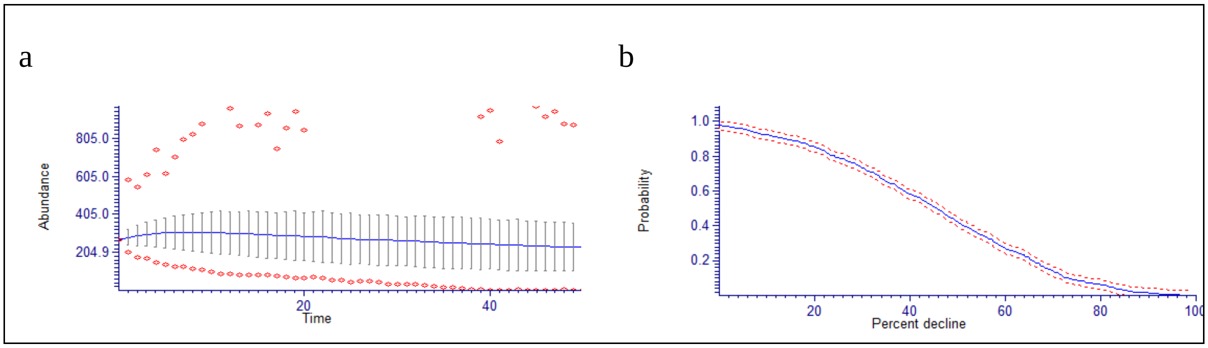
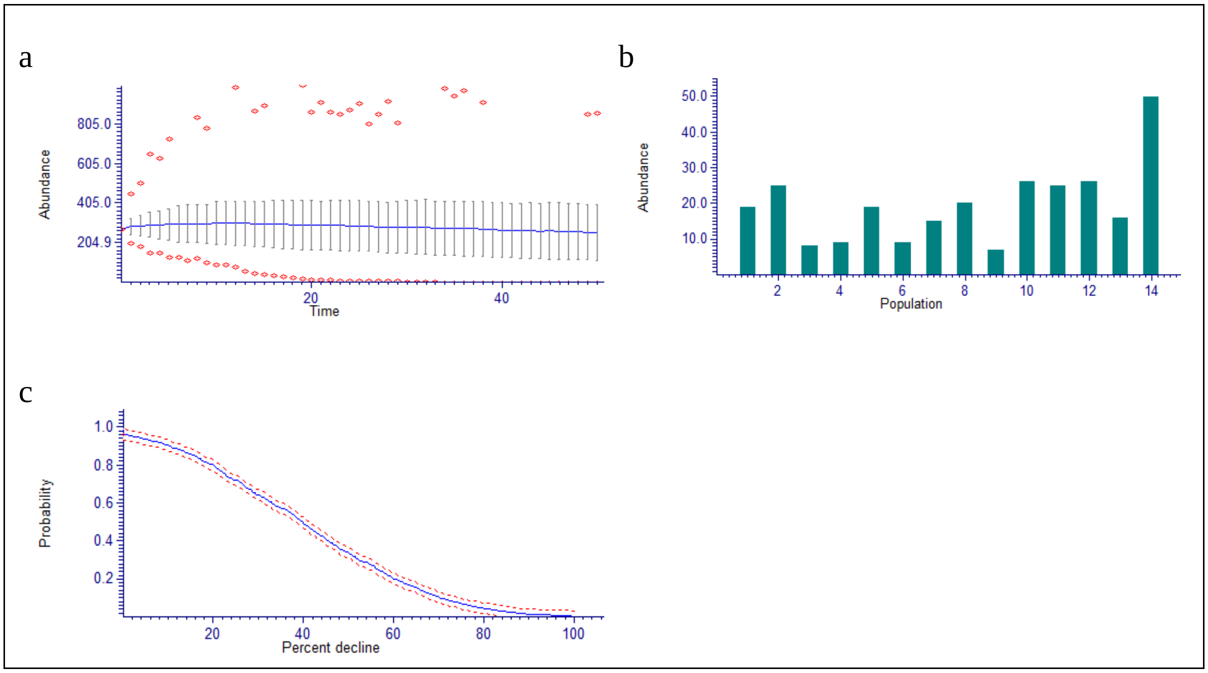


Figure 18: (a) average population trajectory for 1000 replications over 50 years; (b) interval percent risk of decline; extinction risk for a habitat suitability threshold of 0.1 was 0%, expected minimum abundance (EMA) 152; average population abundance decreased from 274 adults in the initial year to 233 in the final year.



We then hypothesized that the population decline is due to the low abundance (i.e., small patch size) of many local populations with most of them below the minimum viable population size (i.e., 44 breeding adults). We therefore reduced the carrying capacity of the largest patch (# 11, Figure 17b) and distributed the surplus to smaller patches resulting in a more equal patch size distribution (Figure 19b). This resulted in a near stable population trend of 0.93 (i.e., a 7% decline from initial to final population size). EMA for this scenario was 154 with an extinction risk 0%. In other words, under an optimal patch size distribution a habitat amount of 6.56% is sufficient to support a viable *and* stable metapopulation (performance target of <5% extinction risk and <10% population decline for a time frame of 50 years). However, note that this does not apply to current landscape conditions in the Québec pilot study area due to the high degree of fragmentation. Therefore, for most agriculture dominated landscape we suspect that this threshold may be significantly higher, in particular, if the assumed neighborhood distance (i.e., home range) in the model is smaller than estimated.

Figure 19: Simulation results with a HS threshold of 0.1 and a modified patch size distribution (see text): (a) average population trajectory for 1000 replications over 50 years; (b) average population structure (abundance) after 50 years of simulation; (c) functionality measured as risk of interval percent decline; extinction risk was 0%, expected minimum abundance (EMA) 154; average population abundance decreased from 274 individuals in the initial year to 255 in the final year.



7.4 Recommendations for habitat-based standards

Based on the PVA study for the eastern Ontario (Akçakaya et al., 2007) and the Québec pilot study area (this report) we suggest the following set of habitat-based standards:

- a minimum patch size of 26 km^2 of suitable habitat (based on an average population density of 1.7 breeding individuals per km^2) to support a single, viable population over 50 years with 95% confidence
- a minimum amount of 6.6% of suitable habitat to support viable and stable populations on the NAESI Québec study area scale (4,869 km^2) under optimal patch size distribution; if the metapopulation contains a significant proportions of smaller patches that are not in proximity of each other (with a total area below the minimum viable patch size) the recommended habitat amount may be significantly higher.

8 AMERICAN BITTERN (BOTAURUS LENTIGINOSUS)

The American Bittern (*Botaurus lentiginosus*) inhabits marshes, wet meadows, swamps, bogs, and riparian vegetation. It was chosen as a surrogate species for these habitat types due to its habitat area requirements, large home range, and sensitivity to human disturbance. A PVA study for the eastern Ontario pilot study area suggests that current habitat availability may not be sufficient to support longer term viability. For the base (i.e., medium) scenario with 9 identified habitat patches extinction risk (i.e., viability) was 1.7% for a threshold of 100 individuals (simulation time was 50 years). Median growth rate (i.e., stability) was 0.55 indicating a substantial decline from initial abundance. Functional presence (measured as one minus risk of interval decline to a threshold of 167 individuals) was 0.42.

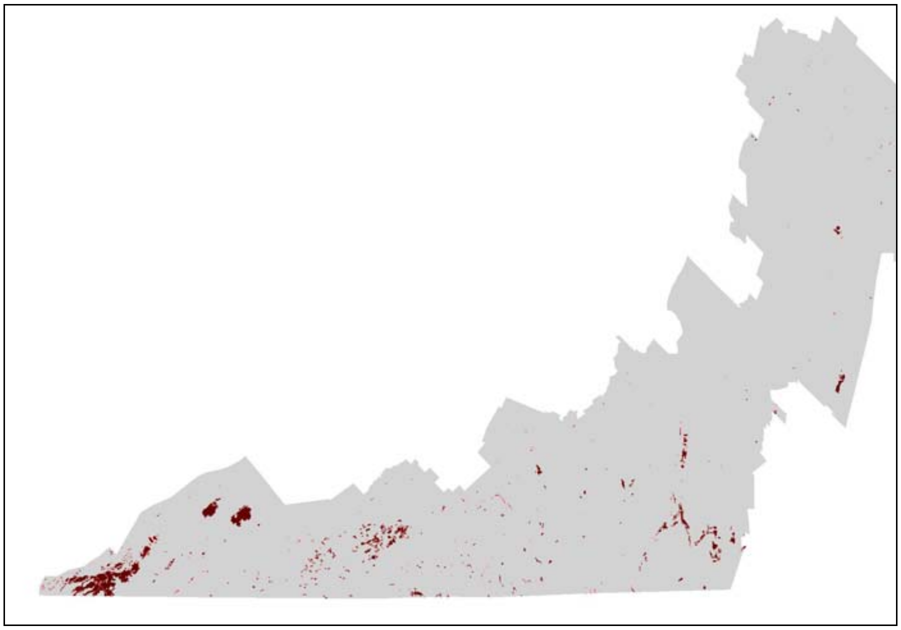
8.1 Non-Spatial Demographic Model

A demographic population model was developed as part of a PVA study for the eastern Ontario pilot study area (see Akçakaya et al., 2007). The intermediate scenario was based on a medium parameterization for the stage matrix and variability in vital rates and a contest competition density dependence function with a maximum growth rate of 1.1 (Akçakaya et al., 2007). For this base scenario an initial MVP size of 48 individuals is needed to ensure an extinction risk of less than 5% over a time frame of 50 years (assuming that the carrying capacity is equivalent to the initial population size). Based on the study by Gibbs et al. (1992), Brininger (1996), and Wiggins (2006) (see Akçakaya et al., 2007) we used an average population density of 127 ha per male (which corresponds to 1.57 breeding individuals per km^2) to calculate a minimum viable patch size of 30.6 km^2.

8.2 Habitat Suitability Model

The habitat suitability model for the Québec PVA re-analysis was based on the model developed for the eastern Ontario pilot study area (see Akçakaya et al., 2007 for details). The habitat suitability scores for the American bittern ranged from 0.0 (unsuitable) to 1.0 for suitable wetland cells with no adjacent disturbance (i.e., without rural development, urban areas).

Figure 20: HSI map for the American Bittern in the Québec pilot study area based on the eastern Ontario HS model (see Akçakaya et al., 2007). HSI values range from 0.0 (no suitability) to 1.0 (highest suitability).



8.3 Spatial population viability analysis

For a habitat suitability threshold of 0.2 and an intermediate neighborhood distance of 1.3 km (based on empirical estimates of average breeding home ranges, see Akçakaya et al., 2007 for details) we identified a total of 71.18 km^2 suitable habitat distributed across 9 population patches. This amount of suitable habitat is equivalent to approximately 1.46% of the Québec pilot study area (4,869 km^2). As a comparison, the same parameterization resulted in approximately 3.5% habitat amount in the eastern Ontario pilot study area.

As in the original study, a population of fewer than 5 individuals, i.e., 0 to 2 breeding pairs was used as a threshold to exclude small habitat fragments which might overestimate carrying capacity. The carrying capacity was otherwise based on the density of calling males observed in Maine with 5.2 breeding individuals per km^2 (see Akçakaya et al., 2007). Initial abundance was equivalent to 50% of the estimated carrying capacity. We did not introduce a quasi-extinction threshold as in the original study where persistence probability was defined as the probability that the population will remain above a certain threshold for the entire duration of a simulation (50, 100 or 250 individuals, respectively. Other spatial model parameters such as dispersal and correlation-distance function were the same as in the base scenario of the eastern Ontario pilot study PVA (Akçakaya et al., 2007).

Figure 21: (a) Typical simulation run for the spatial model; (b) average population trajectory for 1000 replications over 50 years; (c) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time; (d) metapopulation occupancy over 50 years showing the average number of patches occupied. Extinction risk for the base scenario was 0%, expected minimum abundance (EMA) 97 individuals; average population abundance increased from 164 adults in the initial year to 114 in the final year.

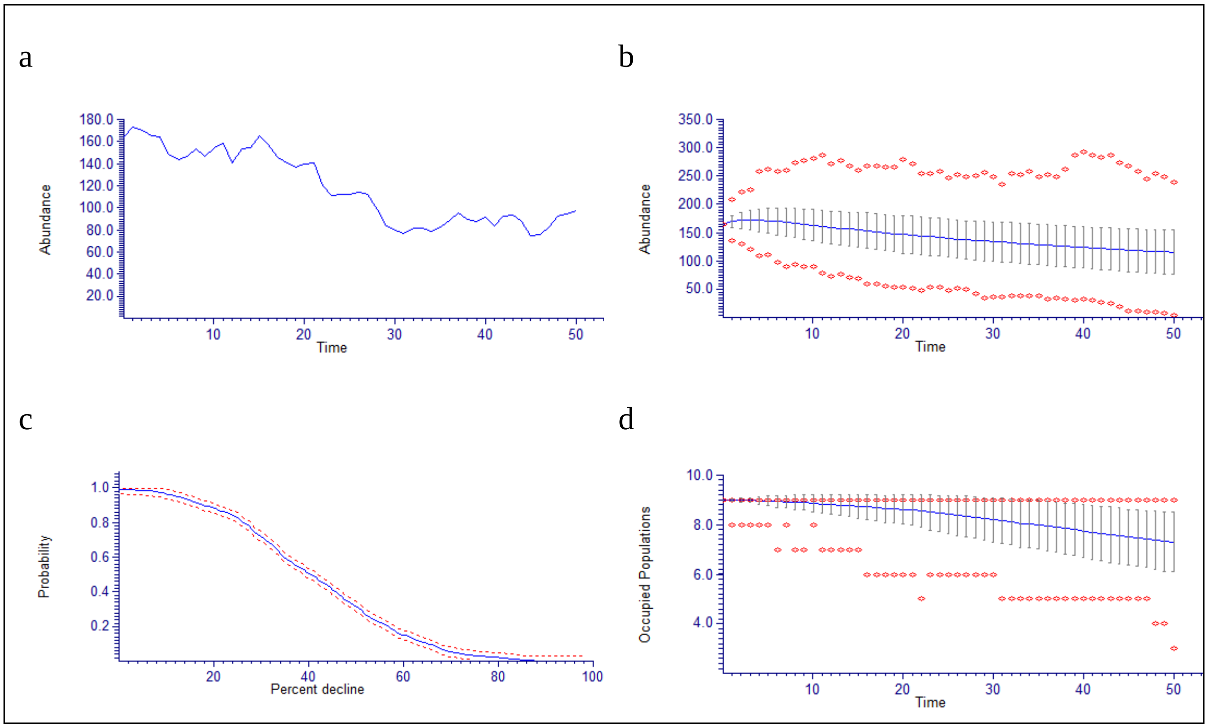
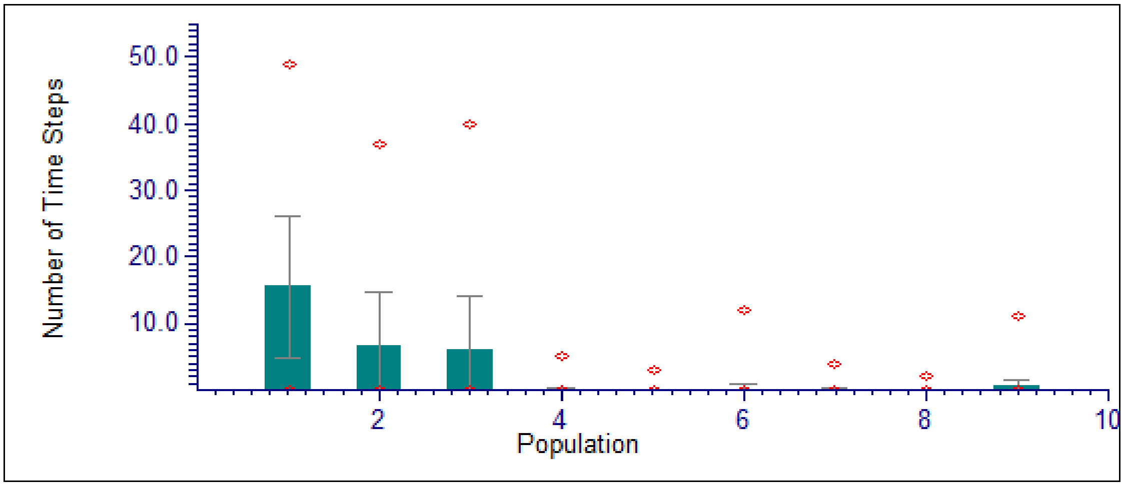


Figure 22: Local extinction duration for all populations. The bars show the average number of time steps that a patch is unoccupied. Populations 1, 2 and 3 are smaller, isolated patches in the north-eastern portion of the study area (see Figure 1).

