THE ACADIAN FLYCATCHER

POPULATION VIABILITY AND CRITICAL HABITAT IN SOUTHERN ONTARIO, CANADA

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Summary

The Acadian Flycatcher was designated as “Endangered” 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 Acadian Flycatcher 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, dependency on immigration from external populations, susceptibility to habitat loss and fragmentation and critical habitat for the Acadian Flycatcher population. The results indicate that the Acadian Flycatcher population in southern Ontario may be demographically limited due to either climatic constraints or factors associated with habitat quality. The observed fecundity may not completely compensate the observed survival probability resulting in a declining population. The minimum viable population size for a time frame of 20 years is estimated to be 70 breeding pairs. The current population size of 30 breeding pairs is far less and would ensure a viable population for a time frame of about 12 years. These model predictions contradict the observed stability in the population size over the last few years. One assumption has been that the lack of self-sustainability in the Acadian Flycatcher population in southern Ontario may be offset by immigrants from external populations. Results of simulation experiments show that one immigrating breeding pair every 2 years may be sufficient to eliminate the extinction risk. The viability of the Acadian Flycatcher population may generally increase with increasing habitat amount and may decrease with habitat fragmentation. The effect of habitat fragmentation on extinction risk increases with decreasing habitat amount. Despite these general effects, it is unlikely that the particular habitat configuration in southern Ontario constitutes a limiting factor for the Acadian Flycatcher population. In fact, the results of the population models indicate that the Acadian Flycatcher may be unable to utilize all suitable habitat, even though its observed dispersal capability of up to 100 km. Critical habitat has been identified based on simulating the population dynamic of the Acadian Flycatcher 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 Acadian Flycatcher. Habitat patch removal experiments revealed those critical habitat areas, which are most important to the viability of the Acadian Flycatcher population. Habitat at the sites “Skunks M”, “Kettle Po” and “Lambton C” are currently most critical for the Acadian Flycatcher based on its observed distribution in 2002. Other habitat areas have lower but also substantial effects on the population viability and may become more critical when the population distribution changes. To summarize, the Acadian Flycatcher population in southern Ontario is not self-sustainable and may become extinct without a continuous influx from external populations. Habitat

amount is not likely to be a limiting factor but critical habitat areas must be protected here and elsewhere to ensure a long-term survival of the Acadian Flycatcher in Canada.

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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 Acadian Flycatcher (*Empidonax virescens*)

1.1 Demography

The demographic characteristics for the Acadian Flycatcher (ACFL) 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 Bridget Stutchbury and Bonnie Woolfenden. See also the following references for life-history information on the ACFL (Wilson and Cooper 1998, Schmidt and Whelan 1999, Bisson et al. 2000, Robinson and Robinson 2001).

Characteristic	Observation	References
Breeding period (ON)	mid-June to mid-July	Whitehead and Taylor 2002
Clutch size	1 – 4 avg. 2.92 and 2.94 in Michigan (n=25,95) avg. 2.76 in in Indiana (n=580) avg. 2.90 in Arkansas (n=213) avg. 2.50 in Ontario	Woolfenden & Stutchbury 2002 Whitehead and Taylor 2002 Stutchbury, pers. comm.
Broods/year (PA)	1	Woolfenden & Stutchbury 2002
Incubation period	13 - 15 days	Whitehead and Taylor 2002
Fledging period	unknown	Whitehead and Taylor 2002
Maturity	breed at 1 year	Whitehead and Taylor 2002
Life Span	10 yrs maximum, 2.5 yr estimated average	Stutchbury, pers. comm..
Cowbird Parasitism	11% parasitized (ON: 2002)	Woolfenden & Stutchbury 2002
Fledging Success	2.57 $\pm$ 0.5 fldg (n = 18) (ON: 2002)	Woolfenden & Stutchbury 2002
Nesting Success	60% per female (ON: 2002)	Woolfenden & Stutchbury 2002
Ontario Population Size	35 males/ 30 females	Stutchbury, pers. comm.
Stage/Age class	juvenile / adult	
Annual Survival	juvenile 0.25 $\pm$ 0.05; adult 0.5 $\pm$ 0.1	Stutchbury, pers. comm.
Dispersal/Movement	unknown, max. 100 km	Stutchbury, pers. comm.
Average Territory Size	avg. 1.5 ha	Stutchbury, pers. comm.
Carrying Capacity in the Carolinian Region	potential (70 breeding pairs assumed)	Stutchbury, pers. comm.
Habitat Requirements	forest interior species, prefers large areas of mature undisturbed forest > 40 ha in size, avoids forest edges, nests are build more than 100 meters away from forest edges, closed canopy > 94%, wooded ravines	Sedgwick and Knopf 1987 Donovan and Flather 2002
Threat	habitat loss and further fragmentation	
Sex Ratio	30 % more males than females, 43.5 % females	Stutchbury, pers. comm.

