THE HOODED WARBLER

POPULATION VIABILITY AND CRITICAL HABITAT IN SOUTHERN ONTARIO, CANADA

IRF 18610 - Contract No: K1869-2-0070
prepared under the authority of
Environment Canada, NWRC and CWS

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Summary

The Hooded Warbler was designated as “Threatened” Species in 2000 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The species at risk act (SARA) prescribes identification and protection of critical habitat for this species. This work contributes to and supplements related recovery and conservation efforts. A comprehensive population and habitat viability analysis has been conducted for the Hooded Warbler in the Carolinian region in southern Ontario. Metapopulation and individual-based, spatially explicit population models were used to asses demographic viability, minimum viable population size, susceptibility to habitat loss and fragmentation and critical habitat for the Hooded Warbler population. The results indicate that the Hooded Warbler population in southern Ontario is likely to be viable and self-sustaining. The minimum viable population for a time frame of 100 years is estimated to be 100 breeding pairs, which is about half of the currently known population size. Although the Hooded Warbler population may not be immediately endangered to extinction, its viability may generally decrease with decreasing habitat amount and with increasing habitat fragmentation. The negative effect of habitat fragmentation on extinction risk may increase with decreasing habitat amount. The simulation results also indicate that the Hooded Warbler may utilize all available habitat in southern Ontario based on its known dispersal range of up to 100 km. Critical habitat has been identified based on simulating the population dynamic of the Hooded Warbler on a habitat suitability map. The habitat suitability map is the result of a logical combination of different data layers known to affect the occurrence of the Hooded Warbler. Habitat patch removal experiments revealed those critical habitat areas, which are most important to the abundance of the Hooded Warbler population. Larger habitat patches are most critical to the population and should be prioritised in conservation plans.

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<u>Notice</u>

The results provided in this report are subject to an unknown degree of uncertainty. There is substantial uncertainty in the knowledge of demographic data, such as fecundity, survival and dispersal distances. There is also uncertainty in the habitat suitability models, which may be reflected in an incorrect habitat suitability map. This uncertainty and its propagation over time is partly considered in the demographic and environmental stochasticity of the population model. Due to the stochastic nature of the population models, simulation runs were replicated up to 1000 times and results are averages out of those replicate simulation runs. Absolute numbers should be interpreted with caution. Instead trends and differences between different simulation runs (scenarios) are generally more trustworthy. All information used in this work have been discussed with members of the recovery team and verified as well as substituted from the scientific, peer-reviewed literature. The work therefore represents our best possible educated "guess" based on our current knowledge of the biology, life history and habitat requirements for this species.

1 Hooded Warbler (*Wilsonia citrina*)

1.1 Demography

The demographic characteristics for the Hooded Warbler (HOWA) in the Carolinian Region in southern Ontario have been compiled based on published data from the literature and in collaboration with the Recovery Team and external experts, in particular Lyle Friesen, Debbie Badzinski, Mary Gartshore and Bridget Stutchbury. See also the following references for life-history information on the HOWA (Norris and Stutchbury 2000, 2001and 2002, Nagy and Smith 1997, Pitcher and Stutchbury 2000).

Characteristic	Observation	References
Breeding period (ON)	mid-May to late July	Bisson & Stutchbury 2000
Clutch size	3.5 (ON: 1998)	Bisson & Stutchbury 2000
Broods/year (PA)	1.2 (may be lower for ON?)	Evans Ogden & Stutchbury 1996
Incubation period	12 days	Evans Ogden & Stutchbury 1994
Fledging period	28 days	Evans Ogden & Stutchbury 1994
Maturity	breed at 1 year	
Life Span	8 yrs maximum, 2.5 yr estimated average	Evans Ogden & Stutchbury 1994
Cowbird Parasitism	18% parasitized (ON: 1998)	Bisson & Stutchbury 2000
Nesting Success	82% of nests fledged (ON: 1998)	Bisson & Stutchbury 2000
Fledging Success	2.6 $\pm$ 0.29 fldg (n = 22) (ON: 1998)	Bisson & Stutchbury 2000
Ontario Population Size	251 males/ 225 females	Badzinski, pers. comm.
Stage/Age class	juvenile / adult	
Annual Survival	juvenile 0.32 $\pm$ 0.064; adult 0.64 $\pm$ 0.128	Badzinski, Friesen, pers. comm.
Return Rate to Study Site (PA)	52% for males (n = 174, 43% for females (n = 195)	Howlett & Stutchbury (in press)
Dispersal/Movement	avg. 10-20 km; max. 120 km	Badzinski, Friesen, pers. comm.
Average Territory Size	avg. 7.2; min 1.6; max 8.5	Badzinski, pers. comm. Howlett and Stutchbury 1997
Habitat Requirements	small clearings in the interior of large mature hardwood forests, well closed canopy	Sedgwick and Knopf 1987 Robinson and Robinson 1999 Donovan and Flather 2002
Threat	habitat loss, loss of clearings due to succession	
Sex Ratio (ON: 1998)	83% of males paired 40 – 45 % females in population	Bisson & Stutchbury 2000 Badzinski, Friesen, pers. comm.
Carrying Capacity in the Carolinian Region	unknown, potential (400 pairs assumed)	
Trend in Population size	steady increase since from (80-176) in 1988 to 251 in 2002	Badzinski, unpubl. data

Table 1: Life history data for the Hooded Warbler

1.2 Population Model

1.2.1 Model Characteristics

Two software programs RAMAS® GIS (Akçakaya and Root 2002) and PATCH (Schumaker 1998) were used to model the population dynamics of the Hooded Warbler. RAMAS® GIS provides a comprehensive set of tools to evaluate the viability of a population or a metapopulation, i.e. a population of populations, of which some may become extinct and re-colonized in isolated habitat fragments. PATCH allows to define and simulate a population model in terms of single individuals, which operate in a spatial, territorial environment. Both software programs allow to analyze the viability of populations and to rank the corresponding relative importance of habitat areas.