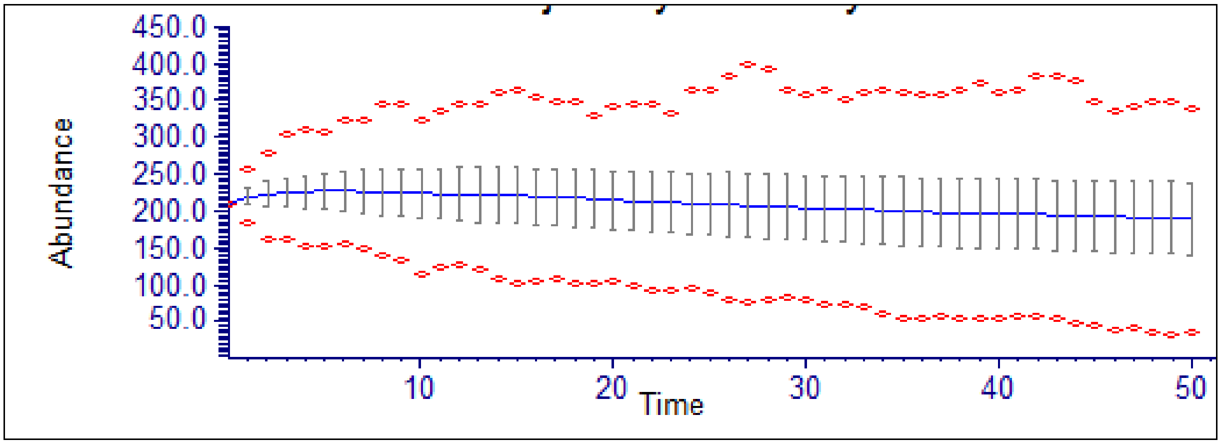


The base scenario of the spatial model showed an extinction risk of 0%. Expected minimum abundance (EMA) was 97 individuals. Average abundance decreased from 164 adults in the initial year to 114 in the final year (Figure 21). The negative change in abundance is equivalent to a population trend with an effective growth rate of 0.70 over 50 simulated years. The interval percent decline risk curve (Figure 25) shows that approximately 30% of all simulation runs had at least one year where the metapopulation decreased to at least 50% of the initial population size. Average metapopulation occupancy rates show that approximately 7 of the 9 population patches were occupied after 50 years of simulation time. The results also show that only three smaller and more isolated population patches in the northeastern portion of the study area were unoccupied for 5-15 years on average (Figure 22).

Based on the model assumptions the PVA re-analysis indicates viable American bittern populations for the NAESI Québec pilot study area. A total of 1.46% or 71.18 km^2 of suitable habitat distributed across the study region provides sufficient habitat supply in order to allow population viability over 50 years. This was also the case for the eastern Ontario study area where total habitat amount was approximately 3.5%. However, the performance target of less than 10% population decline, i.e., a near stable population level, was not met (growth rate=0.7), even for the eastern Ontario study area with a higher abundance of suitable habitat. The performance target 'functionality' was also not met as more than 5% of the simulation runs resulted in a metapopulation declining to at least 50% of the initial population size.

To assess how much habitat is needed and with which patch size configuration stable population trends can be achieved (based on the assumptions of the intermediate model) we tested several habitat scenarios where we increased the carrying capacity of existing populations. We did not choose to increase the habitat suitability threshold instead as the current (intermediate) threshold of 0.2 did already include most of the available habitat in the Québec pilot study area. Results of one scenario where we increased K are shown in Figure 23. In this scenario we increased the carrying capacity of 5 (out of 9) populations to or beyond a minimum carrying capacity of 24 individuals (population 1 from 9 to 40, 2 from 10 to 40, 4 from 22 to 24, 7 from 12 to 24, and 9 from 5 to 24 individuals, i.e., an increase in total K from 325 to 419 individuals). This resulted in an increase in habitat amount from 71.18 km^2 to 89.25 km^2 assuming that the habitat added has a suitability score of 1.0 (i.e., 1.83% habitat on the study area scale). For this habitat amount and minimum patch size the decline in population abundance (i.e., population trend) was near or less than 10% over the course of the 50 simulated years. Based on the simulations it seems that the configuration of patch sizes and their associated source/sink dynamics play an important role in the modeled population dynamics. MVP size from the non-spatial scenario was predicted at 48 individuals for an extinction risk of less than 5% over 50 years. Based on the spatial analysis, it appears that if a patch has a size of at least half of the estimated MVP size strong sink dynamics seem to be buffered. For the changed K values none of the populations exhibited strong sink dynamics and therefore all three performance targets were met. This included also a risk of decline of less than 5% to 50% of the initial population size (‘functionality).

Figure 23: Average population trajectory for the American bittern metapopulation for 1.83% habitat amount and a minimum patch size equal to a carrying capacity of 24 individuals. EMA was 159 individuals (extinction risk = 0%) and average population abundance declined from 210 to 189 individuals (equivalent to a 10% population decline). Risk of decline to below 50% of the initial population was 4.6%.



We then also used the latter type of analysis to assess the minimum habitat amount needed to ensure viability (i.e., less than 5% extinction risk over 50 years) only (without achieving the performance targets stability and functionality). For the base scenario 1.46% habitat amount resulted in 0% extinction risk. A reduction of K in the amount of 119 individuals (by reducing K of the largest population from 149 to 30) resulted in an extinction risk of nearly 5% over 50 years. This translates to a decline in habitat amount from 71.18 km^2 to 48.38 km^2 assuming that only high quality habitat (i.e., K=1.0 at 5.2 breeding individuals per km^2) is removed. Thus, based on the previous patch removal scenario and the general model assumptions estimated minimum habitat amount to support viable populations can be calculated as 0.99% (on the Québec study area scale).

8.4 Recommendations for Habitat-Based Standards

Based on the PVA study for the eastern Ontario pilot study area (Akçakaya et al., 2007) and the Québec re-analysis (this report) we suggest the following set of habitat-based standards:

- a minimum patch size of 30 km^2 of suitable habitat (based on an average population density of 127 ha per male or 1.57 breeding individuals per km^2) to support a single, viable population over 50 years with 95% confidence
- a minimum amount of 1% suitable habitat to support a viable metapopulation on the NAESI Québec study area scale (4869 km^2) (subject to patch size distribution)
- a minimum amount of 1.8% suitable habitat (with a minimum patch size that supports at least 12 breeding pairs) in order to support a viable, stable and functional metapopulation on the Québec study area scale; if patches are smaller minimum habitat amount will be significantly larger

9 PILEATED WOODPECKER (*DRYOCOPUS PILEATUS*)

The Pileated Woodpecker (*Dryocopus pileatus*) inhabits deciduous and mixed forests with abundant snags and downed woody debris. It was selected as a surrogate species for mature deciduous and mixed-wood forests due to its habitat area requirements, large home range, and dependence on forest interior habitat. A PVA study for the eastern Ontario pilot study area suggests that current habitat quantity and quality may be sufficient to support longer term viability (Akçakaya et al., 2007). For the medium scenario extinction risk was only 0.1% for a threshold of 250 individuals. Stability was 0.79 indicating a decline from the initial population abundance. Functionality was 0.88. In the medium scenario 6 habitat patches were identified based on a neighborhood distance of 1.3 km.

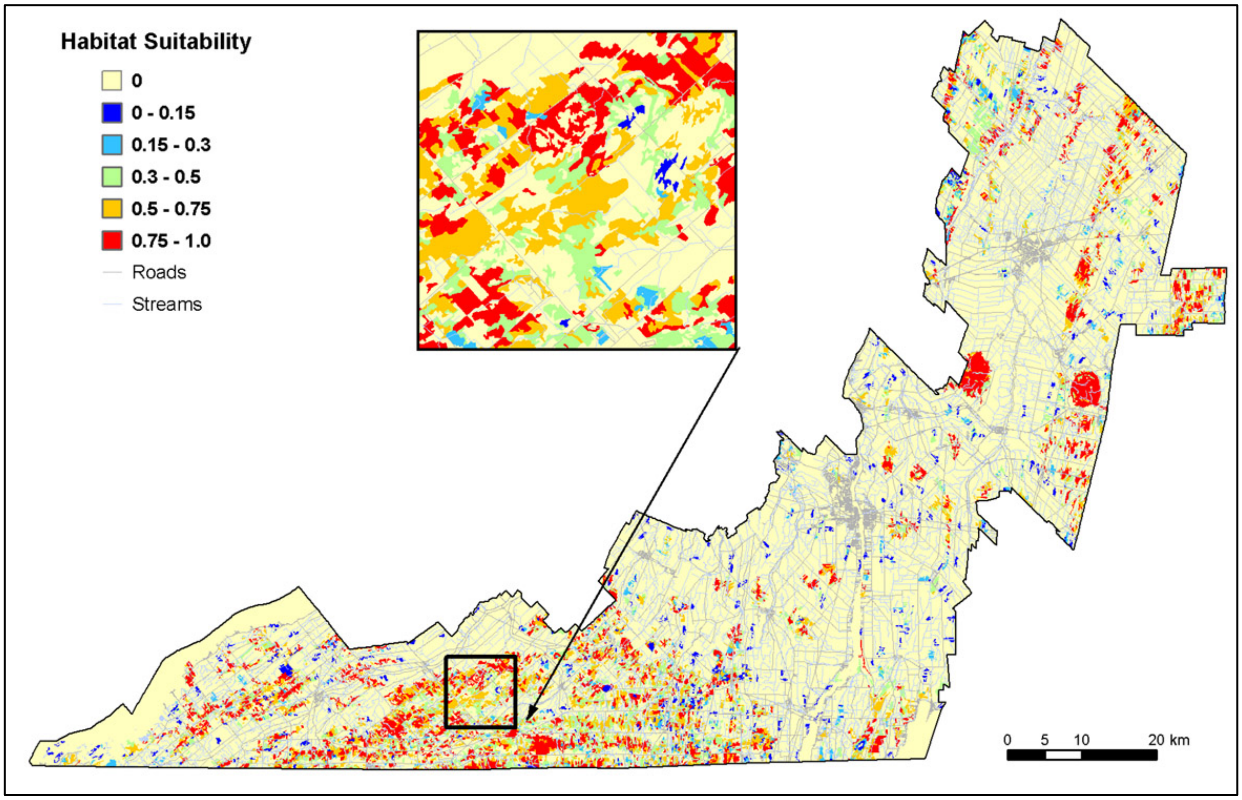
9.1 Non-spatial Demographic Model

A demographic population model was developed as part of a PVA study for the eastern Ontario pilot study area (see Akçakaya et al., 2007). The intermediate scenario was based on a medium parameterization for the stage matrix and variability in vital rates and a contest competition density dependence function with a maximum growth rate of 1.1 (Akçakaya et al., 2007). For this base scenario an initial MVP size of 110 individuals (both females and males) is needed to ensure an extinction risk of less than 5% over a time frame of 50 years (assuming that the carrying capacity is equivalent to the initial population size). Home range sizes for Pileated woodpecker range from 40 to 260 ha (Naylor et al., 1996) with 1-4 pairs (or 2-8 breeding individuals) per km^2 reported for Ontario (see references in Akçakaya et al., 2007). We assumed 5 breeding individuals per km^2 as the average population density for the study area. Thus, minimum viable patch size can be calculated as 22 km^2.

9.2 Habitat Suitability Model

For the PVA re-analysis we chose the habitat suitability model (HSM) developed by Maheu-Giroux (2007) for the Québec pilot study area. The final index of the HSM is based on calculating an index of forest stand type times a function of forest height and density times patch size. The suitability index for forest patch size increases linearly from 0 to 1.0 from 20 to 200 ha, i.e., patches smaller than 110 ha (equivalent to several breeding pairs) are assigned a suitability index of 0.5. Similarly, in the previous HSM for the eastern Ontario pilot study area area-sensitivity was built in by applying a minimum patch size to support 5 individuals (see Akçakaya et al., 2007). The overall suitability score for the Pileated woodpecker in the Québec analysis ranged from 0.0 (unsuitable) to 1.0 for cells in patches larger than 200 ha with mature, deciduous forest stands and high canopy closure (see HS map in Figure 24).

Figure 24: HSI map for the Pileated woodpecker in the Québec pilot study area based on the HS model by Maheu-Giroux (2007). HSI values range from 0.0 (no suitability) to 1.0 (highest suitability). Map source: Maheu-Giroux (2007).



9.3 Spatial Population Viability Analysis

For the parameterization of the spatial model we used the intermediate scenario described in Akçakaya et al. (2007). We used a carrying capacity of 8 breeding individuals per km^2 which is equivalent to maximum densities reported for Ontario (see Akçakaya et al., 2007). All other demographic and spatial model parameters including dispersal and the correlation-distance function were the same as in the intermediate scenario of the eastern Ontario pilot study PVA (Akçakaya et al., 2007).

For a habitat suitability threshold of 0.5 and a neighborhood distance of 1.3 km RAMAS©GIS generated 38 population patches for the Québec study area with a total amount of 562.8 km^2 habitat. This is equivalent to approximately 11.5% of the Québec pilot study area. Initial abundance was 1872 individuals which is equivalent to 50% of the estimated carrying capacity. For this scenario the model showed an extinction risk of 0%. Expected minimum abundance (EMA) was 1496 individuals. Average abundance slightly decreased from 1872 individual breeding birds in the initial year to 1804 in the final year (Figure 25b). This change in abundance is equivalent to a population trend with an effective growth rate of 0.96 over 50 simulated years. The interval percent decline risk curve (Figure 25c) shows that less than 5% of all simulation runs had at least one year where the metapopulation decreased to at least 50% of the initial population size. Average metapopulation occupancy rates show that on average 25 of the 38 population patches were occupied after 50 years of simulation time (Figure 25d). The results also show that a large proportion of the populations were extinct for at least 10 years (Figure 26). Based on the model assumptions this base scenario indicates viable, stable and functional populations for the NAESI Québec pilot study area. A total of 562.8 km^2 of suitable habitat distributed across the study region provides sufficient habitat in order to allow population viability and stability over 50 years. In addition, the performance target ‘functionality’ was met as less than 5% of the simulation runs resulted in the metapopulation declining to at least 50% of the initial population size.