Table 1: Life history data for the Acadian Flycatcher

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 Acadian Flycatcher. 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.
Fecundity rates per female have been extracted from the literature and discussed with the Recovery Team, in particular Bridget Stutchbury and Bonnie Woolfenden. According to data published for the ACFL in the Birds of North America series, the mean clutch size in the southern range of the ACFL distribution varies from 2.76 to 2.9. Observations for Ontario indicate a lower mean clutch size of 2.5. The ACFL may attempt up to 4 nests in its southern range of distribution, but only 1 nest in Ontario. Hatching success is generally high (see Whitehead and Taylor 2002) but nest success varies widely. The effective nest success rate per pair per season is not known. While nest success may be as low as 30 percent, additional nest attempts may result in at least one successful nest per pair per female. Since there is much uncertainty about the effective reproductive rate per pair (after considering nest success, multiple nest attempts), the fecundity rate for the population model will be based on the known average clutch size in Ontario.
Annual survival rates for adults and juveniles are unknown. The observed return rates for juveniles are about 25 percent and for adults 50 percent. These rates are likely much lower than the actual survival rates (Woolfenden, pers. com.), since many birds do not return, but move to different territories or regions.
Deciding about fecundity and survival rates for the ACFL population model based on the data available today is not easy. The following experiment helped to make the most informed decision. One important clue is that ACFL populations seem to be viable in their southern range of distribution. For these populations, the average clutch sizes are known and consistent. It is also commonly agreed that survival rates of adults usually double those for juveniles. Furthermore, survival rates must be higher than the observed return rates. Using this information, the first step was to use the clutch sizes for the southern populations and adjust the survival rates in the population model so that it produced a stable population over a time frame of 100 years. Since there is no evidence that the survival rates are lower in Ontario, the rates extracted from this initial experiment were used for the final model (juvenile = 0.31, adult = 0.62). There is evidence, however, that the average clutch size in Ontario is lower than those observed in southern regions. This indicates a limitation to the fecundity rate for the ACFL in Ontario. The fecundity rate in the population model has therefore been adjusted to the observed average clutch size in Ontario (see Table 1), which will result in a less viable population for Ontario as observed by Stutchbury and Woolfenden. The parameter values used in the population model are listed in Table 2.

Parameter	Value/Range	Comments
stage classes	juvenile/adult	Stutchbury, pers. comm.
juvenile fecundity	0	
adult fecundity (female juveniles per female adult)	1.0875 ± 0.108 (10% stddev.)	1 (brood) * 2.57 (fledglings) * 0.435 (sex ratio) = 1.0875
juvenile survival	0.31 ± 0.031 (10% stddev.)	estimated (see text)
adult survival	0.62 ± 0.062 (10% stddev.)	estimated (see text)
density dependence	ceiling exp. growth up to carrying capacity of 70 breeding pairs	estimated
simulated years	100	
initial population size	30	Stutchbury, pers. comm
replications	1000	
dispersal	negative exponential up to 100 km	Stutchbury, pers. comm
demographic stochasticity	yes	number of survivors and dispersers (emigrants) to be sampled from binomial distributions, number of young from a Poisson distribution. (important for small populations)
environmental stochasticity	lognormal	statistical distribution (normal or lognormal) to be used in sampling random numbers for vital rates

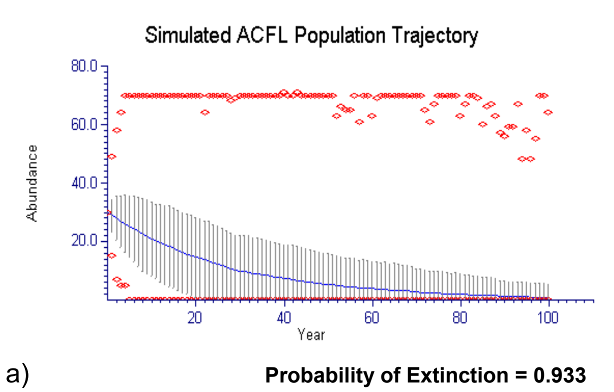
Table 2: Parameter values for the ACFL population model (RAMAS© GIS)

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.

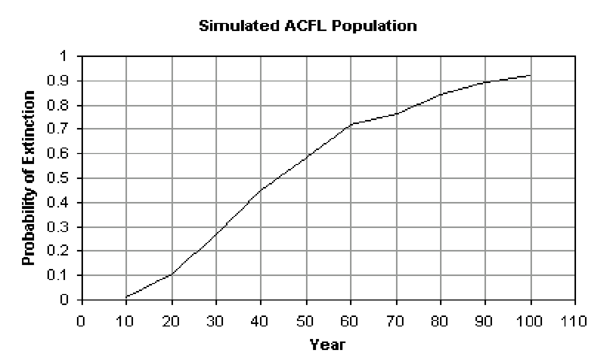
1.2.3 Analysis of the demographic population viability (non-spatial)

The viability of a non-spatial ACFL 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 70 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 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 70 individuals (breeding pairs). The simulation results predict a distinctive population decline on average down to 1 female individual over 100 years. The predicted probability of extinction (or extinction risk) is 93 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 933 out of 1000 replicate simulation runs.



a)



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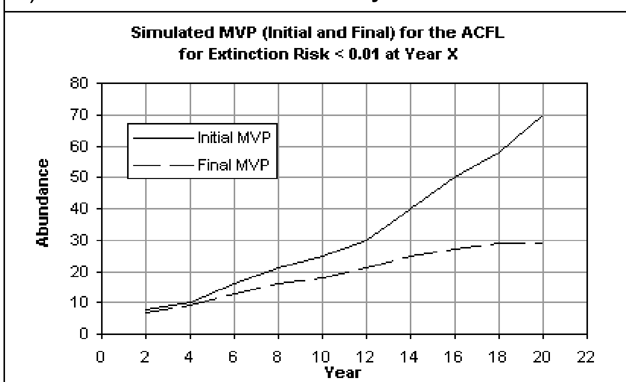

c)

Figure 1:

a) Predicted population (females only) abundance over 100 years (based on initial population size of 30 females and carrying capacity of 70 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.

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 a low extinction risk for a time span of up to ten years and a 93 percent risk of extinction after 100 years. These numbers are based on the initial population size of 30 breeding pairs and a carrying capacity of 70 breeding pairs.

The graph in Figure 1c shows the minimum viable population size (MVP) for a 99 percent viable population (extinction risk of less than 1 percent) over different time spans. For example, an initial population size of 30 breeding pairs is required to realize a 99 percent viable population over a time span of 12 years. This initial population of 30 breeding pairs would decline during the 12 years to a final population size of 25 pairs.

The results of this non-spatial population viability analysis indicate that the ACFL population in Canada, according to our current understanding of the local life history and carrying capacity, is demographically limited and not intrinsically self-sustainable. The ACFL population is likely to decline without continual immigration from external populations residing south of the Canadian border.