1.2.2 Parameter Values

A population model is defined by its conceptual structure (e.g. presence/absence, age classes, individual based) and by its parameter values. Latter must be defined based on the biology and life history of the species of interest.
For the HOWA fecundity rates per female have been extracted from a breeding survey in Ontario (Bison & Stutchbury 2000). The study revealed an average of 2.6 successfully fledged young per nest. These data are not consistent with those obtained by Badzinski (unpubl. data), but are generally in line with the observed annual reproductive success for the HOWA in Pennsylvania (Ogden and Stutchbury 1994).
Survival rates for the HOWA are unknown. However, estimates for juveniles range from 0.28 – 0.36 and for adults from 0.56 – 0.72 (Friesen, Badzinski pers. comm.). Survival rates of 0.31 and 0.62 for juveniles and adults respectively resulted in a moderate population increase in preliminary simulations, which reflects the observed trend of the population size in Ontario. The parameter values used in the population model are listed in Table 2.
The population model is a “female only” model and the results are based on the number of females. The lower proportion of females in the population (uneven sex ratio, see Table 1) is reflected in the adult fecundity rate. This adjustment (see Table 2) implies that the number of female offspring is less than 50 percent. Another reason for the uneven sex ratio may be a lower survival probability for female adults. If this is the case, the model will slightly underestimate the fecundity of the population resulting in conservative results with respect to the viability of the population.

Parameter	Value/Range	Comments
stage classes	juvenile/adult	pers. comm. with Friesen, Badzinski, Gartshore, Stutchbury
juvenile fecundity	0	
adult fecundity (female juveniles per female adults)	1.404 ± 0.14 (10% stddev.)	1.2 (broods) * 2.6 (fledglings) * 0.45 (sex ratio) = 1.404
juvenile survival	0.32 ± 0.064 (20% stddev.)	pers. comm. with Friesen, Badzinski, Gartshore, Stutchbury
adult survival	0.64 ± 0.128 (20% stddev.)	pers. comm. with Friesen, Badzinski, Gartshore, Stutchbury
density dependence	ceiling exp. growth up to carrying capacity 400 breeding pairs	pers. comm. with Friesen, Badzinski, Gartshore, Stutchbury
simulated years	100	
initial population size	225	Badzinski, unpubl. data.
replications	1000	
dispersal	negative exponential up to 120 km	pers. comm. with Friesen, Badzinski, Gartshore, Stutchbury
demographic stochasticity	yes	number of survivors and dispersers (emigrants) to be sampled from binomial distributions, number of young from a Poisson distribution.
environmental stochasticity	lognormal	statistical distribution (normal or lognormal) to be used in sampling random numbers for vital rates

Table 2: Parameter values for the HOWA population model (RAMAS© GIS)

1.2.3 Analysis of the demographic population viability (non-spatial)

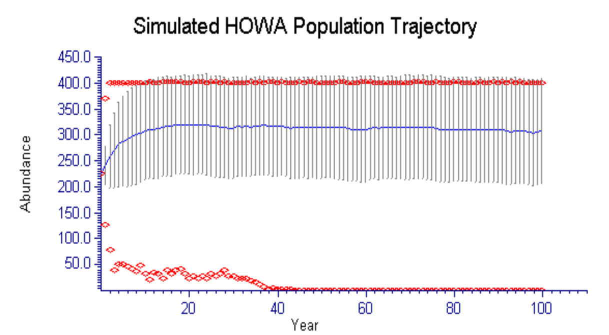
The viability of a non-spatial HOWA population was analyzed based on the model parameter values presented in 1.2.2 using RAMAS© GIS. This non-spatial population model assumes that all breeding females reside in one single habitat patch (a cluster of adjacent territories). No dispersal was required and the population could grow exponentially up to a carrying capacity of 400 individuals. The results of this non-spatial population model identify the demographic viability of the population and will serve as a benchmark for the results of subsequent spatially explicit population and habitat viability analyses. The results are presented in Figure 1.

The graph in Figure 1a shows the average population abundance over the time span of 100 years. The vertical lines indicate the range of the standard deviation and the red trapeziums show the observed maximum and minimum values. The maximum values are cut off at the carrying capacity of 400 individuals (breeding pairs). The simulations predict an increase in population size up to an average of 311 female individuals over 100 years. The predicted probability of extinction (or extinction risk) is less than one percent. The extinction risk is calculated as the proportion of replicate simulation runs in which the population became extinct. In this case the population went extinct in 2 out of 1000 replicate simulation runs.

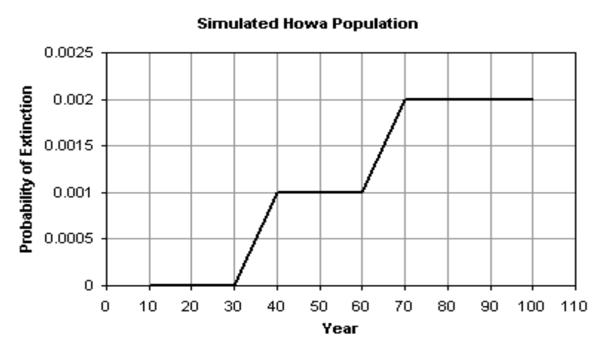
The graph in Figure 1b shows the extinction risk as a function of time. Due to the proliferation of uncertainty and the accumulated effects of stochastic events throughout the course of the simulation (and also in nature), the extinction risk increases over time. The results indicate an extinction risk near zero for the entire time span of 100 years. These numbers result from the actual known initial population size of 225 breeding pairs in southern Ontario and the applied carrying capacity of 400 breeding pairs.

The graph in Figure 1c shows the minimum viable population size (MVP) for an extinction risk of less than 1 percent over different time spans. For example, an initial population size of 50 breeding pairs is required to realize a 99 percent viable population over a time span of 40 years. This initial population of 50 breeding pairs would increase during the 40 years to a final population size of about 240 pairs.

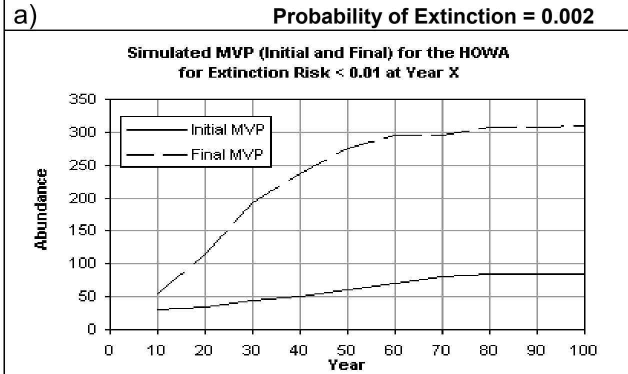
The results of this non-spatial population viability analysis indicate that the HOWA population in southern Ontario, according to our current understanding of the local life history and carrying capacity, appears to be viable and intrinsically self-sustainable.



a) **Probability of Extinction = 0.002**



b)



c)

Figure 1:

a) Predicted population (females only) abundance over 100 years (based on initial population size of 225 females and carrying capacity of 400 females);

b) Probability of Extinction over 100 years;

c) Minimum viable population (MVP) size. Solid line shows initial MVP and dashed line shows final MVP.

