THE WHOOPING CRANE

POPULATION VIABILITY AND CRITICAL HABITAT IN THE WOOD BUFFALO NATIONAL PARK AREA NT/AB CANADA

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Summary

The Whooping Crane 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 delineation of critical habitat for this species. This work contributes to and supplements related recovery and conservation efforts. A comprehensive population and habitat viability analysis for the Whooping Crane in the Wood Buffalo National Park and surrounding areas has been conducted. Metapopulation and individual-based, spatially explicit population models were used to asses demographic viability, minimum viable population size and critical habitat for the Whooping Crane population. The results indicate that the Whooping Crane population is demographically viable and self-sustaining. Presuming that habitat is available for and accessible to 500 breeding pairs over 100 years, the calculated extinction risk may be less than one percent. Under such conditions the minimum viable population size over a time span of 100 years is estimated to be 40 breeding pairs, which is 20 percent less than the actual number of breeding pairs in the Wood Buffalo National Park. However, actual habitat amount and fragmentation may limit future population growth of the Whooping Crane. If the Whooping Crane would be confined to its currently occupied habitat (about 200 km², 50 territories), the population would face an extinction risk of about 13 percent together with a steady population decline. In contrast, when all identified suitable habitat within the Wood Buffalo National Park (about 927 km², 231 territories) remains suitable and available for the Whooping Crane, the population may double within 100 years without being endangered to extinction. The potential for population growth may increase when all suitable habitat within and outside the borders of the Wood Buffalo National Park (1615 km², 403 territories) are conserved. The predicted population growth, however, is far less than the observed growth rate of 3.5 percent per year in the past. The results indicate that the actual growth rate for the Whooping Crane population may be limited by the fragmentation and dispersion of breeding habitat. Some of the habitat fragments may be too small and too far apart to be steadily utilized and colonized by the Whooping Crane, whose observed natal dispersal range is limited to 55 km. The model predicts average habitat utilization rates of 30 percent and maximum habitat utilization of 75 percent over 100 years. The identified suitable habitat within the boundaries of the Wood Buffalo National Park may be sufficient to support a viable and self-sustaining population of the Whooping Crane. However, the growth rate of the population may significantly increase when habitat outside the park boundaries remains intact and suitable.

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Notice

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 Whooping Crane *(Grus americana)*

1.1 Demography

The demographic characteristics for the Whooping Crane (WHCR) breeding in the Wood Buffalo National Park, Alberta, have been compiled based on published data from the literature and in collaboration with the Recovery Team, in particular Mark Bradley and Brian Johns.

Characteristic	Observation	References
breeding period	May	Lewis 1995
clutch size	2	Lewis 1995
#broods per year	1	Lewis 1995
incubation period	30 days	Lewis 1995
fledging period	3 months	Lewis 1995
maturity	after 4 years	Kuyt and Goossen (1987) Johns et al. (in press)
life span	22 – 40 years, 25 years in the wild	Moody (1931) Johns et al. (in press)
nesting success	50%	
fledging success	0.76 hatchlings per nest	B. Johns, pers. comm.
nestling survival	about 73% of the hatchlings (172 of 234) reached Aransas NWR (between 1976 – 1989) 59.1% of hatched young (381 of 689) reached Aransas between 1976 and 2002	B. Johns, pers. comm.
population size (AB/NWT)	50 pairs 2002: 185 individuals and 50 nests from 56 breeding pairs	Bradley, pers. comm. B. Johns, pers. comm.
stage/age classes	5, juvenile, adult_1, adult_2, adult_3, adult_4+	
survival	juvenile = 0.764, adult_1 = 0.91, adult_2 = 0.91, adult_3 = 0.91, adult_4+ = 0.91	Bradley, pers. comm.
dispersal/movement	Natal Dispersal: Males .3-53km Females 4-55km	Johns et al. 2003
migration	arrive late March – late April, leave mid September	
home range (AB/NWT)	3-4 km² in dense areas, 12 – 19 km2 in isolated areas. Nests are a few km away. Territories are not always exclusive, but more, when chicks are about to fly. circular radius: 380 m (for chicks in June), 717 m (in August)	Bradley, pers. comm. Kuyt, 1993 Bergeson et al. 2001 Timoney 1999
habitat requirements	marshes, bogs, shallow lakes separated by narrow ridges	
Sex Ratio	50 percent females	Lewis 1995
Carrying Capacity	unknown, recovery goal is habitat for 1000 individuals, assumed 500 in model	Johns, pers. comm.
Trend in Population size	slow growth at a rate of 3.5% annually over the last 60 years.	Johns, pers. comm.