Figure 25: (a) Typical simulation run for the spatial model; (b) average population trajectory for 1000 replications over 50 years; (c) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time; (d) metapopulation occupancy over 50 years showing the average number of patches occupied. Extinction risk for the base scenario was 0%, expected minimum abundance (EMA) 1,496; average population abundance slightly decreased from 1,872 adults in the initial year to 1,804 in the final year.

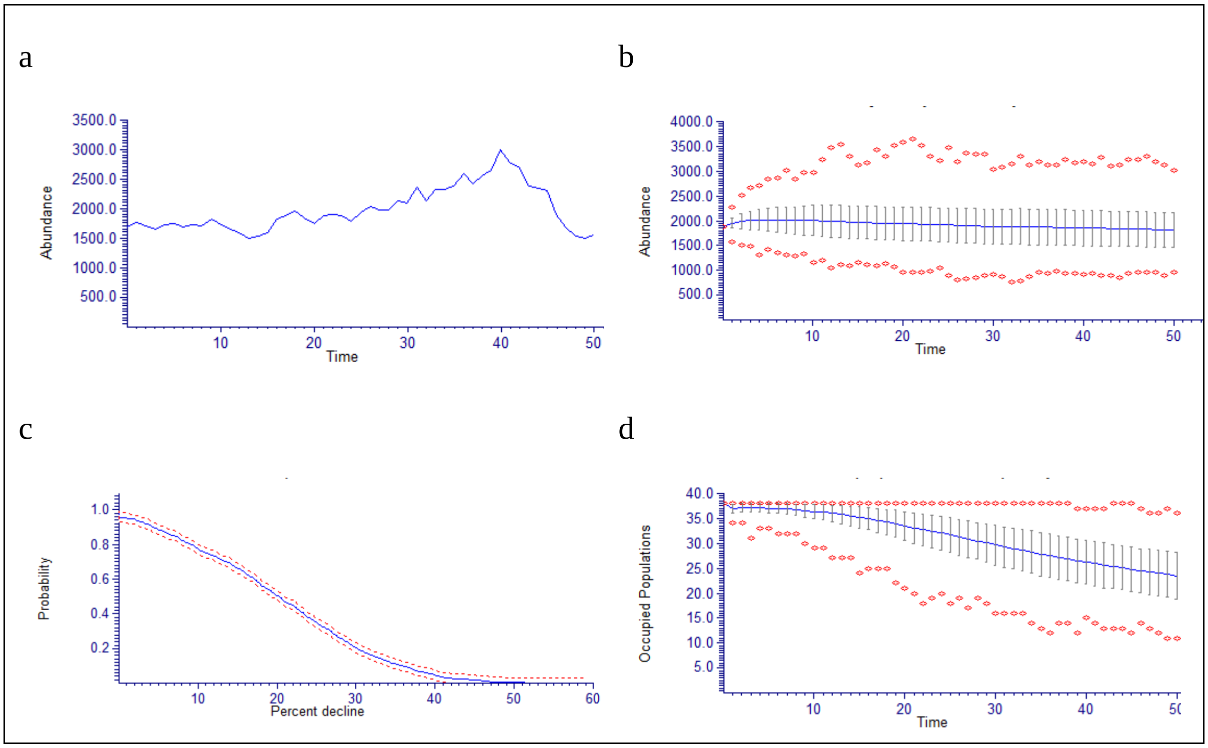
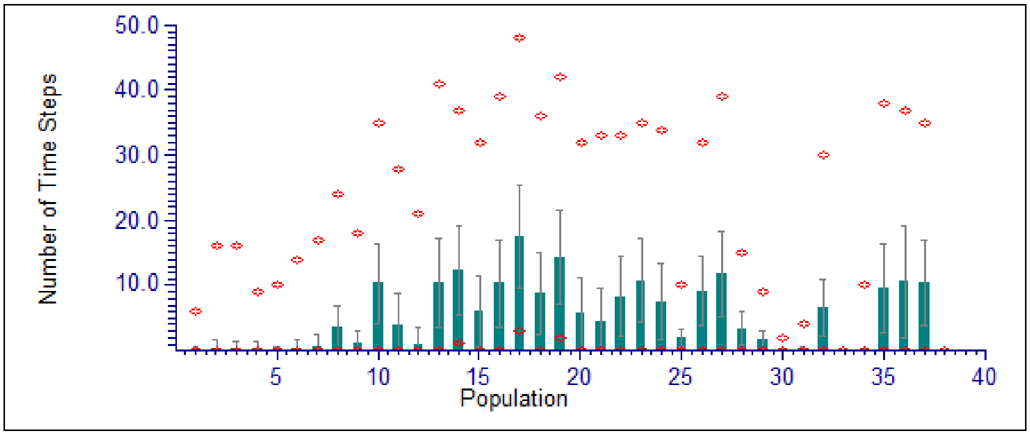
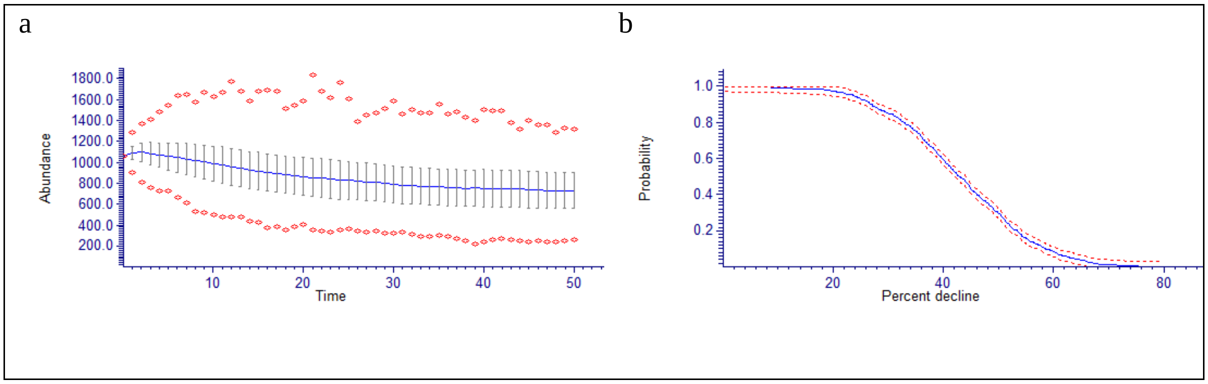


Figure 26: Local extinction duration for all populations. The bars show the average number of time steps that a patch is unoccupied.



In order to assess the minimum habitat amount required for longer term persistence and stability we then ran a scenario where we increased the habitat suitability threshold to 1.0. This change in the threshold results in fewer cells being considered as ‘suitable’ habitat. Cells with a suitability value of 1 comprised a total area of 263.7 km^2 distributed across 42 population patches in the study region (5.4% habitat amount). For this scenario extinction risk and EMA were 0% and 601.9 individuals for a time frame of 50 years, respectively. Average population abundance decreased from 1056 individuals in year 1 to 729 individuals in the final year resulting in an effective growth rate of 0.69 (i.e., a clear negative population trend) (Figure 27a). With respect to the measure of functionality there was a 30% chance that the population declined to below 50% of the initial population in any simulation year (Figure 27b).

Figure 27: Simulation results for a scenario with a HSI threshold value of 1.0 (a) average population trajectory for 1000 replications over 50 years; (b) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time.



Based on the overall simulation results we estimate that at least 11.5% suitable habitat is needed to ensure a viable, stable and functional metapopulation on the Québec study area scale. Based on the assumed carrying capacity and the current distribution of suitable habitat in the study area this corresponds to an initial population of 936 breeding pairs. Below this threshold population viability was still supported, however, the simulated populations did not show population stability and functional presence. In addition, based on the assumptions of the habitat suitability model (Maheu-Giroux, 2007) and further empirical evidence (see references in Akçakaya et al., 2007) we recommend a minimum patch size of 100 ha (equivalent to approximately 2-4 breeding pairs) to avoid patches being significant population sinks.

9.4 Recommendations for Habitat-Based Standards

Based on the PVA study for the eastern Ontario (Akçakaya et al., 2007) and the Québec pilot study area (this report) we suggest the following set of habitat-based standards:

- a minimum patch size of 100 ha (equivalent to supporting a minimum of 2-4 breeding pairs) to avoid patches being a strong population sink
- a minimum patch size of 22 km^2 of suitable habitat (based on an average population density of 5 breeding individuals per km^2) to support a single, viable population over 50 years with 95% confidence
- a minimum amount of 11.5% of suitable habitat to support a viable, stable and functional metapopulation on the NAESI Québec study area scale (4869 km^2) (subject to patch size distribution)

10 NORTHERN LEOPARD FROG (RANA PIPIENS)

The northern leopard frog (*Rana pipiens*) is a pond-breeding anuran with an aquatic and terrestrial life cycle and requires marsh habitat for reproduction and permanent water in the winter. During non-breeding periods in the summer, the frog prefers abandoned fields and meadows as foraging habitat. It has been suggested that the main factor limiting sizes of post-metamorphic populations is the quantity, quality and spatial arrangement of breeding habitats

(Skelly et al., 1999; Pope et al., 2002; Gibbons et al., 2006). A spatial PVA for the eastern Ontario pilot study area identified a total of 215 habitat patches; based on a neighborhood distance of 500 m and a habitat suitability threshold value of 0.5 (see Golder Associates, 2007). Metapopulation extinction risk in the base scenario over a time frame of 100 years was 1.2% and 1.8% with and without dispersal among patches, respectively. A worst-case habitat scenario with a 30% reduction in the quality and quantity of breeding habitat (129 habitat patches) resulted in an extinction risk of 11.7%. Based on the assumptions of the model it appears that 0.1% of suitable marsh habitat is needed to ensure longer-term (i.e., 100 years) persistence on the study area scale (325,000 ha).

10.1 Non-Spatial Demographic Model

Based on the parameterization of the baseline scenario and a stable age distribution a re-analysis of the demographic population model showed that an initial population of 1100 male frogs (1043 young-of-year, 46 sub-adults or immature, 11 mature adult males) is needed to ensure an extinction risk of <5% over 50 years. This estimate includes disturbance by drought with a 20% annual probability that 90% of newly metamorphosed individuals die. Minimum viable population sizes in frogs are particularly useful to assess the number of clutches needed for reintroduction projects and their potential of success. Assuming that survival rates during the tadpole stage are at least 6%, and possibly as low as 3% (Merrell, 1977) and a 120:1 juvenile – adult (sexually mature) ratio (Seburn et al., 1997) as much as 100,000 eggs would be needed to enable population persistence over at 50 years. In a subsequent step, we tested a non-spatial scenario with the introduction of disease such as fungal pathogens and viruses as a disturbance agent (see Golder Associates, 2007). Disease was modeled as a 5% probability catastrophe that resulted in the removal of all young-of-year and 90% reduction in sub-adult and breeding adult abundance. For the latter scenario MVP increased to 60,000 male frogs of which 600 were adults. Anuran populations densities vary highly with abiotic factors and we therefore omitted calculations of minimum viable patch size.

10.2 Habitat Suitability Model

For the PVA re-analysis we chose the habitat suitability model (HSM) developed by Maheu-Giroux (2007) for the Québec pilot study area. The suitability score for the Northern leopard frog in the Québec analysis ranged from 0.0 (unsuitable) to 1.0 for highly suitable cells (see HS map in Figure 28).

Figure 28: HSI map for the Northern leopard frog in the Québec pilot study area based on the HS model by Maheu-Giroux (2007). HSI values may range from 0.0 (no suitability) to 1.0 (highest suitability). Note that most of the cells had a suitability score of less than 0.25. All cells with a score > 0 are therefore indicated in black.

10.3 Spatial Population Viability Analysis

For the parameterization of the spatial model we used the base scenario described in Golder Associates (2007). We assumed a local extinction threshold of 10 male frogs. Both disturbance agents, i.e., drought and disease were assumed to affect the spatially structured population. Due to the low overall habitat suitability scores we did not make fecundity a function of habitat suitability otherwise the stage matrix would underestimate vital rates. We also set the distance-correlation function so that adjacent cells exhibit 100% correlation in vital rates and cells with the longest distance within the study area approximately 0%.

For a habitat suitability threshold of 0.15 and a neighborhood distance of 500 m RamasGIS generated 31 populations across the Québec pilot study area. The base scenario of the spatial model showed an extinction risk of 10%. Expected minimum abundance (EMA) was 5473 male frogs. Average abundance increased from 98,725 males (of all stage classes) in the initial year to 72,763 in the final year (Figure 29b). This negative change in abundance is equivalent to a population trend with an effective growth rate of 0.74 over 50 simulated years. The interval percent decline risk curve (Figure 29c) shows that all simulation runs had at least one year where the metapopulation decreased to at least 50% of the initial population size. This is largely due to the effect of catastrophic events (i.e., drought and disease) with die-offs in particular years. Average metapopulation occupancy rates show that on average 18 of the 31 population patches were occupied after 50 years of simulation time (Figure 29d). The results also show that 8 smaller and more isolated populations are unoccupied for 30 to 40 years (Figure 30).

Figure 29: (a) Typical simulation run for the spatial model; (b) average population trajectory for 1000 replications over 50 years; (c) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time; (d) metapopulation occupancy over 50 years showing the average number of patches occupied. Extinction risk for the base scenario was 10%, expected minimum abundance (EMA) 5473.1; average population abundance decreased from 98,725 adults in the initial year to 72,763 in the final year.