Predictions from PATCH

Population dynamics for the Acadian Flycatcher have also been simulated with the individual based, spatially explicit model PATCH. The model parameters correspond to those used in RAMAS© GIS (see Table 2). All 70 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 RAMAS© GIS. The predicted projection of the population abundance over 100 years is shown in Figure 2. The predicted decline in population size is comparable to those calculated by RAMAS© GIS.

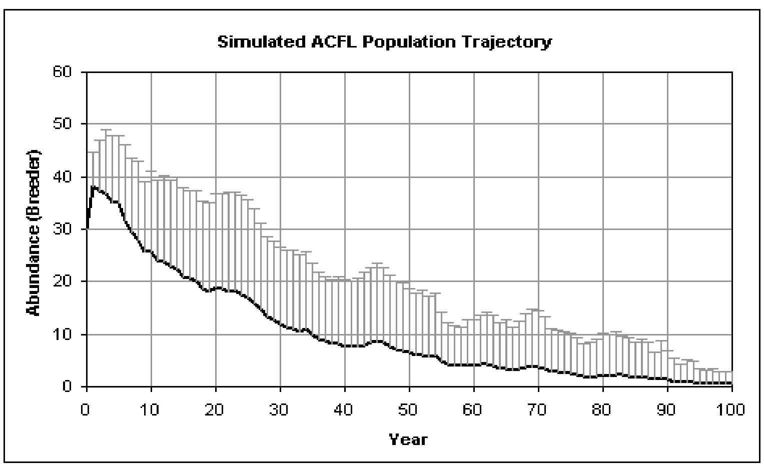

Figure 2: Population abundance for the Acadian Flycatcher in non-fragmented habitat simulated with PATCH. Standard error bars are symmetric and are shown for one direction only. The initial peak in the abundance is attributed to the initial distribution of adult individuals only (non-stable initial age abundance distribution).

1.2.4 Immigration and demographic viability

The assumed dependency of the Canadian ACFL population on immigration from external populations has been evaluated in a separate set of simulations. The effect of immigration on the Canadian ACFL population is shown in Figure 3. The simulation results suggest that one immigrating breeding pair (female) per year should be sufficient to eliminate the extinction risk for the ACFL population. Even one immigrating pair every 5 years may reduce the extinction risk to near 10 percent. This quite strong effect of only very few immigrants is surprising. However, these immigrants will reproduce in the population and will boost the overall fecundity of the population, which seems to be lower in the northern range of the species distribution and responsible for the low viability of the ACFL population in Canada.

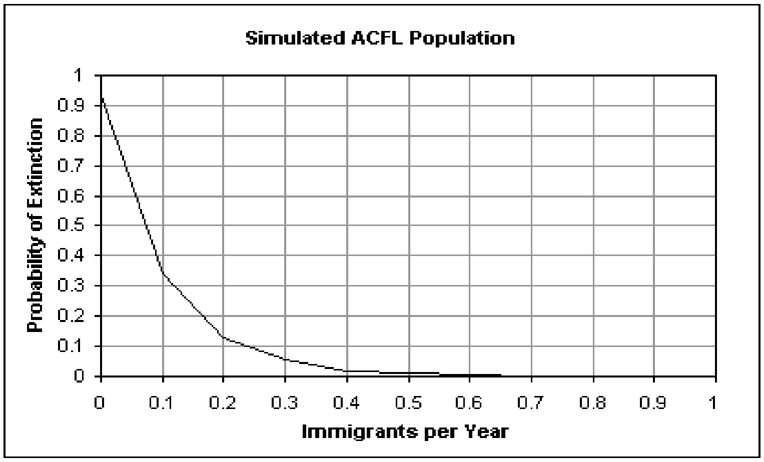

Figure 3: Effect of immigrating breeding pairs from other ACFL populations into the Canadian ACFL population on the extinction risk. One immigrating breeding pair every two years (0.5 on the x axis) may eliminate the extinction risk.

1.2.5 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 in part 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 on the viability of the Acadian Flycatcher 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 125 meter edge length per pixel. The extent of a landscape is therefore 12.5 km resulting in an area of 156.25 square km. The pixel size of 1.5625 ha corresponds roughly to the size of one territory of the Acadian Flycatcher (see 1.1, Table 1). The value of each pixel can be either 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 4. The amount of habitat (or number of 1.56 ha territories) was varied between 20 and 80 and the fragmentation for each of the habitat levels was varied across 6 levels from low to high. In Figure 4 each row shows from left to right increasingly fragmented distributions of a certain number of 1.56 ha territories (or habitat amount). The numbers to the right of the figures show the actual number of 1.56 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.