Table 1: Life history data for the Whooping Crane

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 Whooping Crane. 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 WHCR fecundity rates per adult female have been extracted from the literature in collaboration with Brian Johns and Mark Bradley. Although the WHCR is one of the best studied birds in North America, information on fecundity rates is not consistent.
According the figures published in Lewis 1995, the number of successful juveniles per breeding pair calculates as follows. 1(brood per year) * 0.6(percentage of breeding adults) * 0.76 (hatchlings per nest) = 0.456. According to information from Brian Johns, 40.3 percent of adults produce one hatchling, which translates into a fecundity rate of 0.403. Brooks et al. 1999 used 0.47 as fecundity rate in a population model.
Annual survival rates for juveniles and adults are well known. Still the figures are also not consistent. Lewis 1995 published annual survival rates of 0.733 and 0.9094 for juveniles and adults respectively. Mark Bradley observed annual survival rates of 0.76 and 0.94 for juveniles and adults, while Brian Johns provided 0.901 for adults. Yet, the model used by Brooks et al. 1999 uses 0.9064 as annual adult survival rate.
There are many options to parameterize the model based on the data available today. One clue to find the best possible combination of the given numbers is the observation about the trend in the population size. The population growth has been monitored over 60 years and an average 3.5 percent annual growth rate was observed. The model used for this analysis should reflect this intrinsic pattern of population growth. The following combination of fecundity and annual survival rates reproduced the observed trend in population size in a non-spatial model: adult fecundity = 0.49, juvenile survival = 0.76, adult survival = 0.91. These numbers are close to the ones published and observed and allow to examine the population model based on a reproduced known growth rate. The fecundity rate chosen is slightly higher than those published and observed, still a lower fecundity rate combined with slightly higher survival rates would produce very similar results. The most important characteristic of the model is the number of age classes. The model uses one juvenile and four adult age classes, since birds start breeding on average in their fifth year after birth.

Parameter	Value/Range	Comments
stage classes	juvenile/adult_1/adult_2/adult_3/adult_4+	
juvenile fecundity	0	
adult fecundity	adult_1 – adult_3 = 0 adult_4+ = 0.245 ± 0.0245(10% stddev.)	(0.43 juveniles per adult pair, corrected for sex ratio and adjusted to observed 3.5% growth rate (0.43 * 0.5 * 1.14) 1.14 multiplier realizes the 3.5% growth rate
juvenile survival (female)	0.764 ± 0.07 (10% stddev.)	estimated, see text
adult survival	0.91 ± 0.091 (10% stddev.)	estimated, see text.
density dependence	ceiling exp. growth up to carrying capacity 500 females	Bradley, pers. comm.
simulated years	100	
replications	1000	
initial population size	50 (females, represent one breeding pair)	Johns, pers. comm.
dispersal	negative exponential up to 55 km	
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 WHCR population model (RAMAS© GIS)

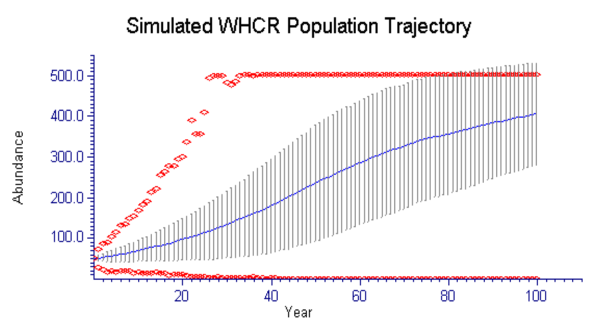
The population model is a "female only" model and the results are based on the number of females. Since the sex ratio is known to be even and survival rates are similar for males and females, the number of females is a good indicator for the actual number of breeding pairs.
Overall, the structure of the non-spatial population model (i.e. age classes) and the demographic rates reproduce a population growth close to those observed for the Whooping Crane over 60 years.