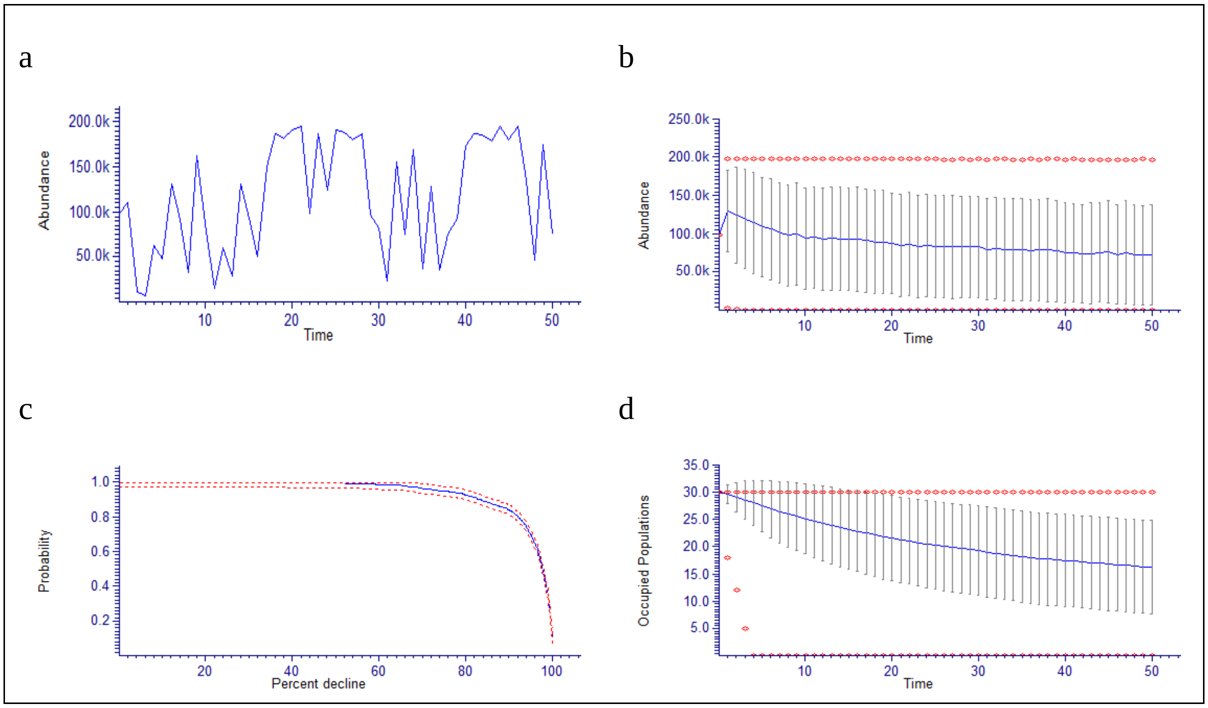
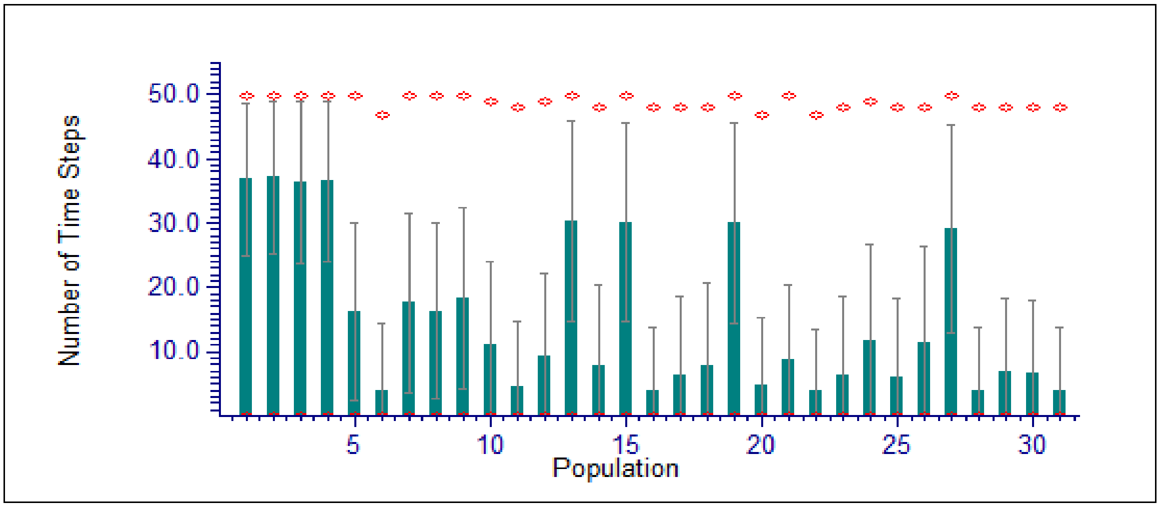


Figure 30: Local extinction duration for all populations. The bars show the average number of time steps that a patch is unoccupied.



Based on the model assumptions the PVA re-analysis indicates slightly non-viable populations for the NAESI Québec pilot study area. The simulated population trend was also negative with an effective growth of 0.76 over 50 years. Not surprisingly the performance target of functional presence could not be met in any case as leopard frog population dynamics are highly fluctuating, independent of the viability of populations. As opposed to territorial bird or mammal species the Northern leopard frog is not a useful surrogate for habitat-based standards that focus on amount of habitat or size of patches. From a habitat-based point of view anurans such as the leopard frog are rather limited and affected by inter-patch distance and matrix quality. In particular, road density and limited dispersal success are primary factors. Dispersal is especially important, as this species exhibits frequent local extinction and re-colonization events (due to the high influence of abiotic and climatic factors).

10.4 Recommendations for Habitat-Based Standards

Based on empirical literature, the PVA study for the eastern Ontario (Golder Associates, 2007) and the Québec pilot study area (this report) we suggest the following set of habitat-based standards:

- a maximum inter-patch distance of 500 m between breeding locations to facilitate movement and re-colonization
- high quality matrix habitat including low road densities and low traffic volume to avoid high dispersal mortality
- a minimum size of 0.1 ha of suitable breeding habitat to allow longer term patch occupancy (or equivalent habitat to support a minimum of 600 adult males)

11 AMERICAN MINK (*MUSTELA VISON*)

Mink are a territorial, primarily nocturnal mammal (DeGraaf and Rudis, 1986) consuming small mammals (particularly muskrats), fish, waterfowl, invertebrates, and amphibians (Melquist et al., 1981). Habitat preferences show a strong affinity for aquatic resources, such as those found in and near streams and rivers, lakes, and marshlands (Allen, 1986). With minimum habitat suitability necessary for breeding set to 0.4 and a neighborhood distance of 1.5 km (resulting in three patches) and 6.5 km (one patch) extinction risk for 100 years of simulation was 0% in both scenarios (see Golder Associates, 2007). Metapopulation models for the baseline scenario predicted very low extinction risks, even with the addition of harvesting. Local extinction risks of the mink remain low until an annual harvest of 40% juveniles and 20% adults, upon which regional populations may become vulnerable to local extinction. Results from sensitivity analyses show that even with 20% reductions in the estimates of most demographic parameters, mink populations remain stable. Overall, current landscape conditions seem to support viable mink populations over a wide range of scenarios.

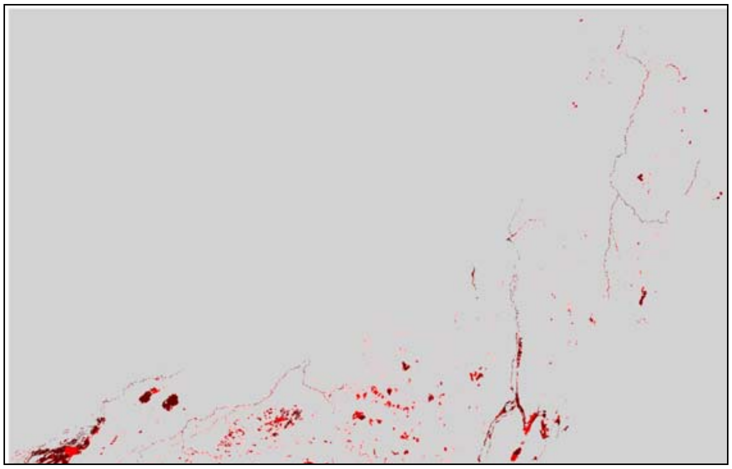
11.1 Non-Spatial Demographic Model

Based on the parameterization of the baseline scenario and the pre-breeding census stage matrix (Table 3, page 30 in Golder Associates, 2007) a re-analysis of the demographic population model showed an initial minimum viable population size of 7 and 9 adult mink for an annual drought probability of 5% and 10%, respectively. At a conservative estimate of 2 individuals per km^2 as average population density this results in a minimum viable patch size of 14 and 18 km^2 for an annual drought probability of 5% and 10%, respectively. With respect to droughts it was assumed that fecundity for all stages in a drought year is reduced to 25% of that of a normal year, i.e., 75% of the offspring dies in a drought year due to a temporary reduction in aquatic prey. The periodicity of droughts in south-eastern Ontario has been found to range between 0.05 and 0.1 (10 to 20 years per cycle; Girardin et al., 2004). The overall results suggest that the current stage matrix with a finite rate of increase of 1.35 (i.e., 35% annual population growth if demographic and environmental stochasticity and density dependence would be absent) might overestimate population growth unless other so far unaccounted effects would have a detrimental affect on mink population dynamics. Further research needs to be done in order to improve demographic estimates in mink. Considering the high population growth potential of accidentally introduced mink in central Europe, it appears that inter-specific competition and other unknown factors might limit population growth in native American habitat.

11.2 Habitat Suitability Model

For the PVA re-analysis we chose the habitat suitability model (HSM) developed by Maheu-Giroux (2007) for the Québec pilot study area. The suitability score for the American mink in the Québec analysis ranged from 0.0 (unsuitable) to 1.0 for highly suitable cells (see HS map in Figure 31).

Figure 31: HSI map for the Mink in the Québec pilot study area based on the HS model by Maheu-Giroux (2007). HSI values range from 0.0 (no suitability, pink) to 1.0 (highest suitability, brown).

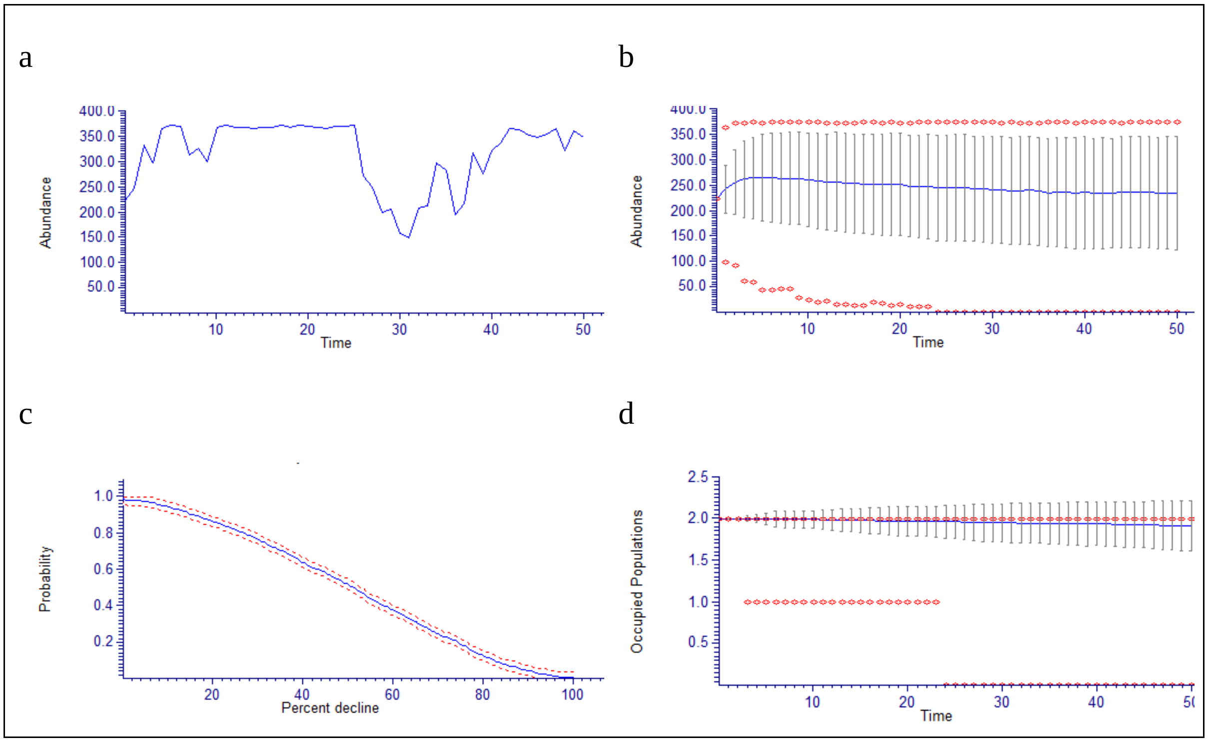


11.3 Spatial Population Viability Analysis

For the parameterization of the spatial model we used the base scenario described in Golder Associates (2007). We assumed a local extinction threshold of 2 individuals (i.e., 1 female and 1 male). We also assumed the same drought probability and associated die-offs as in the non-spatial scenario. The distance-correlation function was set so that adjacent cells exhibit 100% correlation in vital rates and correlation declined towards 0% among cells with the longest distances within the study area. We assumed a maximum dispersal distance of 45 km as in the PVA for the eastern Ontario study area. Setting the neighborhood distance at a mid-point of 3.5 km resulted in two population patches (HSI threshold was 0.5) being more than 45 km apart. However, since both population 'patches' are actually comprised of several smaller, connected sub-patches we introduced a dispersal rate of 1% among both patches. For the harvest scenario we chose the mid-point between the two scenarios selected in the Golder Associates study (2007), i.e., 25% and 12.5% annual culling of juveniles and adults, respectively.

For a habitat suitability threshold of 0.5 and a neighborhood distance of 45 km RAMAS©GIS generated 2 populations across the Québec pilot study area with a total of 141.6 km^2 of suitable habitat. The base scenario of the spatial model showed an extinction risk of 0.6%. Expected minimum abundance (EMA) was 112.6 individuals. Average population abundance increased from 224 adults in the initial year to 233 in the final year (Figure 32b). This positive change in abundance is equivalent to a population trend with an effective growth rate of 1.04 over 50 simulated years. The interval percent decline risk curve (Figure 32c) shows that nearly 50% of all simulation runs had at least one year where the metapopulation decreased to at least 50% of the initial population size. Fluctuations in population abundance in the model are largely due to the die-off effect of droughts. Despite low rates of dispersal, average metapopulation occupancy rates show that on average both population patches remained occupied after 50 years of simulation time (Figure 32d). Based on the assumptions of the model, the Québec metapopulation appears to be both stable and viable over a time frame of 50 years. The performance target ‘functional presence’ was not met as mink population abundance fluctuates to a considerable degree.

Figure 32: (a) Typical simulation run for the spatial model; (b) average population trajectory for 1000 replications over 50 years; (c) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time; (d) metapopulation occupancy over 50 years showing the average number of patches occupied. Extinction risk for the base scenario was 0.6%, expected minimum abundance (EMA) 112.6; average population abundance increased from 224 adults in the initial year to 233 in the final year.



Based on the previous results we did not further assess the minimum habitat amount needed for viability and stability and also do not recommend a habitat-based standard with respect to habitat amount. This is primarily due to the high finite rate of increase and the low minimum viable population size which we believe is highly uncertain. Based on the current stage matrix (and due to the high dispersal capabilities), modeling population dynamics spatially explicit results in less than 8-12 animals needed for stability and persistence in the Québec study area. However, this applies only to scenarios with drought catastrophes included; no drought events would require (in most simulations) only a female and a male for establishing a viable population. Due to the high uncertainty with the stage matrix, the arbitrary introduction of drought frequencies in the model (and the lacking knowledge of how these dry years would actually impact mink populations) we decided to not recommend a habitat amount-based standard associated with this species.