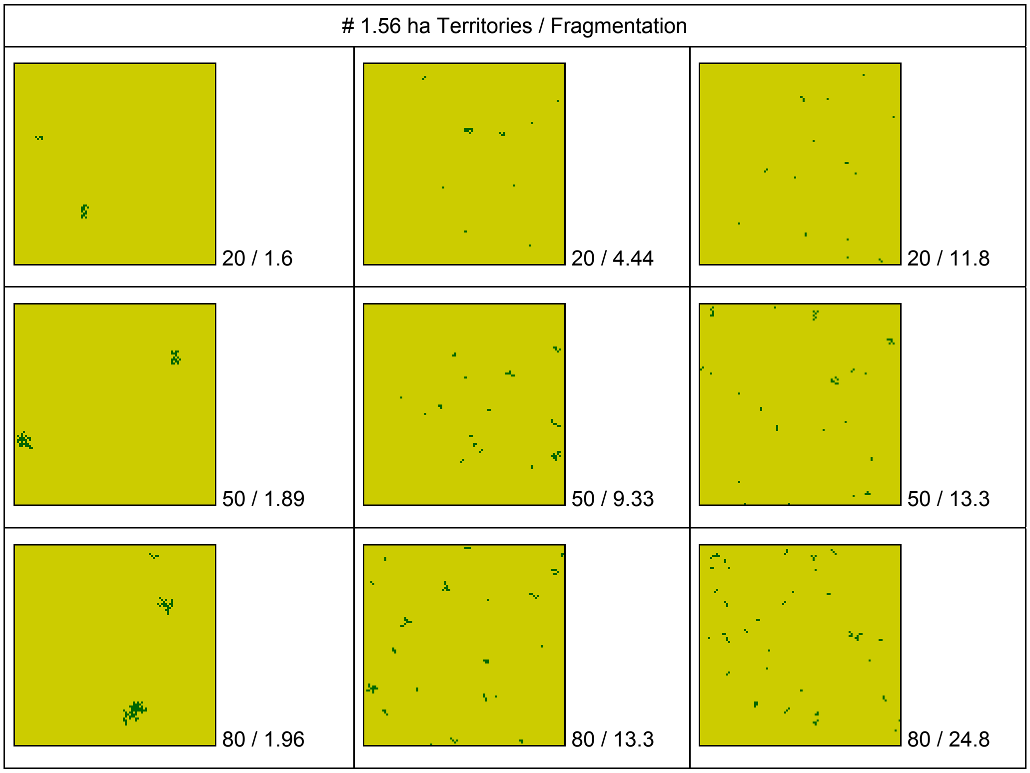

Figure 4: Landscape models used to examine the effect of habitat amount and fragmentation on the probability of extinction for the ACFL. Each row shows 3 (out of actually 6) landscapes containing equal, but increasingly fragmented (left to right), amounts of habitat (green/dark areas).

On each of the 60 generated landscapes the population model of the ACFL 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 ACFL was estimated to be 10 km. (This distance is lower than the maximum distance observed in nature (see Table 1), but corresponds to the 12.5 km 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 1.56 ha territories) and habitat fragmentation (EN, see above). The results are shown in Figure 5-7.

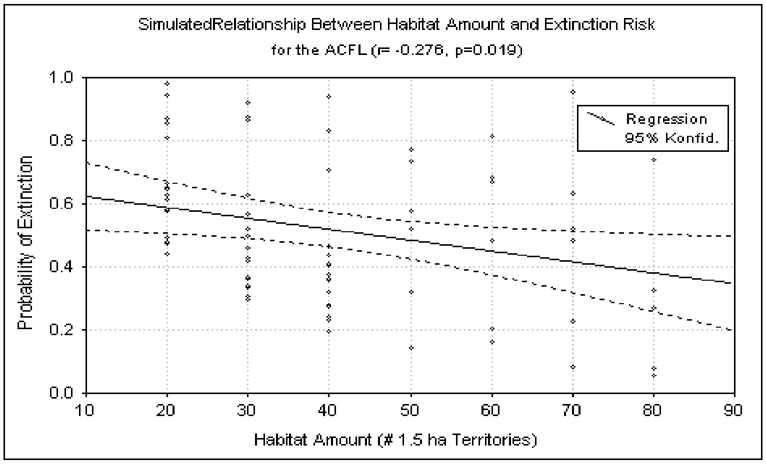

Figure 5: Effect of habitat amount on the probability of extinction. The probability of extinction increases with decreasing habitat amount, but is affected by the spatial distribution of habitat as indicated by the dispersion of the plots.

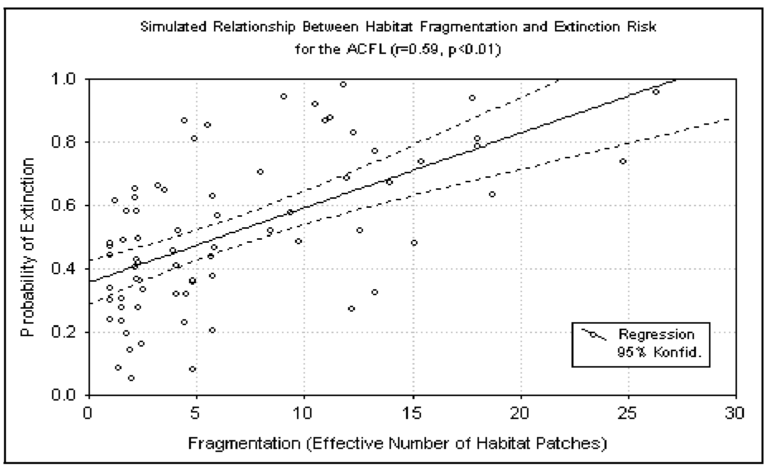

Figure 6: Effect of habitat fragmentation on the probability of extinction. Increasing habitat fragmentation results in overall higher extinction risk, but also depends on the amount of habitat in the landscape.

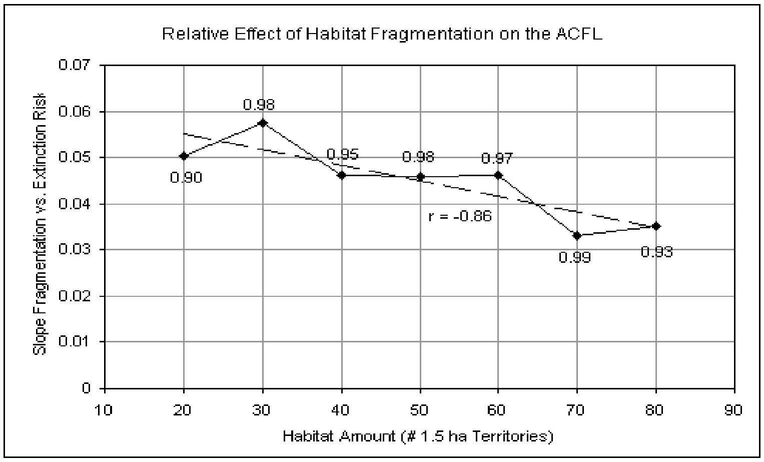

Figure 7: Interaction between habitat fragmentation and habitat amount. The data points are the slopes of the regression lines between habitat fragmentation (EN, see above) and the probability of extinction. The numbers at the plots show the corresponding correlation coefficient r, for the regressions. 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 ACFL in the Carolinian region is based on the habitat suitability map as shown in Figure 9. This map has been produced based on the currently known habitat preferences of the ACFL. (documentation of the habitat suitability model will be provided by Mike Flaxman) The geographical context for the habitat suitability map is shown in Figure 8. The occurrence range of the ACFL 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 ACFL (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 ACFL. The unoccupied habitat shows those areas, which meet the known habitat requirements for the ACFL, but which are currently not occupied by this species.