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

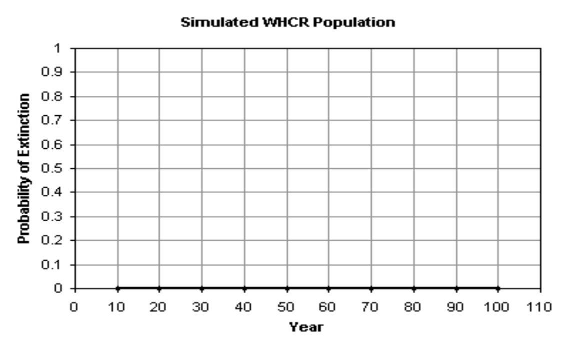
The viability of a non-spatial Whooping Crane population was analysed based on the model parameter values presented in 1.2.1 using RAMAS© GIS. This population model was non-spatial meaning that all females were residing in one single habitat patch (i.e. a cluster of adjacent territories). The population could grow up to a carrying capacity of 500 females (breeding pairs). A density dependent reduction in fecundity and survival prevented the population from exceeding the carrying capacity. The results are presented in Figure 1.

The graph in Figure 1a shows the predicted 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 abundance values. The maximum values do not exceed the carrying capacity of 500 individuals (breeding pairs). The simulations predict a population growth on average up to 400 female individuals over 100 years. The steady population growth indicates that the population is not demographically limited. The probability of extinction (or extinction risk) was 0.5 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 5 out of 1000 replicate simulation runs.

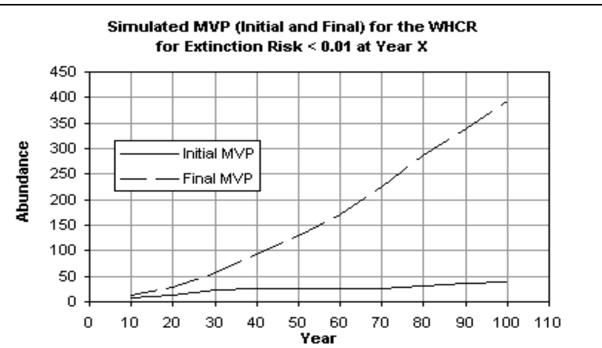
The graph in Figure 1b shows the extinction risk as a function of time. This result indicates that a WHCR population living in non-fragmented habitat with a carrying capacity of 500 breeding pairs and an initial population size of 50 breeding pairs may face an extinction risk of near zero over the time span of 100 years.



a) **Probability of Extinction = 0.005**



b)



c)

Figure 1:

a) Predicted population (females only) abundance over 100 years (based on initial population size of 50 females and carrying capacity of 500 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 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 25 breeding pairs is required to establish a 99 percent viable population over a time span of 40 years. This initial population of 25 breeding pairs would increase during the 40 years to a final population size of 100 pairs. This graph indicates that the WHCR population, according to our current understanding of the local life history and carrying capacity of its breeding habitat, appears to be viable and intrinsically self-sustainable.

Predictions from PATCH

Population dynamics for the Whooping Crane have also been simulated with the individual based, spatially explicit model PATCH. The model parameters reflect those used in RAMAS© GIS. All 500 available territories 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 model as used in RAMAS© GIS. The predicted projection of the population abundance over 100 years is shown in Figure 2. The predicted increase in population size is comparable to those calculated by RAMAS© GIS.