11.4 Recommendations for Habitat-Based Standards

Based on the current assumptions of the mink PVA for the Québec pilot study area we suggest the following habitat-based standards:

- a minimum patch size of 14-18 km^2 of suitable habitat to support a single, viable population over 50 years with 95% confidence (strongly subject to estimates in vital rates and frequency of drought events)

12 BELTED KINGFISHER (*MEGACERYLE ALCYON*)

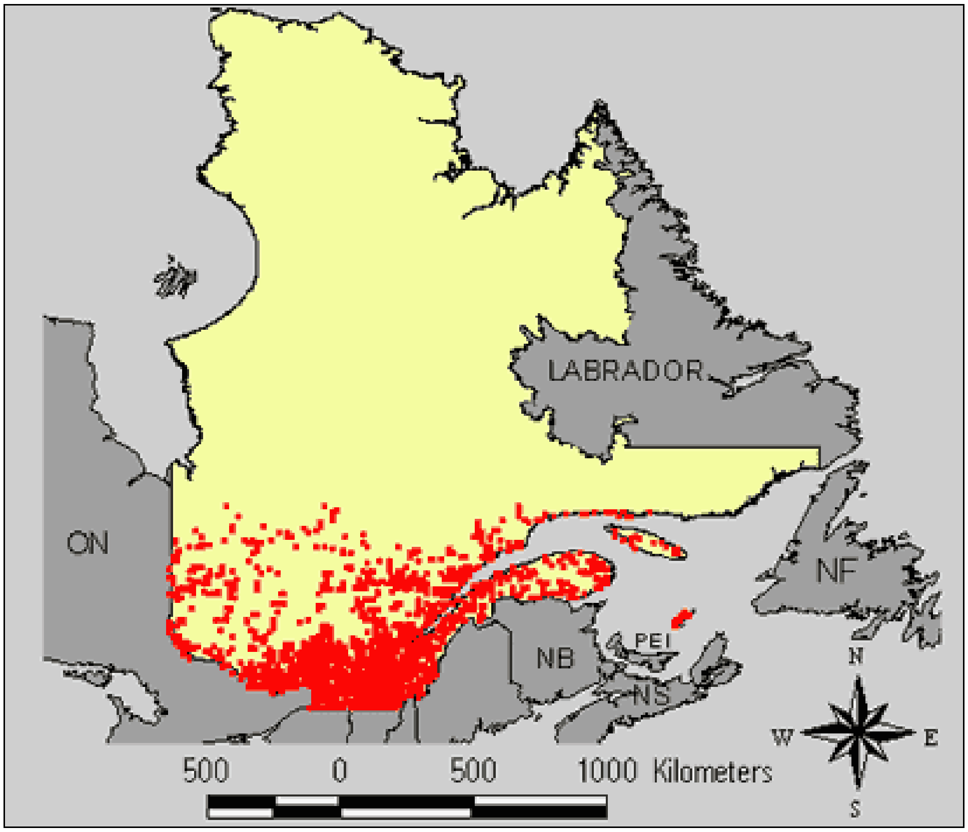
The belted kingfisher is a water-obligate species of streams, rivers, lake and pond edges, and large wetlands (e.g., Davis, 1982; Brooks and Davis, 1987; Sullivan et al., 2006). It is migratory throughout much of Canada, including eastern Ontario and the Québec pilot study area. For a neighborhood distance of 8 km (equivalent to maximum daily range of nesting adults) and a cut off HSI value of 0.5 a total of 3 sub-populations/habitat patches were found (see Golder Associates, 2007). For the baseline scenario simulations indicated a rapidly declining metapopulation with a median time to local extinction of 37 years (extinction risk = 100%). For 50 simulated years extinction risk was 86.1%. A watershed restoration simulation with 50%

increase in habitat suitability for shorelines within 3 km of non-urban sandy soils resulted also in near certain probability of extinction with a median time to extinction at 45 years. Overall, current landscape conditions do not seem to support viable populations.

12.1 Non-Spatial Demographic Model

The current model appears to have overestimates of mortality rates as survival rates in the belted kingfisher PVA include low return rates of juveniles and adults to natal sites (i.e., survival *and* emigration, see page 39 in Golder Associates, 2007). Based on the parameterization of the pre-breeding stage matrix in the baseline scenario (Table 6, page 40 in Golder Associates 2007), a re-analysis of the demographic population model showed a viable meta-population only for a very large initial population size. This is due to the low finite rate of increase (lambda) of 0.91 inferred from the stage matrix. Generally, a lambda of <1.0 means that a population would only be sustainable over the longer term if sufficient immigration occurs (which was not assumed in the Golder Associates PVA). The reasons for the low demographic rates may be threefold: biased estimates of mortality rates, occurrence at distributional range margins, or the cumulative effects of agricultural pesticides (which may apply to the Belted kingfisher). However, since the belted kingfisher does not occur at any range margin in southern Québec (where populations may only persist if sufficient immigration occurs) (see Figure 33), and we intended to utilize a baseline model without detrimental effects of pesticide accumulation, we assumed that low return rates were due to emigration and not an indicator of high mortality events. Thus, we developed a best case scenario with an increase in juvenile survival rates by 25%. This translates to a finite rate of increase of 1.0066 which we will further use for the re-analysis. Based on these changes in the Leslie matrix an initial MVP size of 182 males is needed for a population to be persistence over a time frame of 50 years. This abundance translates to 182 km of suitable shoreline as the minimum viable patch area, assuming an average population density of 1 km shoreline per adult male bird. Assuming a shoreline habitat buffer of 100 m this would translate to 18.2 km^2 of suitable shoreline habitat.

Figure 33: Distribution of belted kingfisher in the province of Québec. (retrieved on Oct. 9th, 2007 from http://redpath-museum.mcgill.ca/Qbp/birds/Specpages/beltedkingfisher.htm)



12.2 Habitat suitability model

For the Québec pilot study area we used the HSI model previously developed for the eastern Ontario pilot study area (see details in Golder Associates, 2007). However, due to the unavailability of certain spatial data components we needed to modify the existing model. Firstly, for the Québec HS map 'pseudo-basins' were calculated by setting 1 km buffers away from water body segments. Secondly, sand composition was simulated using the drier classes of a drainage variable available in the data combined with only dry/fresh forest classes occurring on these dryer drainage classes. The resulting HS map can be seen in Figures 34 and 35.

12.3 Spatial Population Viability Analysis

For the parameterization of the spatial model we used the base scenario described in Golder Associates (2007) with a neighborhood distance of 8 km and a habitat suitability threshold value of 0.5. The local threshold at which a patch (i.e., subpopulation) was considered occupied was 5 male birds. We assumed a maximum dispersal distance of 66 km as in the PVA for the eastern Ontario study area. As in the original model, carrying capacity of breeding habitat was assumed as one pair of breeding adults and 6 juvenile birds per 0.8 km of shoreline (or one male bird per 200 m). Initial abundances of patches were calculated as 50% of the estimated carrying capacities (75% in original Golder PVA). In the original model no distance correlation was unintentionally (or intentionally) assumed and we therefore set the distance-correlation function so that adjacent cells exhibit 100% correlation in vital rates and correlation declined towards ~0% among cells with maximum inter-cell distances within the study area (parameter a=1, b=20, c=1). Belted kingfishers nests can be susceptible to flooding; therefore (as in the original PVA) we incorporated environmental fluctuations in the simulations by including a 10% probability of a catastrophe that would reduce juvenile abundance by 25%.

Figure 34: HSI map for the Belted kingfisher in the Québec pilot study area based on a modified HS model from the eastern Ontario pilot study area (see text). HSI values range from 0.0 (no suitability, pink) to 1.0 (highest suitability, brown). See Figure 35 for a detailed map (black square).

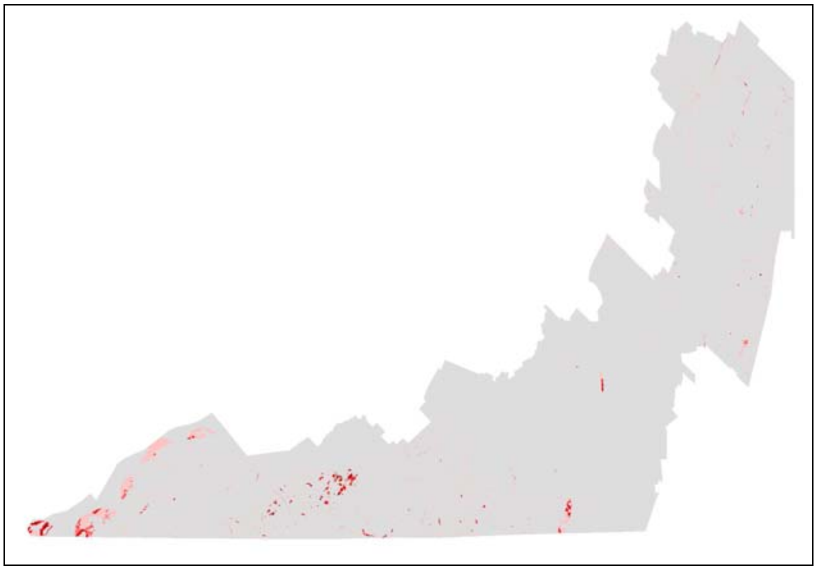
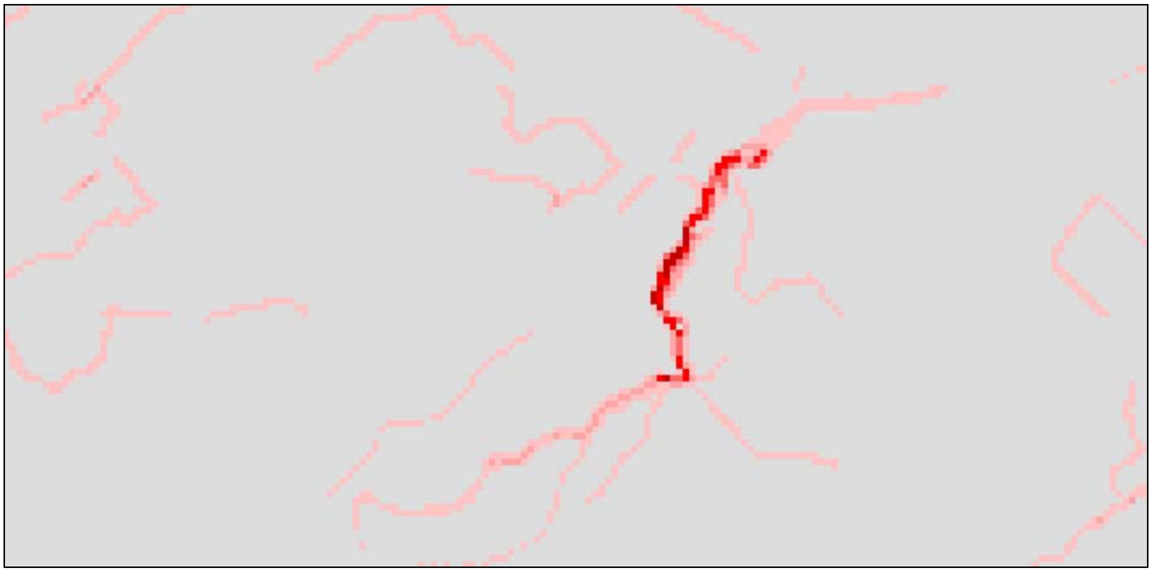


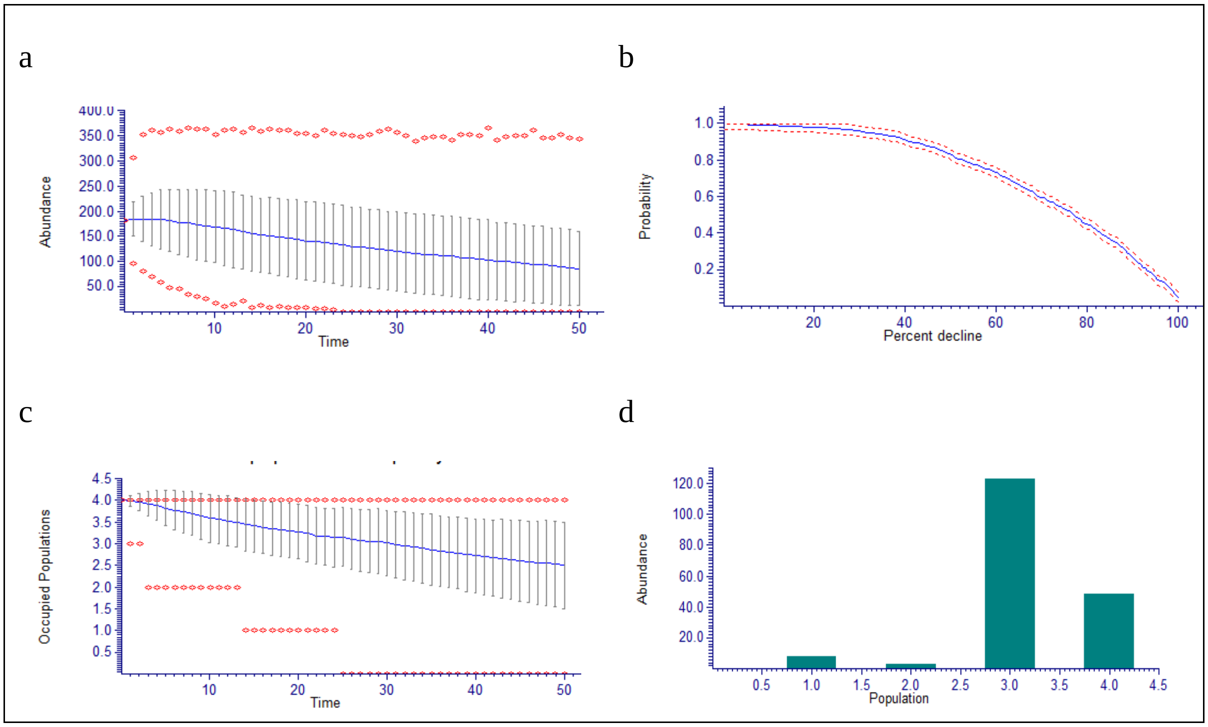
Figure 35: Detailed HSI map for the Belted kingfisher in the Québec pilot study area.



For the above parameterization RAMAS©GIS generated 4 population patches across the Québec pilot study area covering a total of 12.05 km^2 of suitable habitat with a carrying capacity of 365 male birds. Extinction risk was 5% and the estimated minimum abundance (EMA) 50 males (Figure 36). Average population abundance decreased from 182 male birds in the initial year to 86 in the final year. This negative change in abundance is equivalent to a population trend with an effective growth rate of 0.47 over 50 simulated years. The interval percent decline risk curve (Figure 36b) shows that nearly 80% of all simulation runs had at least one year where the metapopulation decreased to below 50% of the initial population size. Based on the assumptions of the base model (and the modified stage matrix), the Québec metapopulation appears to be viable over a time frame of 50 years. This is largely due to the relatively high neighborhood distance applied in the Golder PVA, as patches would be otherwise highly fragmented resulting in smaller populations that act as population sinks. However, the simulation results did not indicate a stable or functional population as the metapopulation declined to about half of the initial population size over the simulation trajectory. This was also the case when we ran a scenario without 25% loss in juvenile abundance after stochastic flooding events (4.6% extinction risk).

We did not further evaluate other modeling scenarios as the modified stage matrix represents only one possible combination of demographic rates and is not evidenced by any empirical data. Any further in-depth modeling analyses would require a more thorough understanding of potential demographic limitations or should prove that observed low return rates are due to emigration.

Figure 36: (a) Average population trajectory for 1000 replications over 50 years; (b) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time; (c) metapopulation occupancy over 50 years showing the average number of patches occupied; (d) average population structure after 50 years. Extinction risk for the base scenario was 5%, expected minimum abundance (EMA) 50; average population abundance decreased from 182 males in the initial year to 86 in the final year.