Predictions from PATCH

Population dynamics for the Hooded Warbler have also been simulated with the individual based, spatially explicit model PATCH. The model parameters reflect those used in RAMS© GIS. All 400 available territories (carrying capacity) were grouped adjacent to each other into one circular patch of habitat. This setting allows movement between territories only, but does not require movement across non-habitat. It is therefore the closest approximation to a non-spatial setting as used in RAMS© GIS. The predicted projection of the population abundance over 100 years is shown in Figure 2. The predicted rise in population size exceeds those calculated by RAMAS© GIS and is constrained by the carrying capacity, i.e. the number of available territories.

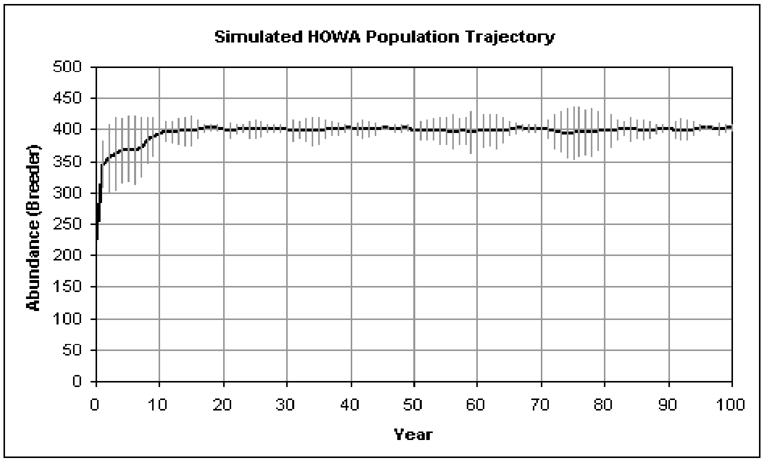


Figure 2: Population abundance for the Hooded Warbler in non-fragmented habitat simulated with PATCH.

1.2.4 Habitat Configuration Analysis

The effects of habitat amount and fragmentation have not been considered in the previous population viability analysis. The amount of habitat necessary to support a viable population can be estimated from the minimum viable population size times the average territory area. This extrapolation is appropriate when all territories are equally accessible to all members of the population. Habitat, however, is distributed in space and territories are often not adjacent to each other. In most situations, habitat is fragmented and its accessibility depends on the movement or dispersal capabilities of a species. Habitat fragmentation and its effect on population viability have become a major area of interest and research in recent conservation ecology. It has been shown in various studies, that the relative importance of habitat fragmentation depends on the actual amount of habitat in a landscape. The following analysis shall help to understand the effects of habitat amount and fragmentation for the viability of the Hooded Warbler based on our current understanding of its population biology.

In order to address this question, 60 simple landscapes have been generated using an algorithm published in Fahrig (1997, 1998), Tischendorf and Fahrig (2000) and Tischendorf (2001). Each landscape consists of 100x100 pixels of 250 meter edge length per pixel. The extent of a landscape is therefore 25km resulting in an area of 625 square km. The pixel size of 6.25 ha corresponds roughly to the size of one territory of the Hooded Warbler (see 1.1, Table 1).
The value of each pixel can either be habitat or non-habitat (matrix). The algorithm used for generating the landscapes allows habitat to be distributed across the landscapes in a more or less fragmented way. Some exemplary landscape models are shown in Figure 3. The amount of habitat (or number of 6.25 ha territories) was varied between 40 and 400 and the fragmentation for each of the habitat levels was varied

across 6 levels from low to high. In Figure 3 each row shows from left to right increasingly fragmented distributions of a certain number of 6.25 ha territories (or habitat amount). The numbers to the right of the figures show the actual number of 6.25 ha territories and the degree of fragmentation. Fragmentation was measured using the “effective number of habitat patches (EN)” (whereas patches are adjacent pixels in the model or neighbouring territories in reality). This new measure of fragmentation was recently developed by Jochen Jaeger (Jaeger et al. 2003). EN has the following features: it is an increasing function of the number of patches; it is an increasing function of the similarity of patch sizes; it is conceptually independent of habitat amount; and it is independent of patch shape and dispersion.