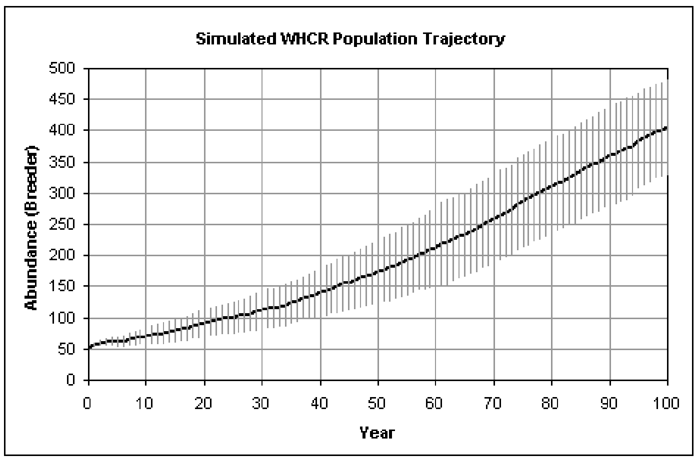


Figure 2: Population abundance for the Whooping Crane in non-fragmented habitat simulated with PATCH.

1.3 Critical Habitat Analysis

1.3.1 Habitat Suitability Map

The critical habitat analysis for the WHCR in the Wood Buffalo National Park and surrounding study area is based on the habitat suitability map as shown in Figure 3. This map has been produced based on the known habitat preferences of the WHCR. (documentation of the habitat suitability model will be provided by Olson & Olson) The habitat suitability map for the WHCR contains 3 land cover types: no habitat, occupied habitat and unoccupied habitat. The occupied habitat presents those areas, which were identified as habitat and which are currently (2002) occupied by the WHCR. The unoccupied habitat shows those areas, which meet the known habitat requirements for the WHCR, but which have not been occupied by this species.

The habitat suitability map as shown in Figure 3 has the following characteristics: north-south extent = 382 km, east-west extent = 257.5 km, pixel size = 100 x 100 m, map size = 3820 x 2575 pixels, total area = 98365 km², occupied habitat area = 214 km², total unoccupied habitat area = 1748 km², unoccupied habitat area within Wood Buffalo National Park = 975 km².