12.4 Recommendations for Habitat-Based Standards

Based on the PVA study for the eastern Ontario (Golder Associates, 2007) and the Québec pilot study area (this report) we suggest the following habitat-based standard:

- a minimum patch area of approximately 180 km of suitable shoreline habitat to support a single viable population over 50 years (assuming an average population density of 1 km shoreline per adult male bird) (low confidence due to modifications in demographic rates); equivalent to 18 km^2 of suitable shoreline habitat assuming a habitat buffer of 100 m

13 NORTHERN FLYING SQUIRREL (*GLAUCOMYS SABRINUS*)

The northern flying squirrel (*Glaucomys sabrinus*) (NFS), a member of the *Sciuridae* family, occupies older coniferous and mixedwood forests and avoids younger forested, fragmented or open habitats. In the PVA study conducted for the Eastern Ontario Model Forest (see Pearce et al., 2007), a total of 275 habitat patches greater than 20 ha in size were identified. This resulted in a total area of suitable habitat of 134.23 km^2 or approximately 4% of the landscape. However, most of these patches were located in the northeastern half of the study area, where squirrel habitat comprised approximately 7% of the landscape. The study concludes that if the habitat model is at least 50% correct the squirrel population is both viable (0% probability of extirpation within 50 years) and stable over the next 50 years.

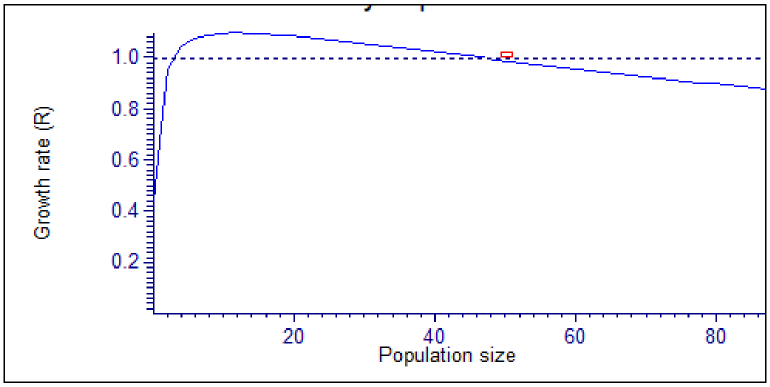
13.1 Non-Spatial Demographic Model

We needed to modify the existing demographic model as the fecundity rates did not include survival rates for the first stage (see Table 10). Assuming a pre-breeding census we changed fecundity to 0.405 for the first age class and 0.729 for the other age classes. Fecundity is now calculated as % breeding (during the first year 50%, thereafter 90%) * sex ratio * survival rate in the first year. We assumed the same survival rates as in the original model. Overall, the updated stage matrix changed lambda (i.e., the finite rate of increase in the stage matrix) from 1.05 to 1.0106. As opposed to implementing Allee effects by setting the minimum population size to 13 females (as in the original model), we introduced an Allee parameter that changes the density dependence in growth rate relationship for the scramble competition density dependence function (Allee parameter = 1) (see Figure 37). The maximum growth rate was set at 1.2. All other parameters such as the CV of vital rates were kept the same as in the original model.

Table 10: Modified Leslie stage matrix comprised of fecundity (first row) and survival rates for the four NFS life stages (pre-breeding census).

	Year 1	**Year 2**	**Year 3**	**Year 4**
Year 1	0.405	0.729	0.729	0.729
Year 2	0.54	0	0	0
Year 3	0	0.33	0	0
Year 4	0	0	0.58	0.18

Figure 37: Changes in the growth rate with increase in NFS population size. Note the Allee effect for very low population sizes.

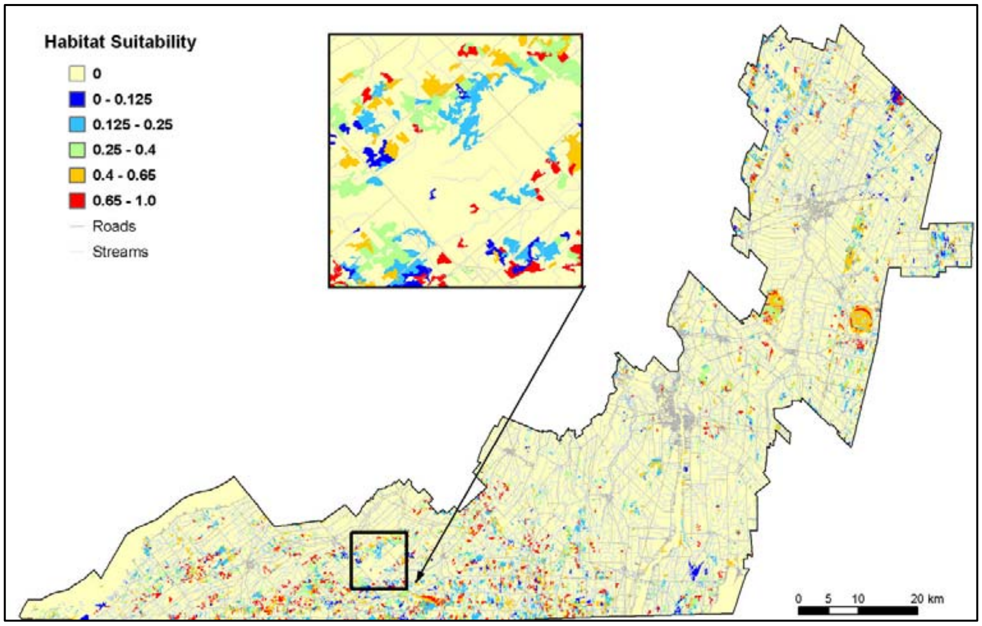


Based on the modified demographic model we found an initial MVP of 40 females for an extinction risk of less than 5% over 50 years (with 21, 12, 4 and 3 initial females in the four age classes, based on a stable age distribution). For the calculation of the minimum viable patch size we assumed an average population density of 0.5 individual per ha. Population densities of northern flying squirrel vary highly across time and space. For example, average population densities for North America are reported at 1.3 individuals per ha (see Table 4 in Pearce et al, 2007) whereas maximum densities observed in the Algonquin Provincial Park region (the nearest study area) were reported at 0.44 individuals per ha. However, Pearce et al. (2007) note that they believe that the latter estimate is too low because (a) their study considered only deciduous habitats which is not a preferred squirrel habitat type, and (b) there was evidence that squirrel populations in Algonquin might have been lower than normal during the study period of Holloway and Malcolm (2006). Thus, we believe 0.5 individual per ha is a reasonable estimate for average population densities for suitable habitat in the Québec study area. This translates to a minimum viable patch size of 160 ha assuming that all individuals reside in one patch and that the carrying capacity is equivalent to the initial population size.

13.2 Habitat Suitability Model

The habitat suitability index model was based on the HS model by Maheu-Giroux (2007) and based on a product of the variables forest composition, forest age, tree density and height and patch size. In the eastern Ontario model area sensitivity was incorporated by excluding patches smaller than 20 ha. In the Québec HS model used here, suitability of patches increased sharply from 0 to 1.0 between 12 and 14 ha patch size. Overall, the suitability for the Northern Flying squirrel in the Québec analysis ranged from 0.0 (unsuitable) to 1.0 (highly suitable) (Figure 38).

Figure 38: HSI map for the NFS in the Québec pilot study area based on the HS model by Maheu-Giroux (2007). HSI values range from 0.0 (no suitability) to 1.0 (highest suitability). HS map source: Maheu-Giroux (2007).



13.3 Spatial Population Viability Analysis

For the parameterization of the spatial model we assumed a local extinction threshold of 2 females. We set the carrying capacity at 1.5 individuals per ha (0.75 female per ha) which is within the range of maximum reported population densities for North America (see Pearce et al., 2007). The highest reported population density was 2.3 animals per ha. However, using 2.3 individuals per ha as K would initialize the population with a density of 1.15 individuals per ha on average (as the initial population size is defined as 50% of K in the NAESI standardized PVA approach). Thus, this would result in a starting population much higher than the average population density used in the calculation of minimum viable patch size (i.e., 0.5 individuals per ha). With respect to dispersal we assumed a maximum dispersal distance of 6 km and a maximum dispersal rate of 50%. For other model parameters we referred to the parameterization in the original PVA (see Pearce et al., 2007).

For generating population patches in RAMAS©GIS we assumed a habitat suitability threshold of 0.5 and a neighborhood distance of 1 km. The area-sensitivity already built into the HS model and the chosen HS threshold resulted in population patches larger than 13-14 ha in size and with a minimum carrying capacity of ~10 female flying squirrels. We believe that including patches with smaller carrying capacities might overestimate K of the metapopulation. Moreover, our approach is similar to the assumption in the original HSM for the eastern Ontario pilot study area with a minimum patch size of 20 ha.

Figure 39: (a) Typical simulation run for the spatial model; (b) average population trajectory for 1000 replications over 50 years; (c) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time; (d) metapopulation occupancy over 50 years showing the average number of patches occupied. Extinction risk for the base scenario was 0%, expected minimum abundance (EMA) 6,024; average population abundance increased from 5,607 individuals in the initial year to 8,206 in the final year.

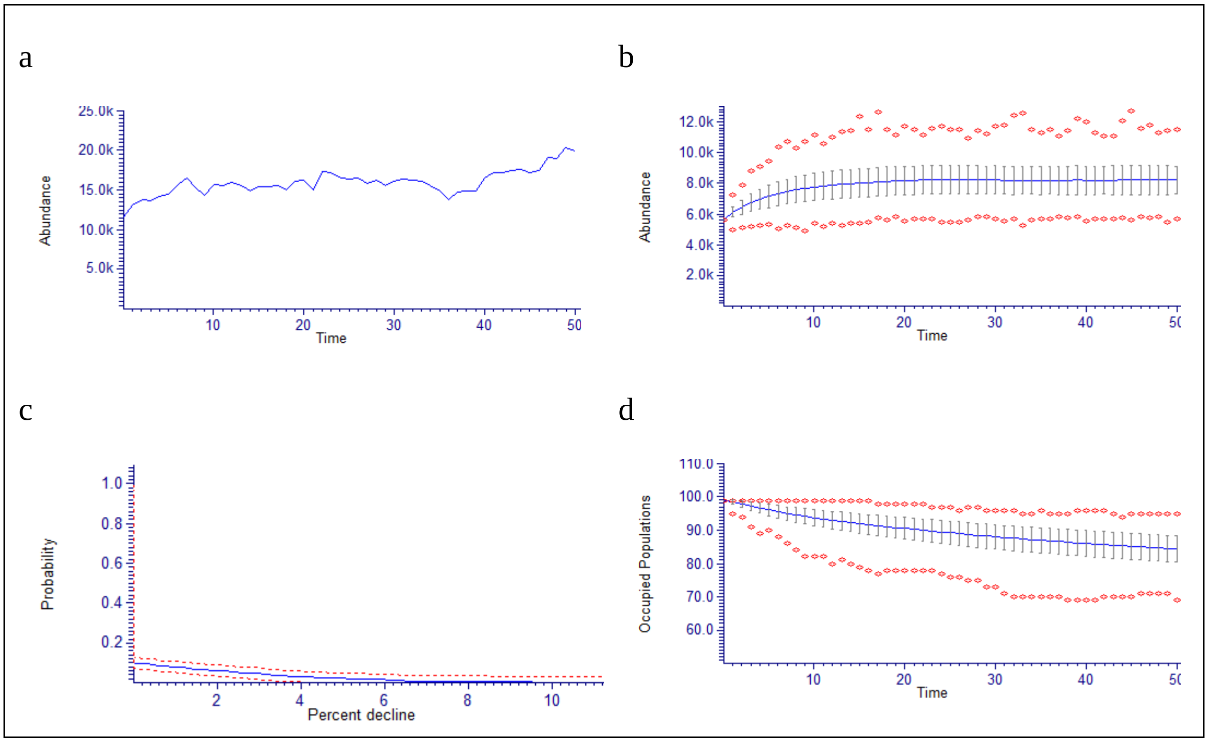
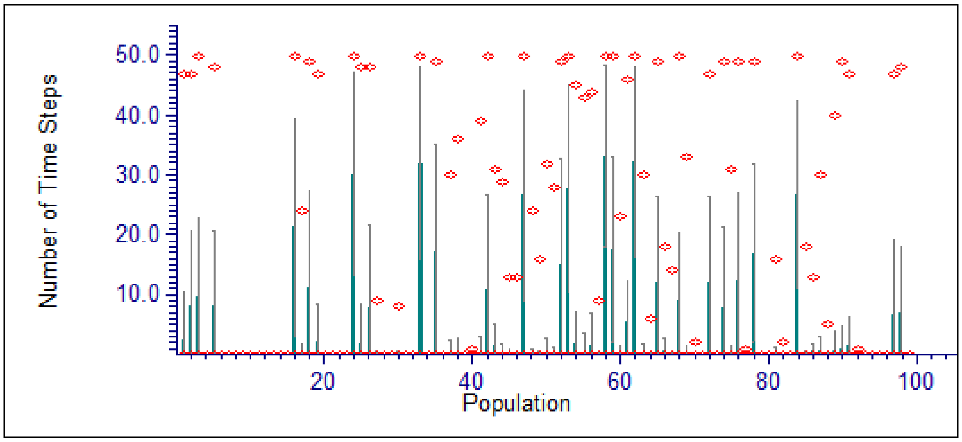


Figure 40: Local extinction duration for all NFS populations. The bars show the average number of time steps that a patch is unoccupied.

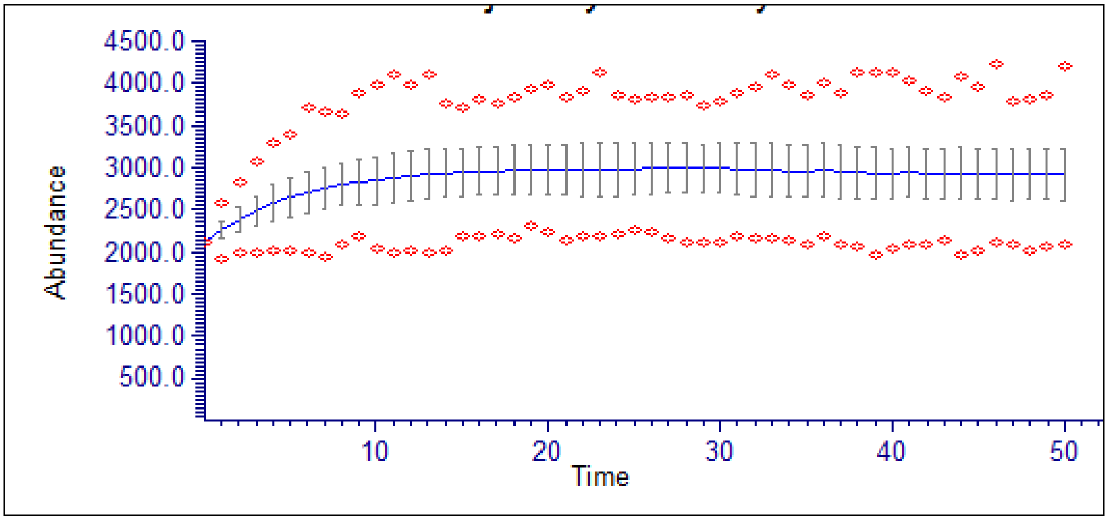


For the latter parameterization RAMAS©GIS generated 99 populations with a total of 230.4 km^2 of suitable habitat. This is equivalent to 4.9% habitat on the Québec study area scale. The base scenario of the spatial model showed an extinction risk of 0%. Expected minimum abundance (EMA) was 6,024 individuals (female only). Average abundance of female increased from 5,607 in the initial year to 8,206 in the final year (Figure 39). This positive change in abundance is equivalent to a population trend with an effective growth rate of 1.46 over 50 simulated years. The interval percent decline risk curve (Figure 39c) shows that none of the simulation runs had at least one year where the metapopulation decreased to at least 50% of the initial population size. Average metapopulation occupancy rates show that less than 15 of the 99 population patches were unoccupied after 50 years of simulation time. The results also show that only a few (smaller and more isolated) population patches were unoccupied during the simulation time (Figure 40).