The habitat suitability map as shown in Figure 9 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 = 193 km²,
unoccupied habitat area = 406 km².

The habitat suitability map as shown in Figure 9 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.

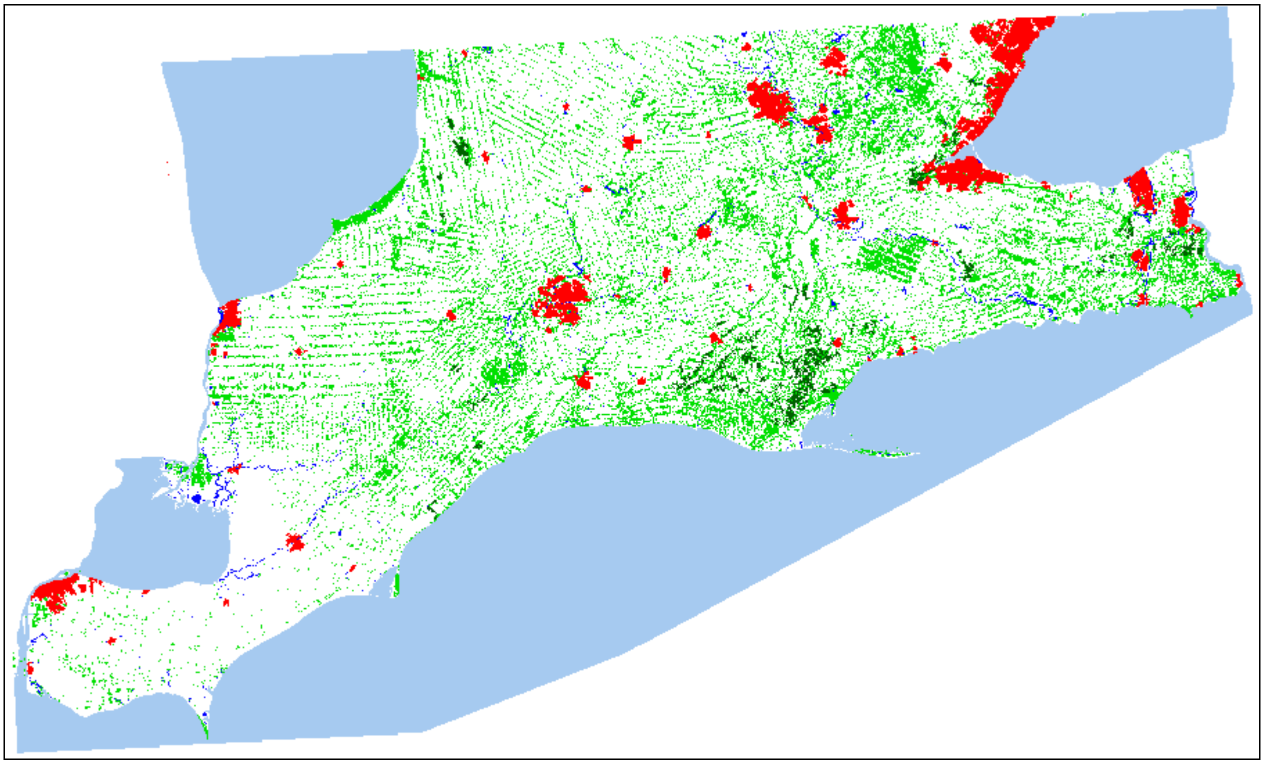

Figure 8: Study area and occurrence range of the ACFL in southern Ontario.