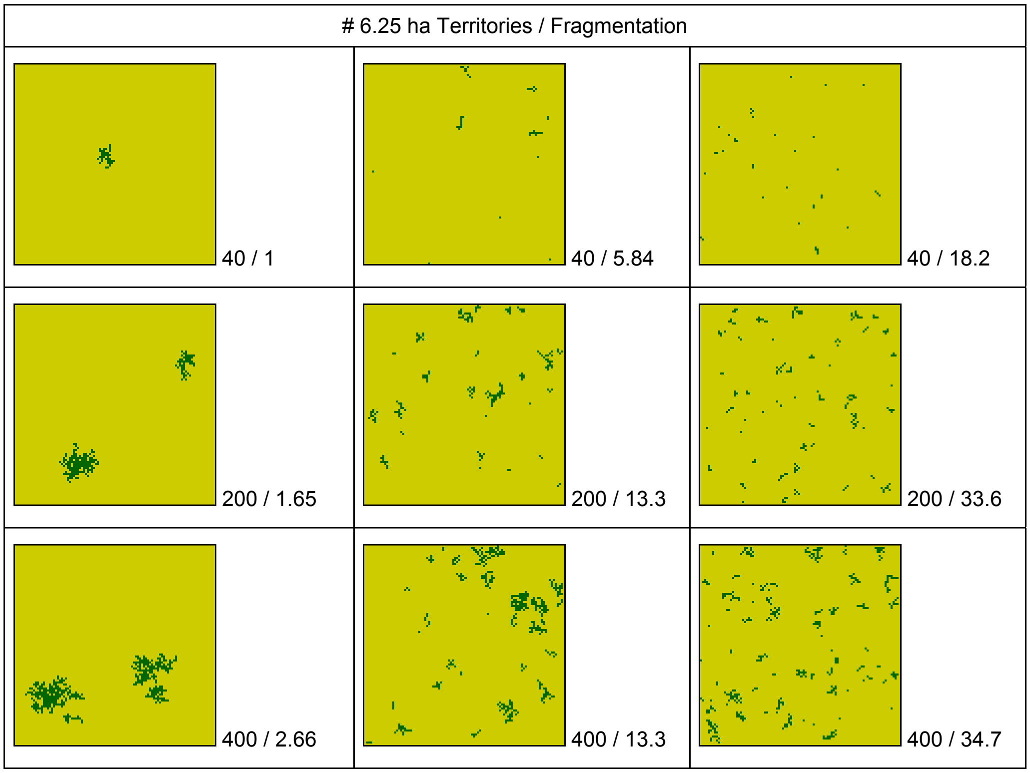


Figure 3: Landscape models used to examine the effect of habitat amount and fragmentation on the probability of extinction for the HOWA. Each row shows 3 (out of actually 6) landscapes containing equal, but increasingly fragmented (left to right), amounts of habitat.

On each of the 60 generated landscapes the population model of the HOWA as described in 1.2.1 was executed using RAMAS© GIS. The population was initially distributed across all territories (habitat pixels in the generated landscapes). The carrying capacity was identical to the number of territories and the initial total population size was half the carrying capacity for each landscape. In addition to the non-spatial model described in 1.2.1, individuals were allowed to move within the landscapes. The maximum dispersal distance of the HOWA was estimated to be 20 km. (This distance is lower than the maximum distance observed in nature (see Table1), but corresponds to the 25km extent of the modelled landscapes). This distance was used as a maximum in a negative exponential function. Probability of extinction was measured for each simulation and subsequently related to the habitat amount (# of 6.25 ha territories) and habitat fragmentation (EN, see above). The results are shown in Figure 4-6.

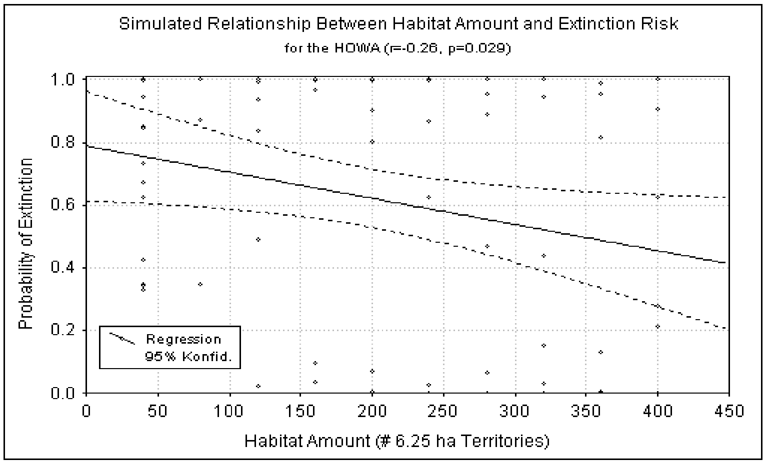


Figure 4: Effect of habitat amount on the probability of extinction. The probability of extinction increases with decreasing habitat amount, but is affected by the spatial distribution of habitat as indicated by the dispersion of the plots.

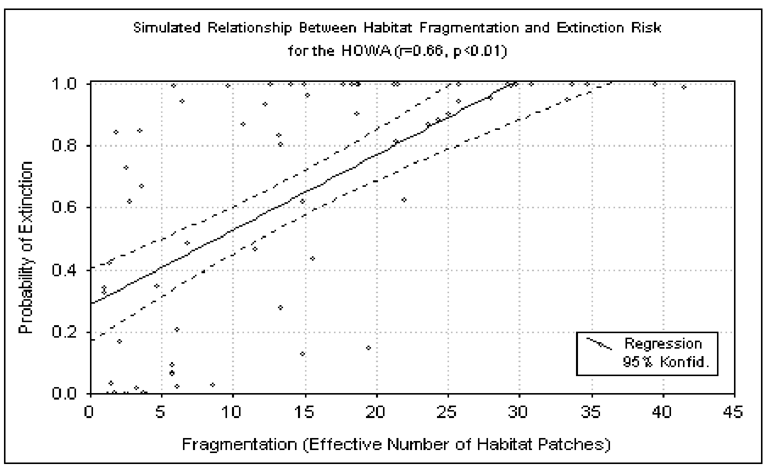


Figure 5: Effect of habitat fragmentation on the probability of extinction. Increasing habitat fragmentation results in overall higher extinction risk, but also depends on the amount of habitat in the landscape.

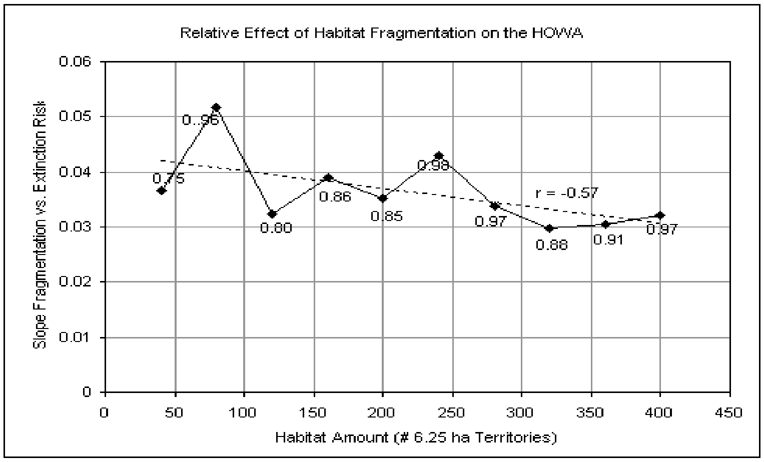


Figure 6: Interaction between habitat fragmentation and habitat amount. The data points are the slopes of the regression lines between habitat fragmentation (EN, see above) and the probability of extinction. The numbers at the plots show the corresponding correlation coefficient r, for the regressions. All regressions were significant at p=0.05. (although some of the relationships are non-linear). The slope of the regression between fragmentation and extinction risk increases slightly with decreasing habitat amount.

The results of this habitat configuration analysis indicate that a) habitat loss increases extinction risk, b) habitat fragmentation increases extinction risk and c) the effect of habitat fragmentation on extinction risk increases with decreasing habitat amount. Matrix quality, roads or landscape topography may still affect and challenge these relationships. The general pattern, however, is in line with the results of many other fragmentation studies.