Overall, the results indicate a viable, stable and functional northern flying squirrel metapopulation on the Québec study area scale. A total amount of 230.4 km^2 of suitable habitat (4.9% habitat amount) allowed longer term persistence and stability. As a comparison, in the PVA for the eastern Ontario pilot study area using RAMAS©GIS Pearce et al. (2007) generated 275 habitat patches greater than 20 ha in size resulting in a total area of suitable habitat of 134.23 km^2 or approximately 4% of the landscape. Similar to our study the Pearce et al. PVA revealed a high likelihood of persistence, however it also showed a strong population decline until the metapopulation size settled at about 50% of the initial population. This marked difference between the population trends of both studies is due to the fact that initial population sizes were different in both studies (100% of K in Pearce et al., 2007 study whereas 50% in our study). Other differences might be due to changes in the stage matrix and of some other model parameters. Yet, overall it appears that the current habitat supply allows viable and stable northern flying squirrel populations in both the eastern Ontario and Québec pilot study area.

To try to assess at which threshold of habitat supply NFS population dynamics in the Québec pilot study area may depart from longer-term viability and stability we ran a patch removal experiment where we deleted all patches larger than 5 km^2. Together these patches comprise an area of 143 km^2, i.e., the amount of available habitat was reduced to 87.4 km^2 (1.8% on the Québec study area scale). This amount of habitat is still able to facilitate a stable, viable and functional metapopulation (Figure 41). Further reductions in habitat may still support viable and stable populations. In fact, further modeling scenarios showed that a metapopulation size of only 100 to 140 females distributed across differently sized population patches (carrying capacity of 10-30 females, total of ~0.1% habitat amount) may be sufficiently large to ensure long-term viability and population stability (assuming 1% annual dispersal rate among all patches and a 50% correlation in vital rates). However, due to the rather hypothetical nature of the latter analysis and the fact that suitable forest patches may have actually lower or no connectivity at all we decided to choose the more conservative standard of 1.8% habitat.

Figure 41: Average NFS population trajectory over 50 years when all patches larger than 5 km^2 were removed from the metapopulation.



13.4 Recommendations for Habitat-Based Standards

Based on the PVA study for the eastern Ontario (Pearce et al., 2007) and the Québec pilot study area (this report) we suggest the following set of habitat-based standards:

- a minimum patch size of 10-20 ha for patch occupancy
- a minimum patch size of 160 ha (based on an average population density of 0.5 individuals per ha) to support a single, viable population over 50 years with 95% confidence
- a maximum inter-patch distance of 6 km (for inter-patch distances larger than 1 km forested corridors or stepping-stone forest habitats need to be present)
- a minimum amount of 1.8% of suitable habitat to support a viable, stable and functional metapopulation on the NAESI Québec study area scale (4869 km^2) (subject to patch size distribution)

14 BOBOLINK (DOLICHONYX ORYZIVORUS)

Bobolinks (*Dolichonyx oryzivorus*) originally inhabited tall-grass and mixed-grass prairies of midwestern and south central Canada. However, today they primarily use hay-fields and meadows and consequently are readily impacted by farm management practices. The PVA study conducted for the Eastern Ontario Model Forest (see Pearce et al., 2007) found approximately 535 km^2 of suitable bobolink habitat evenly spread across the study area - evenly distributed between medium (45% patches) and optimal (55% of patches) size classes. The population in the eastern Ontario pilot study area appears viable, stable and ecologically functional irrespective of estimates of habitat amount and quality. However, the bobolink population cannot withstand more than a 20% reduction in fledging rates annually; consequently widespread annual disturbance because of haying during the nesting season would reduce the viability of this population.

14.1 Non-Spatial Demographic Model

We had to modify the stage matrix in the Pearce et al. (2007) model. Firstly, in the stage matrix adult fecundities did not include juvenile mortality (which is a common mistake in many PVAs). Secondly, the polygynous mating system in bobolink (with different stages for females and males in the stage matrix) was not accounted for. However, we kept the fledgling/juvenile and survival rates the same as outlined in Pearce et al. (2007).

Table 11: Modified Leslie stage matrix comprised of fecundity (first row) and survival rates for the polygynous mating system in the bobolink PVA (pre-breeding census).

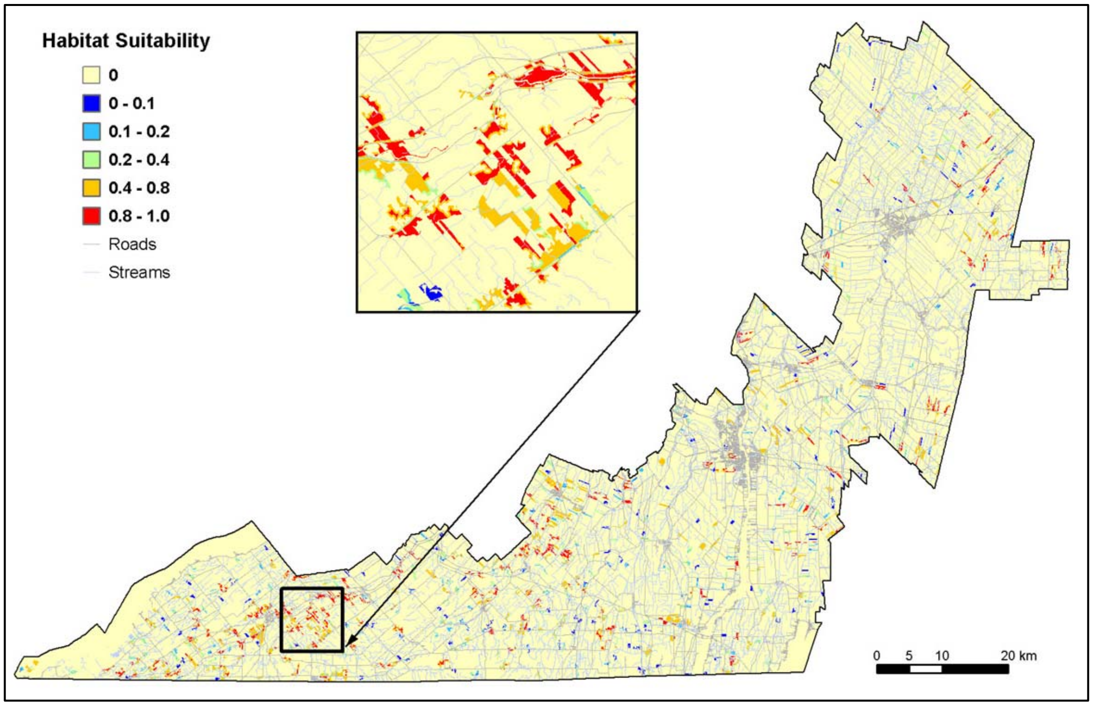
	Female Juvenile	**Female Adult**	**Male Juvenile**	**Male Adult**
Female Juvenile	0.65076	0.65076	0	0
Female Adult	0.34	0.49	0	0
Male Juvenile	0.53244	0.53244	0	0
Male Adult	0	0	0.34	0.49

As shown in Table 11 fecundity is now calculated as fledging rate (3.48) * sex ratio (0.55 for female, 0.45 for males) * juvenile survival (pre-breeding census). For the polygynous mating system we also allowed each male to mate with up to 2 females. These changes to the stage matrix decreased the finite rate of increase (lambda) from 1.0522 in the Pearce et al. (2007) model to 1.0476 in the corrected current model. We furthermore lowered the maximum growth rate for the contest competition density dependence function to a conservative estimate of 1.1. This value is similar to the medium R_{max} value selected in the three Akçakaya et al. PVA studies (Akçakaya et al., 2007). Based on this new parameterization we found an initial MVP of 90 birds (both females and males) for an extinction risk of less than 5% and a time frame of 50 years.

Based on the study by Bollinger and Gavin (1992) we estimated a carrying capacity of 2.68 individuals per ha for high quality habitat and an average density of 1.5 individuals per ha (see Pearce et al., 2007). Thus, minimum viable patch size can be calculated as 135 ha of suitable, primary habitat (i.e., old hayfields).

14.2 Habitat Suitability Model

Figure 42: HSI map for the bobolink in the Québec pilot study area based on the HS model by Maheu-Giroux (2007). HSI values range from 0.0 (no suitability) to 1.0 (highest suitability). HS map source: Maheu-Giroux (2007).



The bobolink habitat suitability index model by Maheu-Giroux (2007) is based on a product of the habitat variables patch type, patch area, and the type and distance of edge effects (Figure 42). However, this model is more general, and will tend to overestimate the total amount of suitable habitat (primarily old hayfields) due to differences in habitat quality identified in the Pearce et al. model (2007). Due to uncertainties in defining suitable habitat we therefore applied a wide range of habitat suitability threshold scenarios. This furthermore allowed us to test different scenarios of the effects of habitat amount on bobolink population viability.

14.3 Spatial Population Viability Analysis

For the parameterization of the spatial model we set the carrying capacity at 2.68 individuals per ha (1.48 females and 1.2 males per ha) based on empirical data (see Pearce et al., 2007). With respect to dispersal we assumed a maximum dispersal distance of 14.2 km and a maximum dispersal rate of 12%. Thus, we reduced the empirical estimate of dispersal rates by 50% otherwise for a considerable number of populations annual dispersers would amount to more than 95% of the stage matrix. We also assumed a neighborhood distance of 500 m as in the original model. For all other model parameters we referred to the parameterization as in the Pearce et al. PVA (see Pearce et al., 2007).

We tested for three thresholds of habitat suitability with changes in the total amount of suitable habitat. Setting the HSI threshold at 0.15 (original parameter value in the Pearce et al. study), 0.5 and 1.0 resulted in 221.06 km^2, 121.94 km^2 and 36.52 km^2 of suitable bobolink habitat and 264, 181, and 140 population patches, respectively. Hence, we tested for three scenarios with 4.54%, 2.5%, and 0.75% amount of suitable bobolink habitat in the Québec pilot study area, respectively.

Due to the relatively high dispersal distance the majority of population patches are well connected (see Figure 43). For a habitat suitability threshold of 0.15 (i.e., 221.06 km^2 and 4.54% habitat) extinction risk was 0% and the EMA 10,086. The average population trend for the metapopulation showed a 30% population decline from an initial population size of 15,782 to 11,126 in the final year (Figure 44). Yet, all populations remain occupied over the course of the simulation due to the high degree of connectivity (Figure 44d).

Figure 43: Connectivity (based on the dispersal-distance function) among 264 bobolink population patches in the habitat scenario with a 0.15 habitat suitability threshold (equivalent to 4.54% habitat amount).

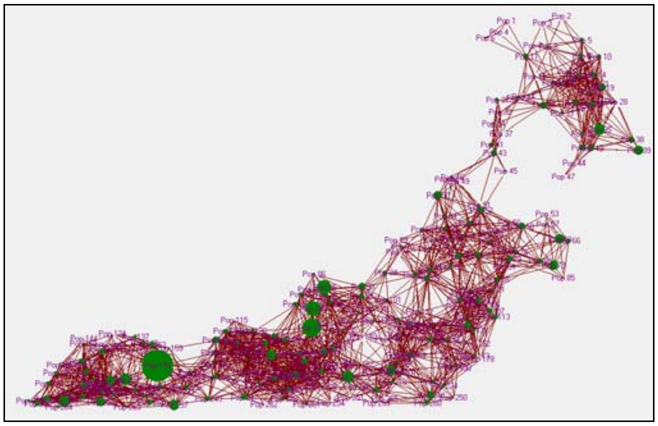
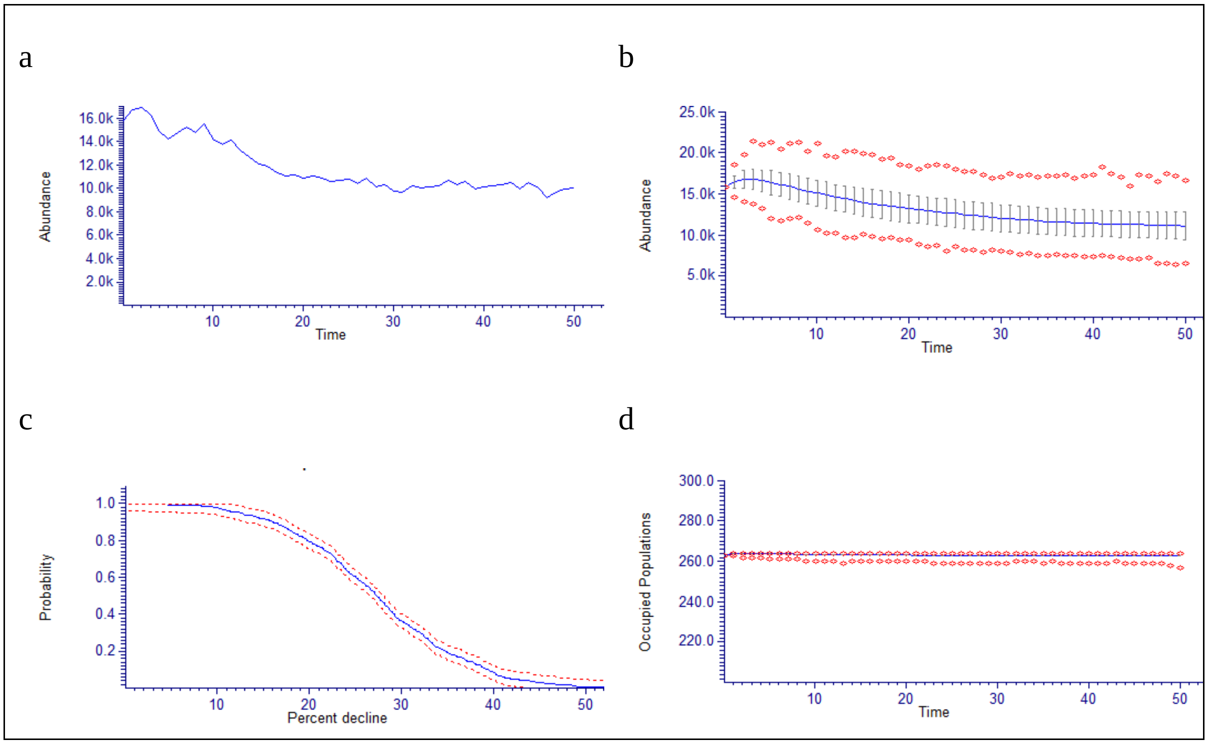
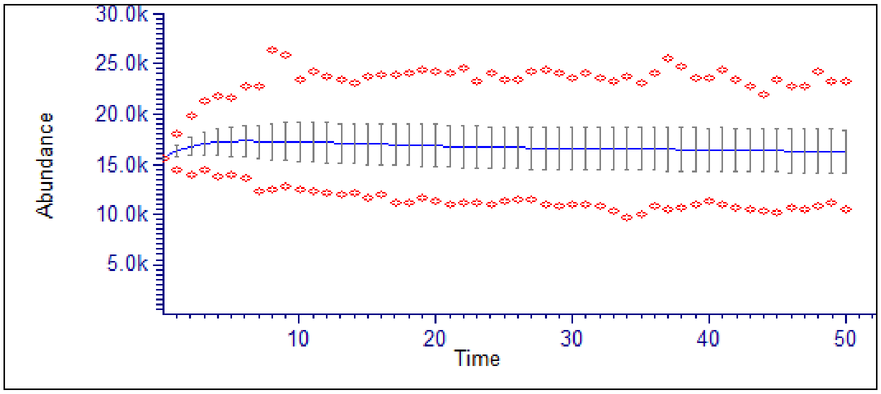


Figure 44: (a) Typical simulation run for the spatial model (HSI threshold=0.15); (b) average population trajectory for 1000 replications over 50 years; (c) functionality measured as interval percent decline, i.e., the probability of a given % decline of the initial population size at least once during the simulation time; (d) metapopulation occupancy over 50 years showing the average number of patches occupied. Extinction risk was 0%, expected minimum abundance (EMA) 10,086; average population abundance decreased from 15,782 individuals in the initial year to 11,126 in the final year.