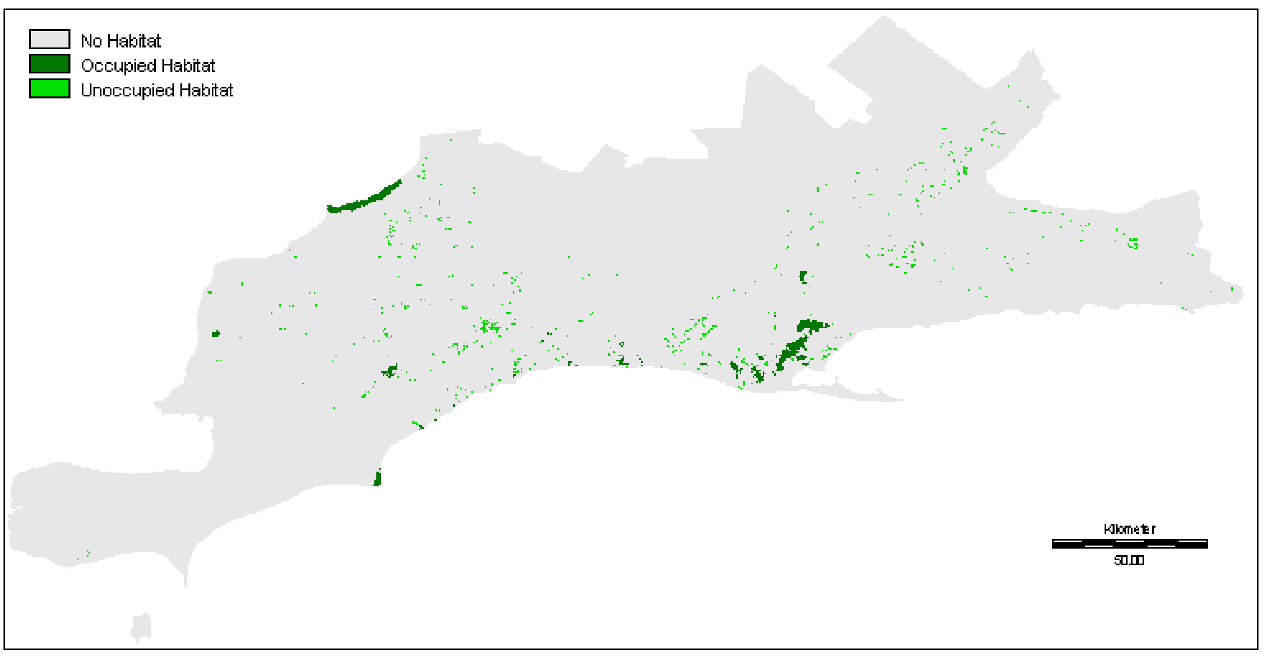

Figure 9: Habitat suitability map for the Acadian Flycatcher (400 x 203 km)

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 9. 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 100 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 ACFL 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 10 and 11.

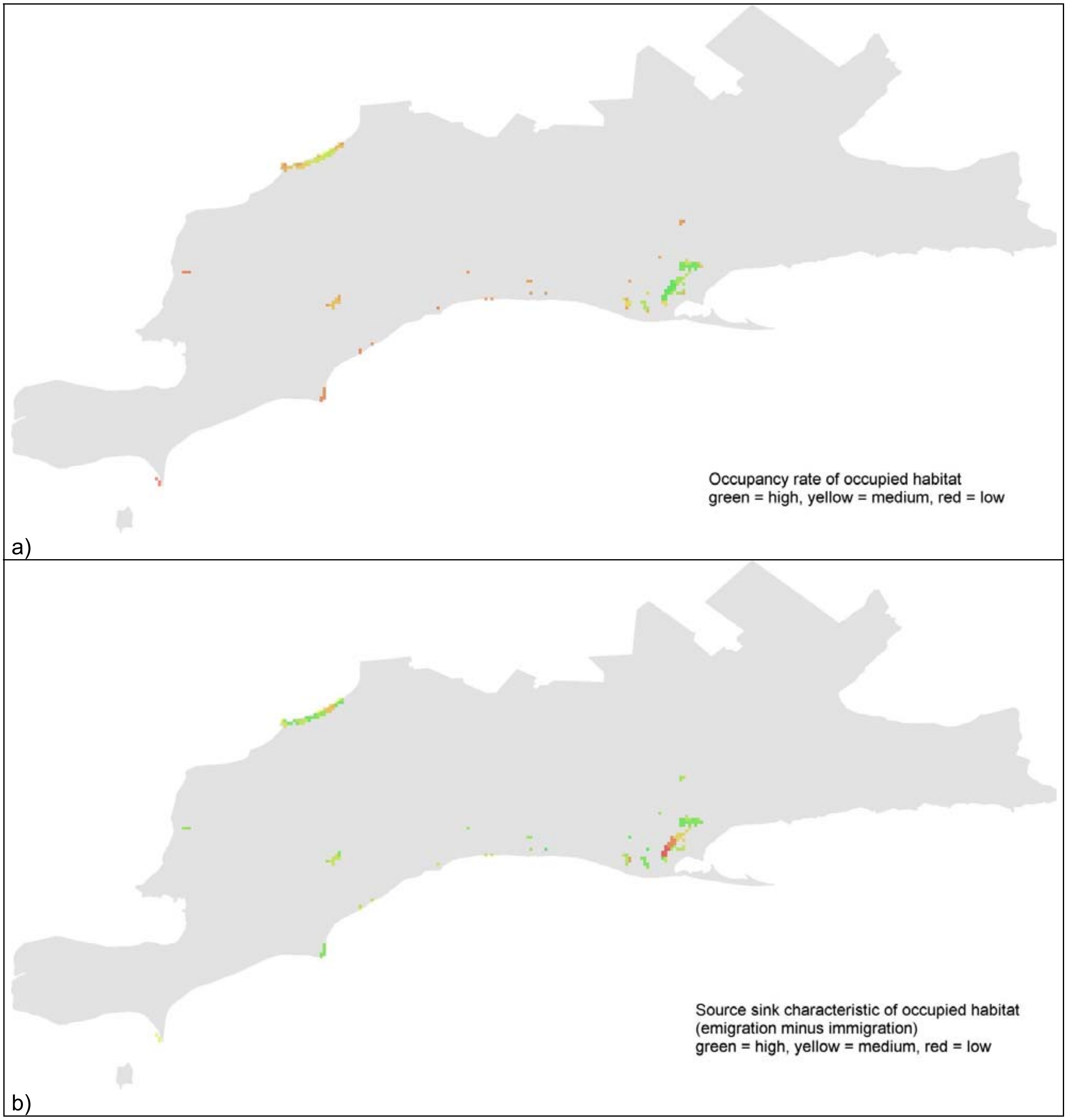

Figure 10: Occupancy rates and source – sink characteristics for occupied habitat.