1.3 Critical Habitat Analysis

1.3.1 Habitat Suitability Map

The critical habitat analysis for the HOWA in the Carolinian region is based on the habitat suitability map as shown in Figure 8. This map has been produced based on the currently known habitat preferences of the HOWA. (documentation of the habitat suitability model will be provided by Mike Flaxman) The geographical context for the habitat suitability map is shown in Figure 7. The occurrence range of the HOWA in southern Ontario is restricted to this area, which is bordered by Lake Ontario, Lake Erie and Lake Huron. Major urban areas are Toronto and Hamilton (east), London (central) and Windsor (west).

The habitat suitability map for the HOWA (Figure 8) contains 3 land cover types: no habitat, occupied habitat and unoccupied habitat. The occupied habitat comprises those areas, which were identified as habitat and which have been occupied by the HOWA in the past. The unoccupied habitat shows those areas, which meet the known habitat requirements for the HOWA, but which are currently not occupied by this species.

The habitat suitability map as shown in Figure 8 has the following characteristics:
north-south extent = 203 km, east-west extent = 400 km, pixel size = 95.26m x 95.26m (9074.250 m²), map size = 4193 x 2134 pixels, total area = 81200 km², occupied habitat area = 540 km², unoccupied habitat area = 723 km².

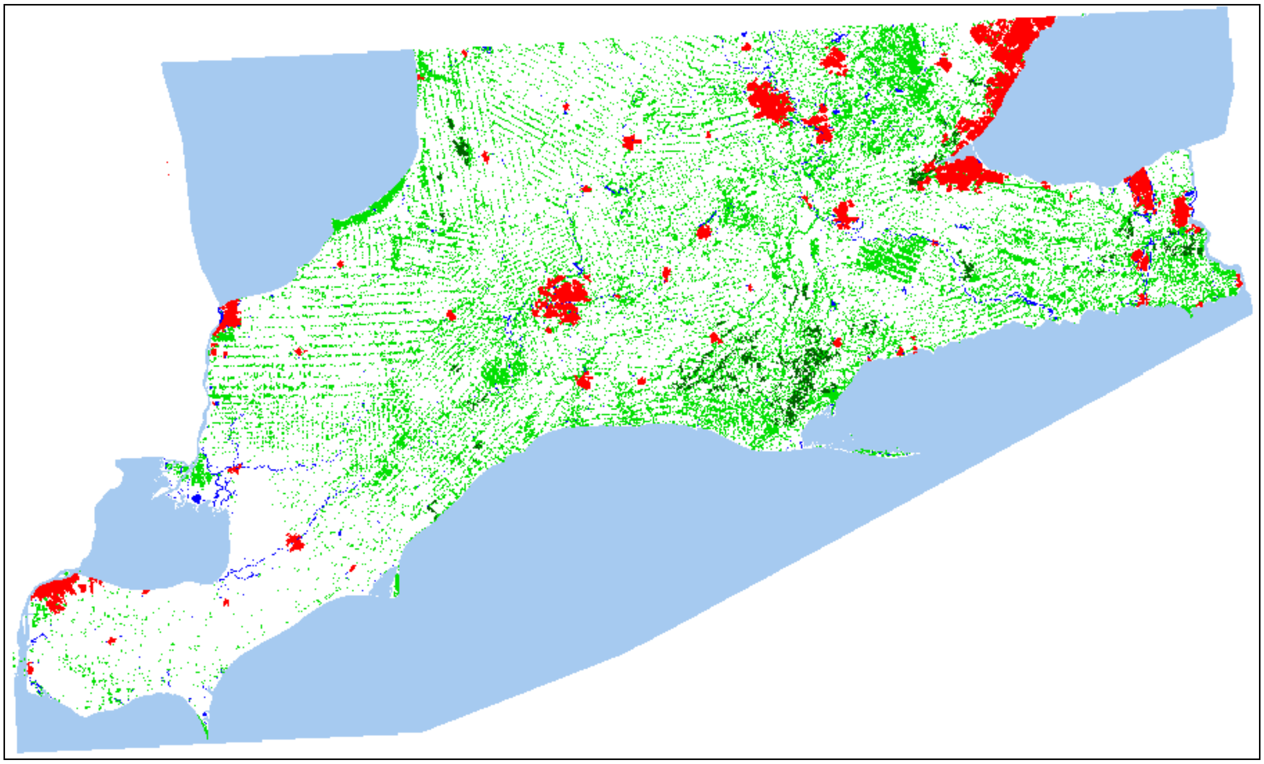


Figure 7: Study area and occurrence range of the HOWA in southern Ontario.