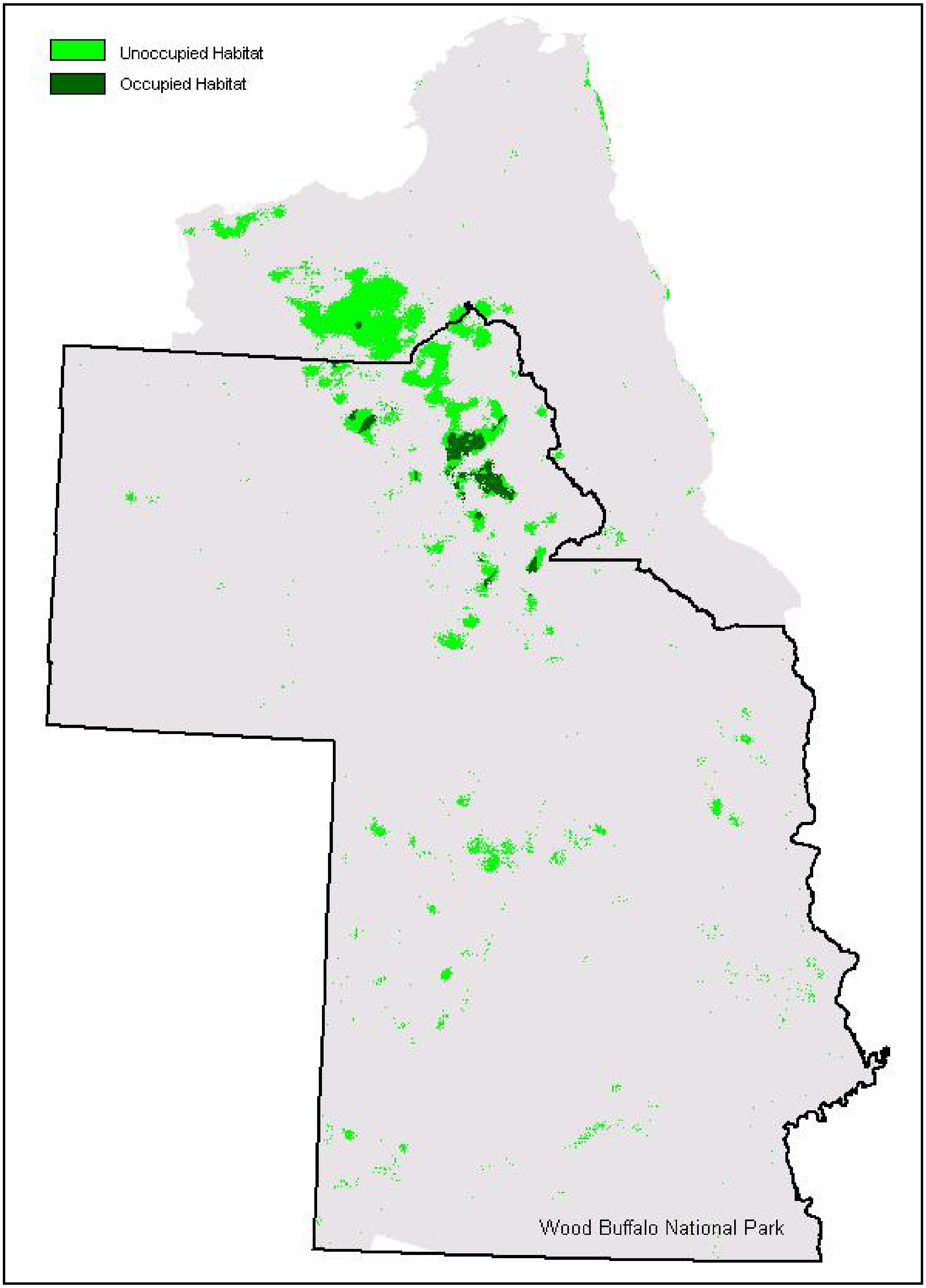


Figure 3: Habitat suitability map for the Whooping Crane (257.5 x 382 km)

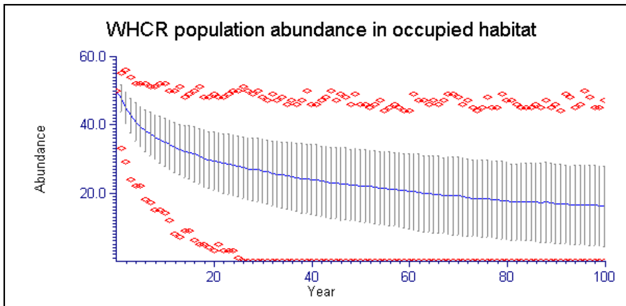
From the total habitat areas only patches with an area equal or larger than 4 km² may be used by the Whooping Crane, because of its known average composite nesting area (CNA) size of 4 km². The total area of identified suitable habitat includes patches smaller than 4 km², which is more than the actual usable habitat. After filtering out habitat patches smaller than 4 km² the following habitat areas were identified as usable for the Whooping Crane:

Usable occupied habitat = 193 km² (54 CNA's (3.5 km² per CNA)
Total usable suitable habitat = 1615 km² (403 CNA's)
Usable suitable habitat in the Wood Buffalo National Park = 927 km² (231 CNA's)

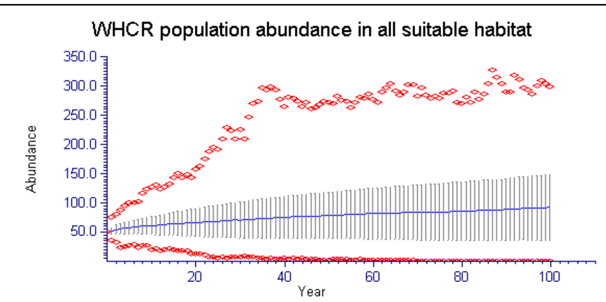
About 12 percent of all identified suitable habitat in the entire study area are currently occupied (193 km²). Only about 2 percent of this occupied habitat lies outside the borders of the Wood Buffalo National Park. The area of all identified usable suitable habitat in the study area comprises 1615 km². About 57 percent (927 km²) of all suitable habitat are located within the borders of the Wood Buffalo National Park.