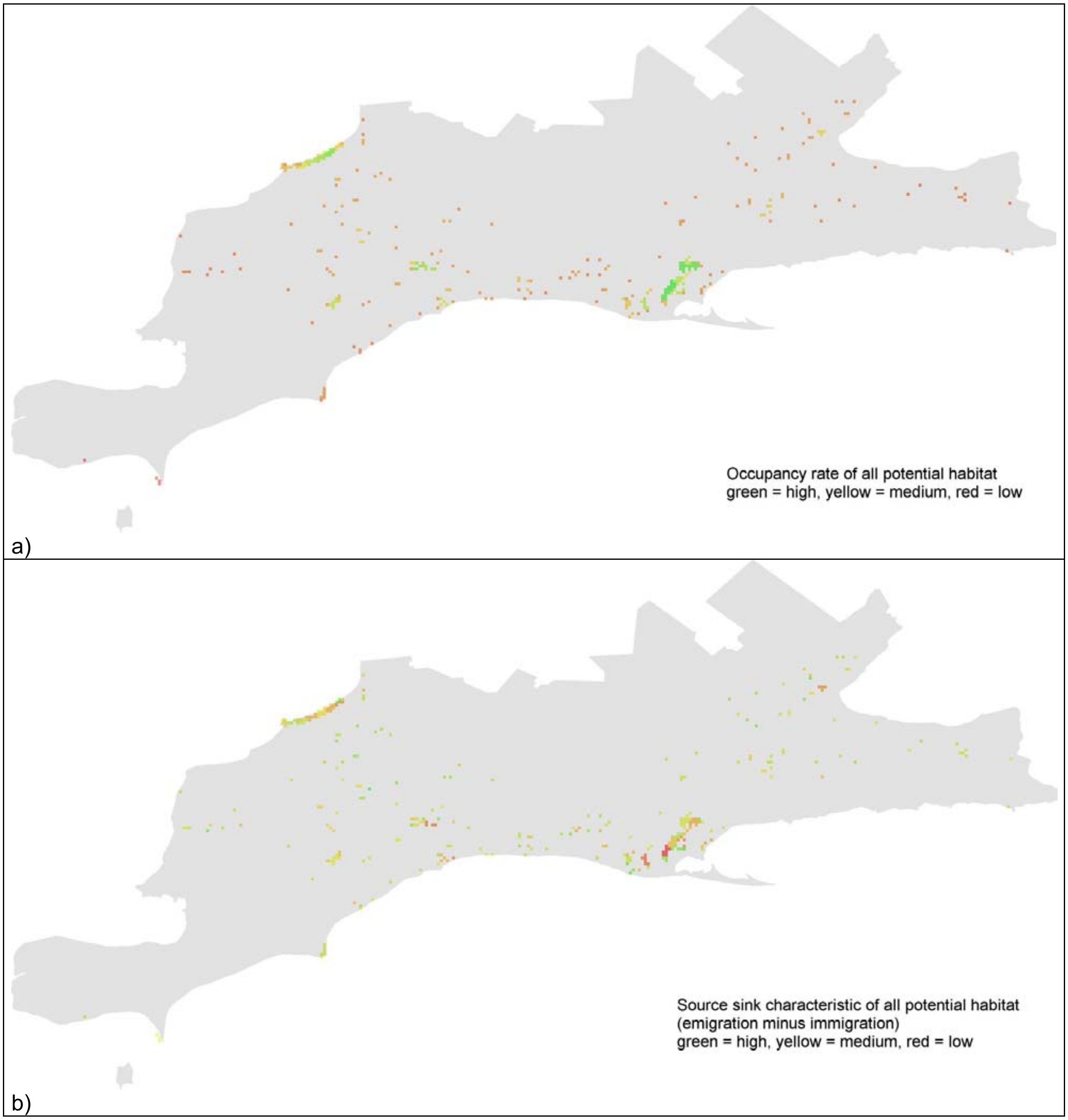

Figure 11: Occupancy rates and source – sink characteristics for all identified suitable habitat

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 ACFL population based on the habitat configuration in the Carolinian region. The simulation procedure corresponds to those used in the habitat configuration analysis (see section 1.2.5). Simulations were conducted on occupied habitat only and on all identified suitable habitat as shown in Figure 9. The results are shown in Figure 12.

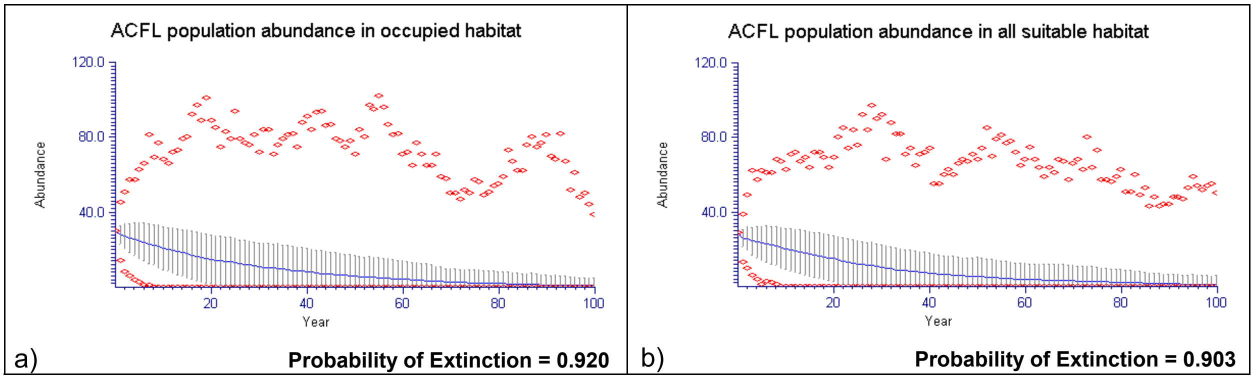

Figure 12: Extinction risk and predicted population abundance for the ACFL in the Carolinian region when residing in occupied habitat only (a) and when using both occupied and potential suitable habitat (b).

The results of the simulated population dynamics on the habitat suitability map indicate a population decline and a high extinction risk for the ACFL population over a time span of 100 years. The maximum recorded population abundances are near 100 individuals and not visibly higher when all suitable habitat can be used (compare Figure 12 a and b). Extinction risk is slightly lower when all suitable habitat is available. Overall, the results are almost identical to those obtained from the initial, non-spatial analysis of the demographic viability of the ACFL population (see section 1.2.3). This indicates and confirms that the demographic limitation may by far offset limitations caused by habitat configuration, such as habitat amount and fragmentation. It is still possible, however, that habitat quality in the Carolinian region (in addition to possible climatic constraints) is the main reason for the lower demographic potential of the ACFL population.