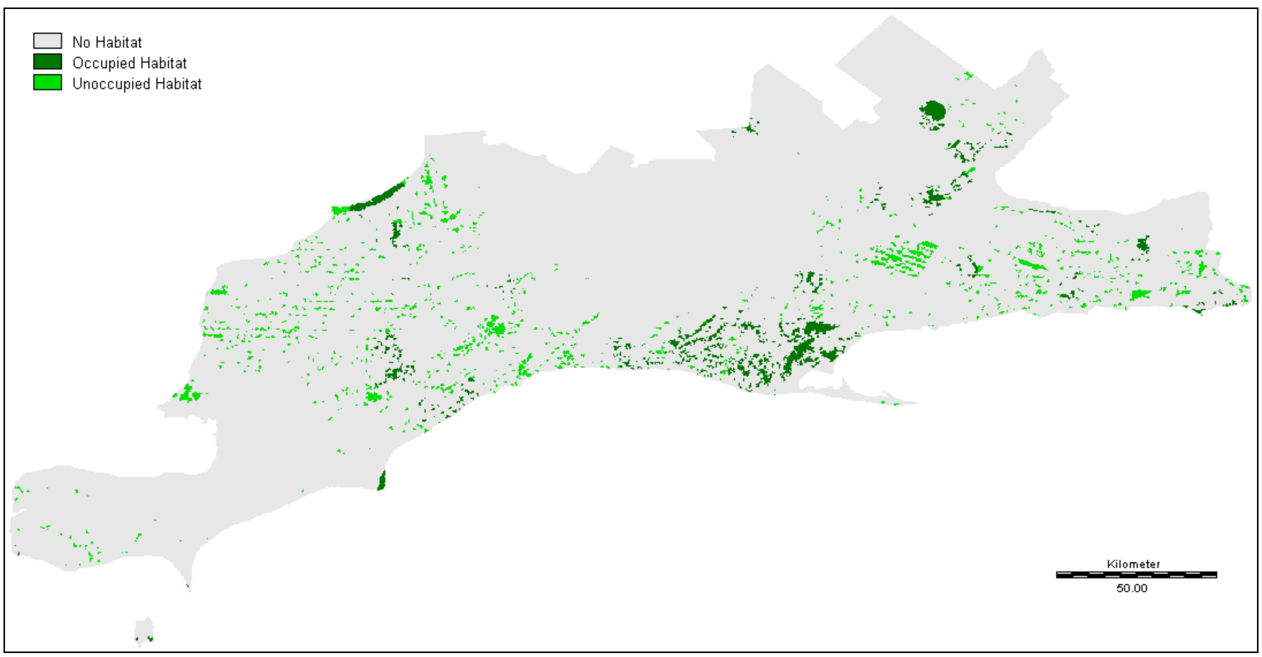


Figure 8: Habitat suitability map for the Hooded Warbler (400 x 203 km)

The habitat suitability map as shown in Figure 8 was aggregated into a coarser resolution, because the number of occupied and unoccupied habitat patches (pixel clusters) was too large to be processed with RAMAS© GIS. The resolution was therefore changed by factor 12 using a pixel thinning algorithm. This algorithm was chosen because it preserved the proportions of each land-cover type in the aggregated maps. The aggregated habitat suitability map used for the population models has the following characteristics: pixel size = 1143m x 1143m (1.306 km²), map size = 349 x 177 pixels.

1.3.2 Source – Sink habitat

The spatially explicit and individual based population model PATCH was used to rank habitat according to recorded average occupancy and net emigration rates. Higher occupancy rates indicate more sustainable populations. Higher net emigration rates indicate source habitat.
The population model as described in 1.2 (Table 2) was applied to the habitat suitability map as shown in Figure 8. In a first step, occupied habitat was extracted from the habitat suitability map and simulations were conducted on occupied habitat only. In a second step, simulations were conducted on all occupied and unoccupied habitat. Initial populations were seeded in locations, which were occupied in 2002. Reproduction was restricted to habitat area, whereas movement (dispersal) could occur in non-habitat. Individuals could move up to 100 territories, which corresponds to the observed movement/dispersal distance of about 120 km. Moving individuals chose the closest available territory while moving. (Note, patch allows to set the movement mode to 'random walk', 'optimal' and 'closest') Since no data are available for the territory selection of the HOWA and random walk is unlikely, individuals are assumed to chose the closest available territory while moving. A sensitivity analysis between the 'optimal' and 'closest' movement mode showed slight but insignificant differences in the model output.
Side fidelity for adult individuals was set to medium out of the options 'low', 'medium' and 'high'. Simulations were conducted for 100 time steps (years) and replicated 100 times. Patch records occupancy rates, emigration and immigration rates into patches among other demographic measures. The results are illustrated in Figure 9 and 10.

The green areas indicate higher occupancy and net emigration rates, whereas yellow or red areas indicate lower rates. The maps in Figures 9 and 10 show high occupancy and net-emigration rates for almost all available suitable habitat. These results indicate that the Hooded Warbler may be able to utilize all available habitat.

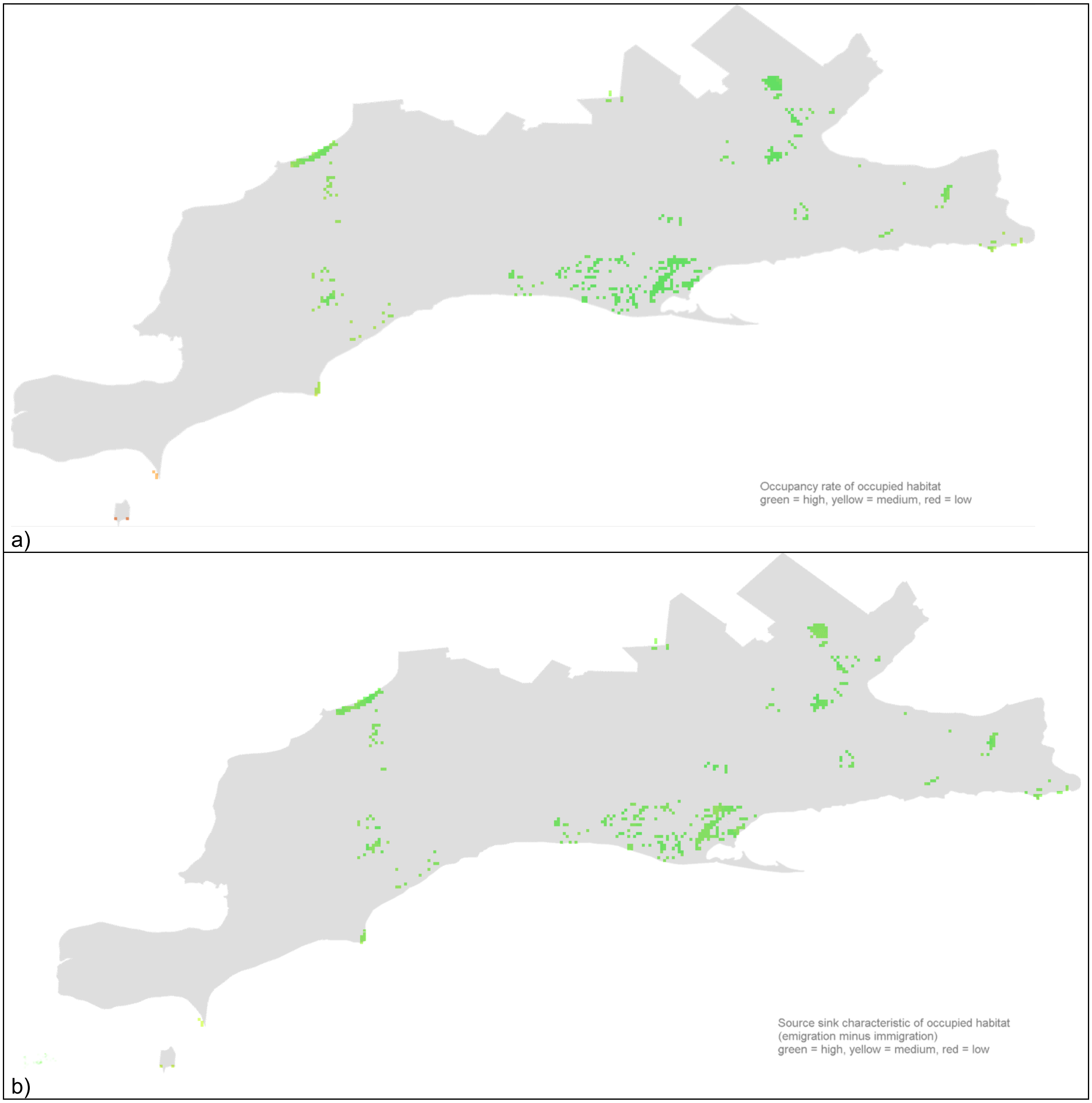


Figure 9: Occupancy rates and source – sink characteristics for occupied habitat.