1.3.2 Analysis of the population viability in the Wood Buffalo National Park area

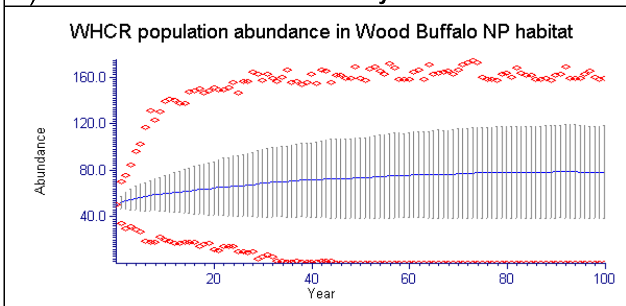
The population model as described in section 1.2 was applied to the habitat suitability map (section 1.3.1) using RAMAS© GIS. At the beginning of each simulation, the initial population of 50 females (corresponds to 50 breeding pairs) was distributed across occupied habitat patches in the habitat suitability map. The carrying capacity for each patch was calculated by dividing the patch size by the average CNA size of 4 km². In addition to the non-spatial model as described in 1.2.1, non-breeding adults (1-3 year old females) were allowed to disperse. The maximum dispersal distance of the WHCR is about 55 km (see Table 1). This distance was used as a maximum in a negative exponential function.
Three sets of 1000 replicate simulation runs were conducted on a) all occupied habitat (dark green areas in Figure 3), b) on all identified suitable habitat in the study area (dark and light green areas in Figure 3) and c) on suitable habitat located within the borders of the Wood Buffalo National Park. The results are shown in figure 4.



a) **Probability of Extinction = 0.135**



b) **Probability of Extinction = 0.01**



c) **Probability of Extinction = 0.008**

Figure 4: Extinction risk and predicted population abundance for the WHCR when:

- **a) residing in and confined to currently occupied habitat only;**
- **b) using both occupied and suitable habitat in the entire study area;**
- **c) confined to suitable habitat in the Wood Buffalo National Park.**

The model predicts a population decline together with an extinction risk of 13.5 percent when the Whooping Crane remains confined to its currently occupied breeding habitat, which provides a carrying capacity of 54 breeding pairs. With the initial population size of 50 females the population cannot grow and faces density mediated reductions in the fecundity and survival rates. These density dependent effects limit population growth and decrease population survival resulting in a steady population decline. Another reason for the population decline is the fragmentation of the occupied habitat. In order to identify the relative importance of density dependence and habitat fragmentation, we simulated a non-spatial population (analogue to 1.2.2) with a carrying capacity of 54 instead of 500 females. The resulting final average population abundance after 100 years was 42 individuals with an associated extinction risk of 1.7 percent. In contrast, the final average population size obtained from simulations on occupied breeding habitat was 16 with an associated extinction risk of 13.5 percent (see Figure 4a). Consequently, habitat fragmentation accounted for an average reduction of 26 females in the predicted final average population abundances and for an increase in extinction risk of 11.8 percent (13.5 minus 1.7). Although these results do not represent a likely scenario (because more suitable habitat is available), they indicate that the Whooping Crane population might be susceptible to breeding habitat fragmentation based on its limited dispersal distance.

The model predicts a population increase with an extinction risk of 1 percent when the Whooping Crane can use all identified suitable habitat in the study area. The predicted final average population abundance after 100 years is 92 females or breeding pairs (Figure 4b). This corresponds to an annual growth rate of less than one percent. The maximum recorded population abundances are about 300 females (3 percent growth rate), which is less than the actual carrying capacity of all suitable habitat (403 breeding pairs). This result indicates that the Whooping Crane may not be able to continuously utilize all available suitable habitat, but at most about 75 percent (300 out of 403 territories) and on average only 23 percent (92 out of 403 territories). Reasons for this limited habitat utilization are likely related to the fragmentation and spatial dispersion of the breeding habitat across an area of about 70.000 km². In fact, the growth rate of the Whooping Crane may be limited not by habitat amount but connectivity between the breeding habitat fragments.