1.3.4 Critical Habitat

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 ACFL were simulated on the habitat suitability map using RAMAS© GIS. Several replicate simulation runs were conducted while each time one patch was removed. The difference in the risk of extinction resulting from simulations on all habitat patches and those from simulations where one patch was removed indicate the relative importance of the habitat patch for the extinction probability. 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.
This experiment was conducted on the occupied habitat map only. The results are shown in Figure 13.

The results indicate that generally larger patches have the stronger effects on the extinction risk and must therefore be regarded as critical habitat. The most important habitat patch (12 in Figure 13a) is "Skunks

M”. This area accounts for 12 percent of the viability of the ACFL population. In other words, removing this habitat would increase the extinction risk of the ACFL population by 12 percent. The second most important habitat patch is the area around “Kettle Po” and “Lambton C” (1 in Figure 13a). This area accounts for about 10 percent of the ACFL population viability. Other areas are larger but less critical. Note that this ranking is based and highly dependent on the initial seeding locations for the populations in the model. Occupancy locations from 2002 were used to distribute the initial 30 females across the habitat area in the habitat suitability model. Habitat patches with initial population sizes greater than zero will have a stronger effects on the extinction probability compared to those, which are not occupied initially. This applies in particular for the ACFL population, which may not have the capability to colonize all available habitat over time due to its demographic limitation.

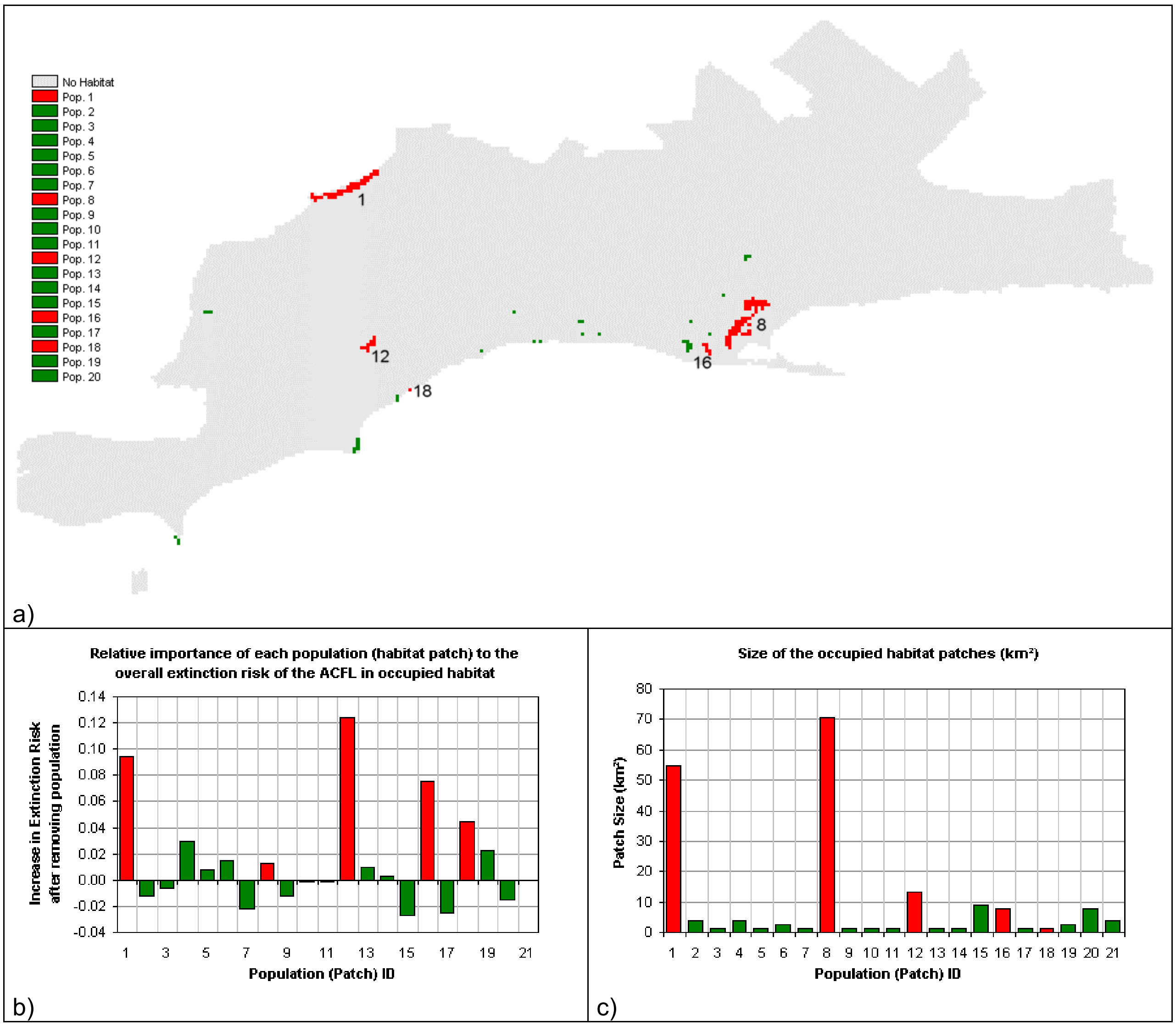

Figure 13: Relative importance of occupied habitat patches to the extinction risk of the ACFL populations. a) Most critical habitat patches are marked in red colours in the critical habitat map. b) Relative importance of the habitat patches to the extinction risk. c) Sizes of the habitat patches.

2 References

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Figures

Tables