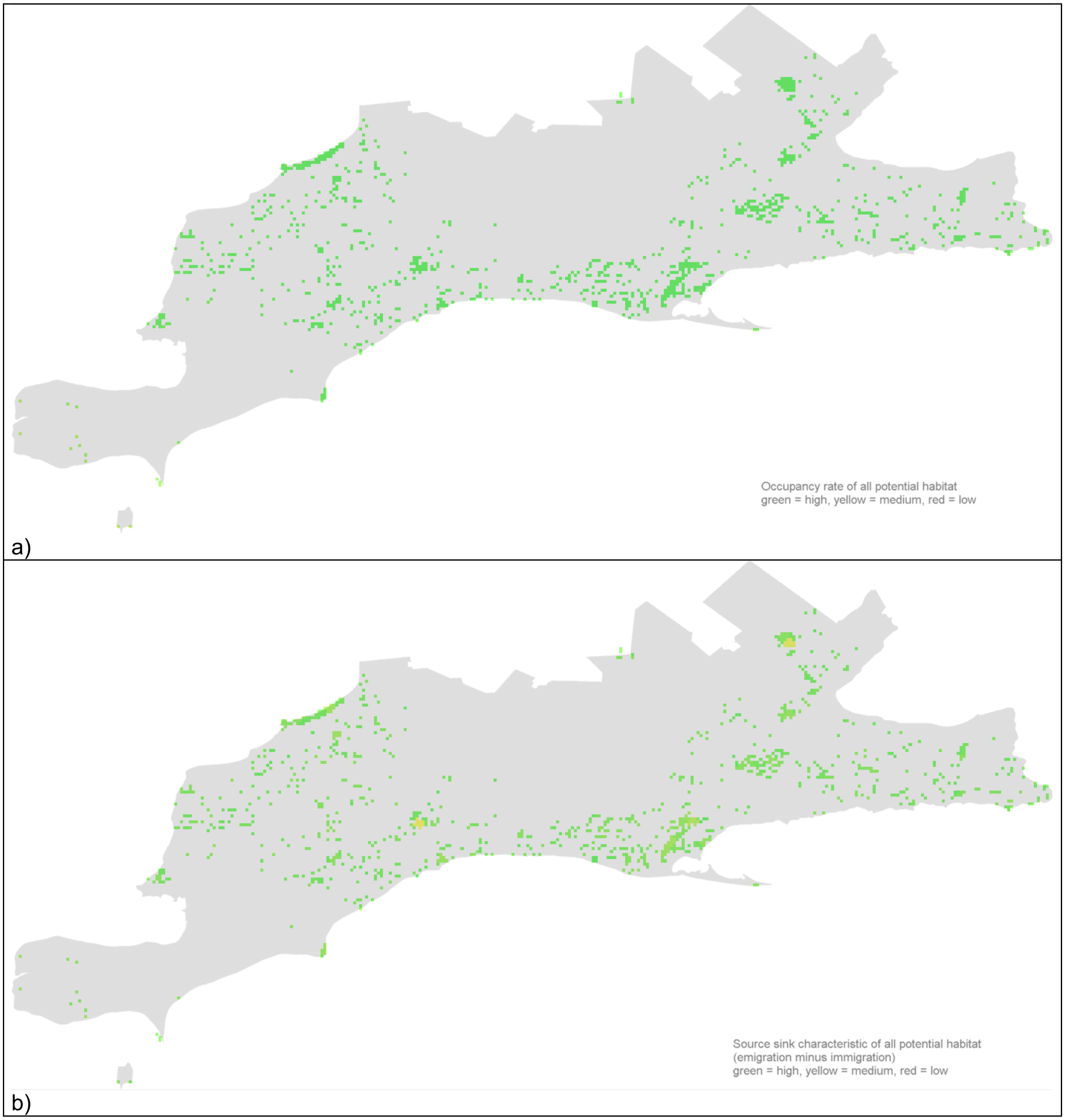


Figure 10: Occupancy rates and source – sink characteristics for all identified suitable habitat

1.3.3 Analysis of the population viability in the Carolinian region

The population model as described in section 1.2 was applied to the habitat suitability map using RAMAS© GIS in order to estimate the viability of the HOWA population based on the habitat configuration in the Carolinian region. The simulation procedure was identical to those used in the fragmentation analysis and described in 1.2.3. Simulations were conducted on occupied habitat only and on all identified suitable habitat as shown in Figure 8. The results are shown in Figure 11.

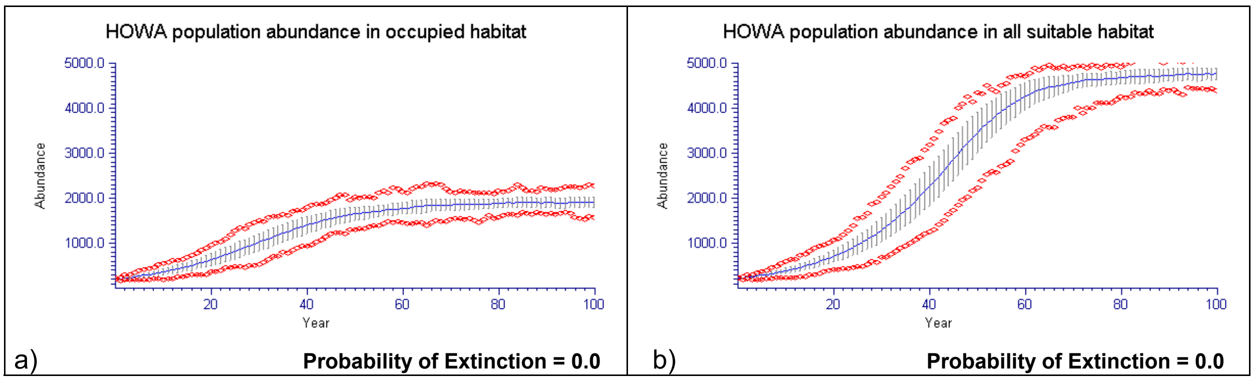


Figure 11: Extinction risk and predicted population abundance for the HOWA in the Carolinian region when residing in occupied habitat only (a) and when using both occupied and potential suitable habitat (b).