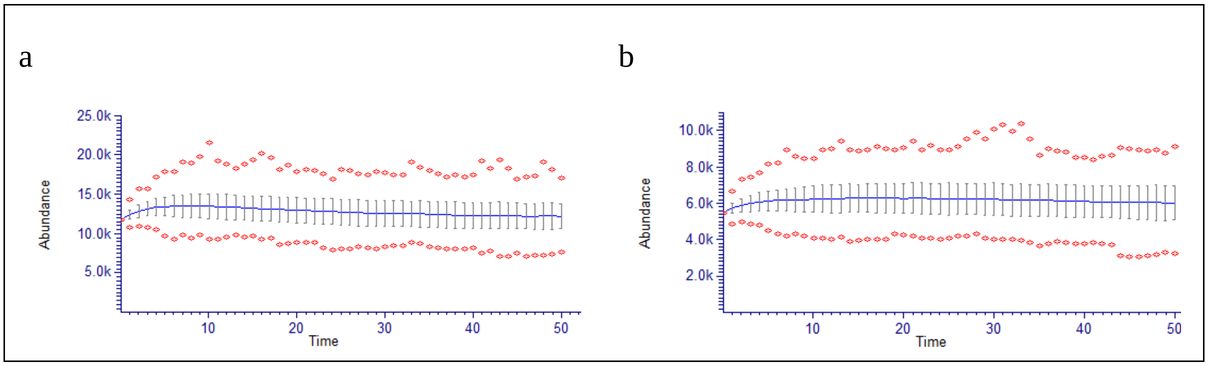
However, a change in the patch size distribution (while keeping total habitat amount constant, i.e., total carrying capacity of the metapopulation) showed that this population trend changed from a negative to a near neutral trend (Figure 45). To change the patch size distribution we removed 90% of the carrying capacity of the four largest patches (108, 121, 191, and 223) and divided this share equally across patches with K < 10. Overall, this resulted in a more even patch size distribution and reduced the degree of sink dynamics imposed trough smaller patches (where individuals from larger patches constantly emigrate to smaller population sinks resulting in an overall reduction in abundance). This scenario changed the population trend to 1.04, i.e., an increase from 15,782 in the initial year to 16,224 in the final year.

Figure 45 Average population trajectory for 1000 replications over 50 years for a HSI threshold of 0.15 and a modified patch size distribution (see text); Extinction risk was 0%, expected minimum abundance (EMA) 13,972; average population abundance increased from 15,782 individuals in the initial year to 16,224 in the final year.



We then reduced the amount of suitable habitat by increasing the habitat suitability threshold. For a HSI value of 0.5 RAMAS©GIS generated 121.94 km^2 of suitable habitat distributed over 181 population patches. This resulted in a viable population with 0% extinction risk, an EMA of 10,594 and a population trend of 1.03 (increase in total metapopulation abundance from 11,793 to 12,204) (see Figure 46). When we furthermore reduced the habitat amount to 0.75% (HSI = 1.0, i.e., only highly suitable habitat is considered) and also modified the patch size distribution (as described for the HSI=0.15 scenario) the bobolink metapopulation still showed stable population dynamics over a simulation period of 50 years. In summary, for a total of 36.52 km^2 of highly suitable habitat in the Québec study area (0.75% habitat amount) (and a slightly changed patch size distribution) bobolink metapopulation dynamics over 50 years were viable (<5% extinction risk), stable (<10% population decline) and functional (<5% risk of decline to 50% of initial population in any year). Further reductions in habitat may still yield viable (and stable) population dynamics. However, due to high potential variations in patch size structure (and the above documented negative effect on the population trend) we recommend using the above assessment as a conservative threshold.

Figure 46: (a) Average population trajectory for 1000 replications over 50 years for a HSI threshold of 0.5 (EMA = 10,594; year 1 = 11793, final year = 12,204) and (b) for HSI=1.0 with a modified patch size distribution as described for Figure 45 (EMA = 5,075; year 1 = 5,564, final year = 6,034)



14.4 Recommendations for Habitat-Based Standards

Based on the PVA study for the eastern Ontario (Pearce et al., 2007) and the Québec pilot study area (this report) we suggest the following set of habitat-based standards:

- a minimum patch size of 20 ha for patch occupancy

- a minimum patch size of 135 ha (based on an average population density of 1.5 individuals per ha) to support a single, viable population over 50 years with 95% confidence
- a maximum inter-patch distance of 15 km
- a minimum amount of 0.75% of high quality habitat to support a viable, stable and functional metapopulation on the NAESI Québec study area scale (4869 km^2) (subject to patch size distribution)
- no hayfield harvesting prior to the first week in July

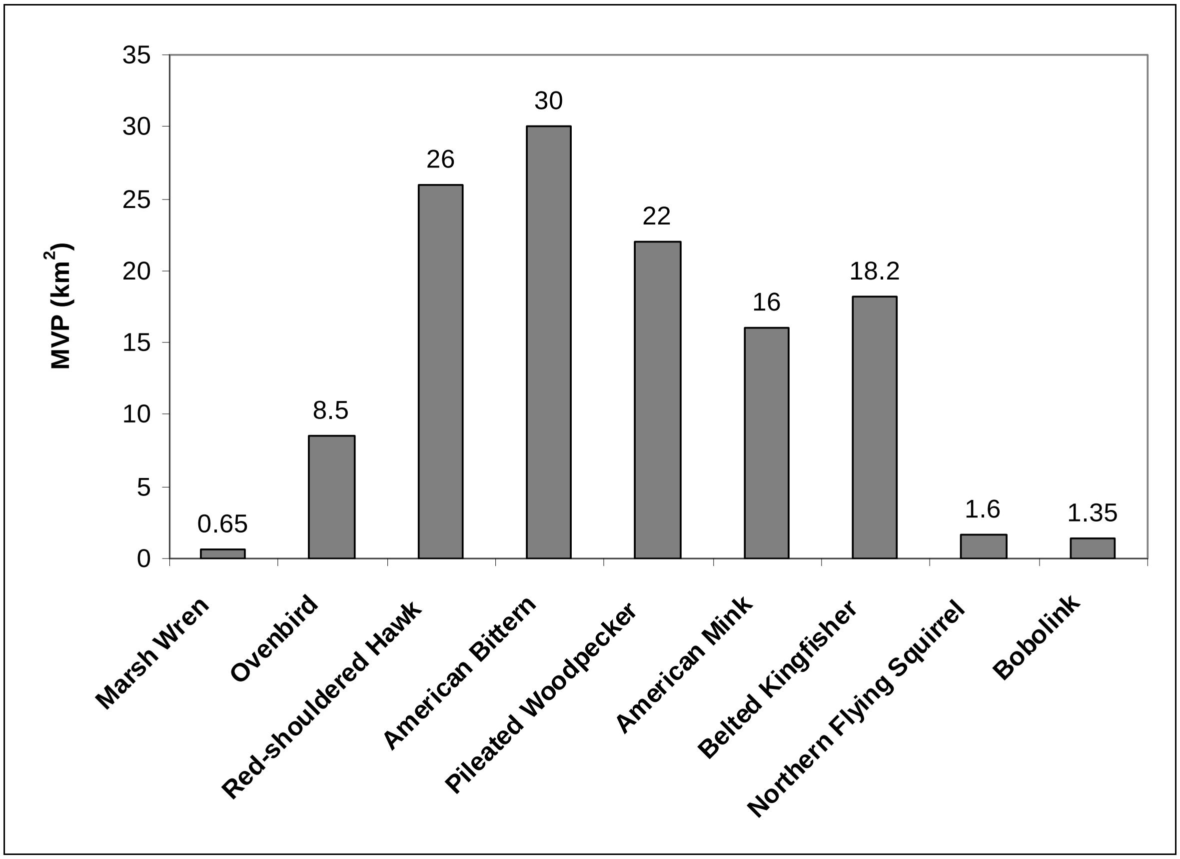
15 CONCLUSIONS AND OUTLOOK

For the purpose of this study we have linked empirical knowledge, demographic analyses and spatially implicit, stochastic population models to develop habitat-based biodiversity performance standards under the Biodiversity Theme of NAESI. For each surrogate species we have proposed a set of habitat-based standards based on a simulation trajectory of 50 years, a 95% confidence for 1000 simulation replicates, and current landscape conditions on the NAESI Québec study area scale. The recommended habitat-based standards were developed as broad guidelines to ensure a sufficient habitat supply so that these populations are viable and near stable and that their ecological functions and processes are maintained at appropriate spatial and temporal scales. However, due to the stochastic nature of population viability models, such standards are subject to an unknown degree of uncertainty and can vary depending on patch size distribution, initial population size, demographic rates or the size of the study area. Thus, many of the recommended standards are based on specific model parameterizations and any changes in the model assumptions will lead to variations in the recommended standards.

A particular focus in this study (and in the overall NAESI Biodiversity Theme Framework) is placed on the goal to assess ‘how much habitat is enough’ for different species’ performance measures and targets. The question of ‘how much habitat is enough’ is not a trivial one to answer. The proportion of habitat on the landscape required for viability depends on the habitat quality in each patch perceived by the species, the demographic rates, the patch size distribution that determines the potential number of individuals in each patch, the inter-patch distance determining dispersal rates, the correlation of fluctuations in vital rates among patches, or the quality of matrix habitat. Even though matrix quality can be incorporated in RAMAS©GIS by calculating patch quality based on adjacent (unsuitable) matrix habitat or by modifying dispersal rates among patches that are separated by specific matrix habitat, RAMAS©GIS only allows for the incorporation of indirect effects. Ideally (but far more complex), a spatial-explicit model would simulate actual movements of individuals on the landscape, within a breeding season or among years. These types of models are often referred to as individual-based (or agent-based) models. Individual-based models (IBM) are built from the perspective of individual organisms and their behavior (Grimm and Railsback, 2005). The bottom-up strategy of such models is to compile relevant information about entities at a lower level of the system (i.e., agents or individuals), formulate theories about their behavior, incorporate these into a computer simulation model, and observe the emergence of system-level properties related to particular questions (Grimm et al., 2005). Most IBMs are spatially explicit as the rules for an agent’s behavior are often governed by space. Mechanistic, bottom-up IBMs have become a popular tool as they are based on simple rules but can generate complex real-world patterns (e.g. Tews et al., 2007).

As mentioned, the proposed standard ‘minimum habitat amount’ (MHA) is subject to parameter uncertainties and available data and, in particular, the distribution of patch sizes in the area sampled and the degree of connectivity. In most cases we were only able to assess one MHA threshold due to the limited scope in each analysis. However, ideally, MHA standards should represent an envelope, i.e., a range of upper and lower MHA values based on a range of possible and current patch size distributions (which would require a thorough theoretical analysis). Due to this and the described uncertainties we recommend using the standard ‘minimum viable patch size’ (MPS-V) as an alternative to MHA (see summary for 9 surrogate species in Figure 47). This applies in particular to smaller spatial scales at the municipality or regional level where potential decisions have to be made whether the conversion of certain habitat patches is tolerable or not. Firstly, a MPS-V standard can be more easily re-calculated if further demographic data become available or if estimates ought to be based on different population densities. Secondly, a MPS-V standard represents a conservative estimate that ensures that the size of a given habitat patch facilitates persistence largely independent of the matrix and other surrounding habitat patches. Thirdly, a non-spatial, demographic analysis is less time consuming. However, we are also aware that most often patch sizes in current agricultural landscapes are significantly lower then the required MPS-V patch size (especially for species with larger home ranges and area requirements) and larger spatial scales may need to be considered to assess appropriate standards (see e.g. large MVP-S for the Red-shouldered hawk, American bittern, Pileated woodpecker or American mink, Figure 47).

Figure 47: Minimum viable patch size (km^2) for 9 selected surrogate species.



Another important prerequisite for an in-depth population modeling exercise should be an appropriate sensitivity analysis (SA). A sensitivity analysis should cover all relevant parameters of the stochastic model and report related changes in model outputs. Two general approaches are most often applied. For the first approach, one model parameter is varied while the rest of the parameters are kept constant. Then, relative changes in model performance can be evaluated and each parameter ranked according to the sensitivity of the model to relative changes in that parameter. For the second approach all parameter values are varied independently in a random fashion and model runs with different parameter sets are replicated until a sufficient range of variation has been simulated for each parameter. Although the latter approach is able to reveal more information on the mechanistic behavior of the model and allows a more comprehensive statistical analysis, it is computational quite intensive and requires an automated, Ramas-external SA routine. Due to a different focus and the temporal constraints SA's were not fully conducted for the Quebec pilot study area PVAs. For the majority of surrogate species a base parameter model was used that was based on an intermediate empirical data value. However, for some models, selected demographic parameters were varied to a certain extent to further assess the models behavior and sensitivity.

Another point that should be finally raised is the question whether the set of selected surrogate species and their modeling analysis did help to answer some of the initial questions and achieve the original project goals. In a previous modeling step surrogate species were carefully selected so that the overall species set covers a wide range of ecological services and functions, habitat types, home range scales and life history types (among other criteria). We are confident that the selected species comprise a significant contribution of important biodiversity elements, including the services, functions and processes that are associated with each species' habitat type. However, it remains open to discussion whether the recommended species standards can be utilized as generally applicable habitat standards. In other words, is 20-40% of deciduous and mixed forest habitat (required for ovenbirds) sufficient to provide the range of biodiversity functions, processes and services that are associated with this habitat type as well as other species utilizing this habitat? Such a question cannot be answered by science alone. To support the NAESI objectives this needs to be approached in concert with political decisions and decisions on the feasibility to achieve certain goals and guidelines.

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