When confined to all suitable habitat within the Wood Buffalo National Park, the model predicts a population increase with an associated extinction risk of about 1 percent. The predicted final average population abundance is 78 females with maximum abundances near 160 individuals (Figure 4c). This results in a maximum habitat utilization of 70 percent (160 out of 231 territories) and on average 33 percent (78 out of 231 territories).
Comparison of these results with those obtained from all suitable habitat in the study area (Figure 4b) indicates that the additional habitat outside the park boundaries will likely not improve the viability of the population (same extinction risk), but will allow for a stronger growth rate. Although the predicted final average population abundance within the park is just 14 individual lower than those obtained from all habitat, the maximum possible abundance is reduced by almost 50 percent when the Whooping Crane remains confined to the park (300 vs. 160). Consequently, protecting all available suitable habitat is imperative to support the maximum possible growth rate for the Whooping Crane population.

To summarize, the results indicate an overall very low extinction risk for the Whooping Crane population. The population does not seem to be demographically limited and is likely to grow based on breeding habitat availability and fragmentation. The growth rate may be restricted by fragmentation and dispersion of breeding habitat and the resulting low connectivity between habitat fragments. It is likely that the Whooping Crane may not be able to continuously utilize all available suitable habitat based on its limited dispersal capability and its relation to the extent of habitat dispersion.

1.3.3 Source – Sink habitat

The population model as described in 1.2 was applied to the habitat suitability map as shown in Figure 3 using the spatially explicit population model PATCH. 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,