The results of the simulated population dynamics on the habitat suitability map indicate no extinction risk for the HOWA populations in southern Ontario. The population may increase up to the actual carrying capacity in the region.

1.3.4 Critical Habitat

Although the previous results indicate that the HOWA population is not likely to be limited by demographic constraints or habitat amount some habitat area may still be more critical to the viability of the population than others.

In order to identify the most critical habitat patches (in addition to the source-sink ranking as shown in Figures 10 and 11), a patch-removal experiment was conducted. The population dynamics of the HOWA were simulated on the habitat suitability map using RAMAS© GIS. Several replicate simulation runs were conducted while each time one patch was removed. Because the extinction risk was always zero in previous simulation experiments, the predicted average abundance after 100 years was used as difference measure. The difference in the predicted average abundance resulting from simulations on all habitat patches and those from simulations where one patch was removed was used to rank the criticality of the habitat patches. Patch size was also considered in ranking the criticality of the habitat patches. In the resulting critical habitat map (see Figure 12) all those patches are categorized as critical (and marked in red colour), which are either larger than 40 km² or which reduce the extinction risk by more than 2 percent. Note that this categorization is arbitrary and for the purpose of highlighting the most critical habitat patches. Criticality is actually directly proportional to the relative importance of a patch to the extinction risk and to its size.
Because of the large number of occupied habitat patches (106 patches, see Figure 8) only patches larger than 50 km² were included in this patch removal experiment (33 habitat patches in total). The results are shown in Figure 12.

The results indicate that the largest patches are most critical to the predicted final abundance of the HOWA and should be protected prior to smaller patches.

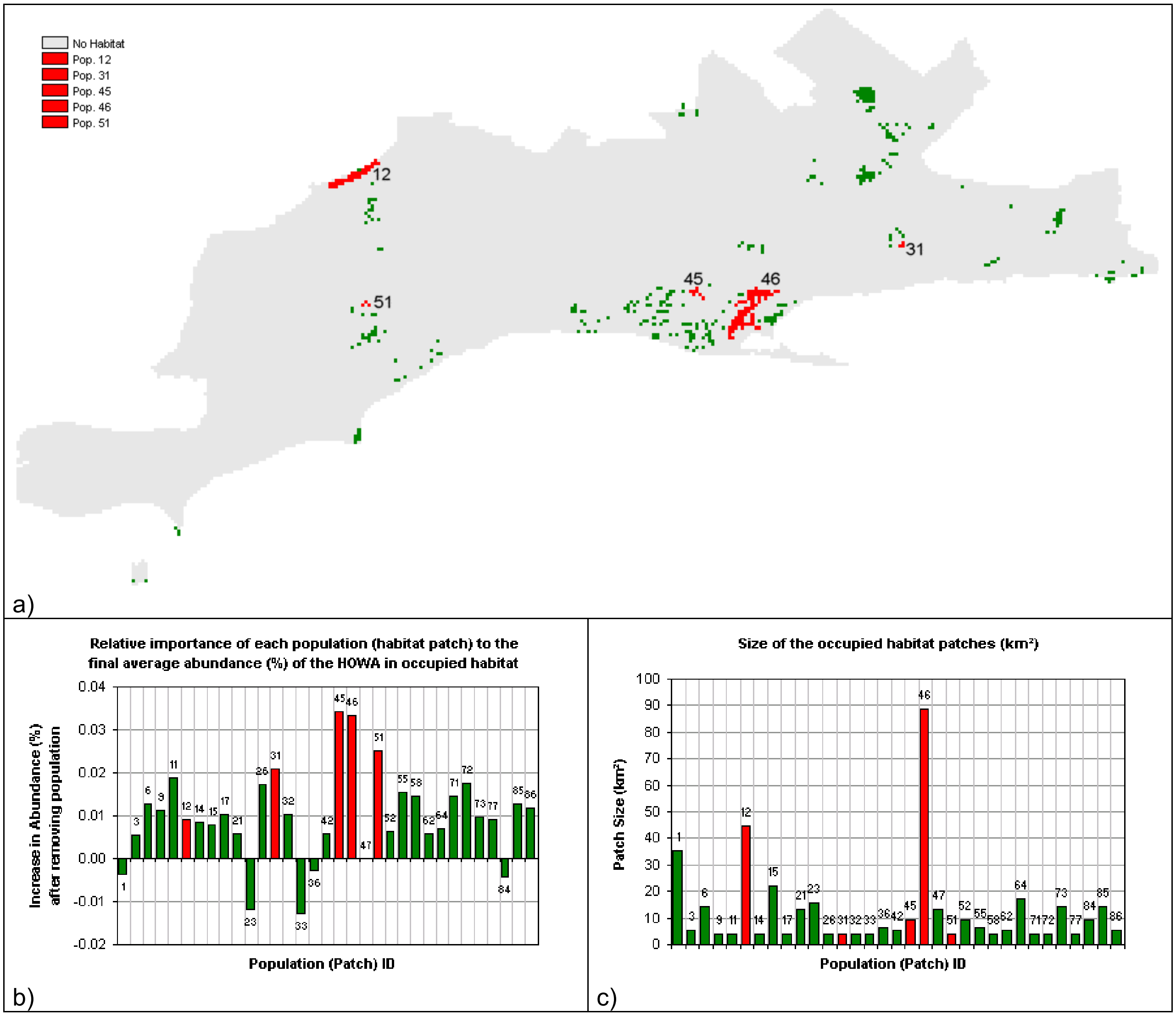


Figure 12: Relative importance of <u>occupied</u> habitat patches to the predicted average HOWA abundance after 100 years. a) Most critical habitat patches are marked in red colours in the critical habitat map. b) Relative importance of the habitat patches to the extinction risk. c) Sizes of the habitat patches.

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Figures

Tables