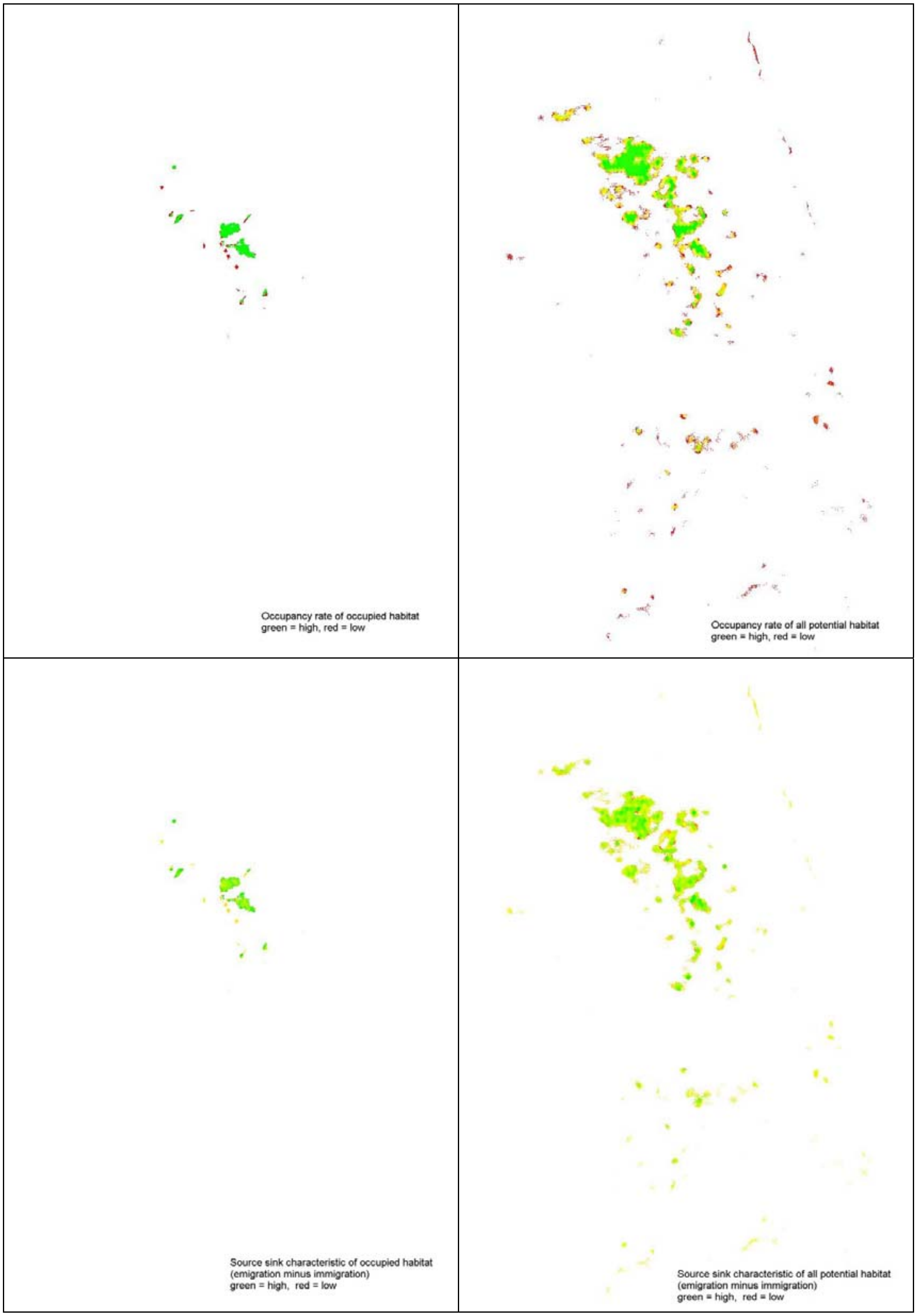


Figure 5: Occupancy rates and source – sink characteristics for occupied habitat only (left column) and all identified suitable habitat (right column)

simulations were conducted on all occupied and unoccupied habitat. The breeding females of the initial populations were seeded according to the current known occupied territories. Reproduction was restricted to habitat area, whereas movement could occur in non-habitat. The demographic rates for the model are listed in Table 2. Individuals could move between 1 and 25 CNA's (each CNA is about 2km wide), which corresponds to the observed movement/dispersal distance of up to 55 km. Moving individuals chose the optimal available CNA while moving. (Note, patch allows to set the movement mode to 'random walk', 'optimal' and 'closest')

Since no data are available for the CNA selection of the WHCR, we assume that individuals will chose the optimal available CNA while moving. Random walk is unlikely. 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 high 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 5.
The green areas indicate higher occupancy and net emigration rates, whereas yellow or red areas indicate lower rates. The maps in Figure 5 show that larger patches, which are also close to each other have the highest occupancy rates and serve as sources for smaller or peripheral territories. Those areas should therefore be regarded as most critical for the viability of the WHCR 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 figure 5), a patch-removal experiment was conducted. The population dynamics of the WHCR were simulated on the habitat suitability map (Figure 3) using RAMAS© GIS while each time one patch was removed. The difference in the probability of extinction resulting from simulations on all habitat patches and those from simulations where one patch was removed indicates the relative importance of a habitat patch for the extinction probability. This experiment was conducted on the occupied habitat map and for all suitable habitat in the study area. The results are shown in Figure 7 and 8.

The results indicate that the largest patches have the strongest effect on the extinction risk and must therefore be regarded as critical habitat. However, vicinity to other patches (isolation) may also affect the relative importance of a habitat patch. Some patches may also serve as "stepping stones" enhancing connectivity amount habitat fragments.

Removing habitat patches may also decrease the extinction risk as indicated by the results shown in Figure 6. While this effect should not be used to argue for removing habitat, it indicates a source-sink or density dependent effect. It is likely that the smaller (sink) patches in the vicinity of larger (source) patches draw immigrants, which may not all reproduce because of the lower carrying capacity of smaller patches. Again, this may just be an artefact of the population model because it did not consider density dependent immigration and must not necessarily hold true in reality.

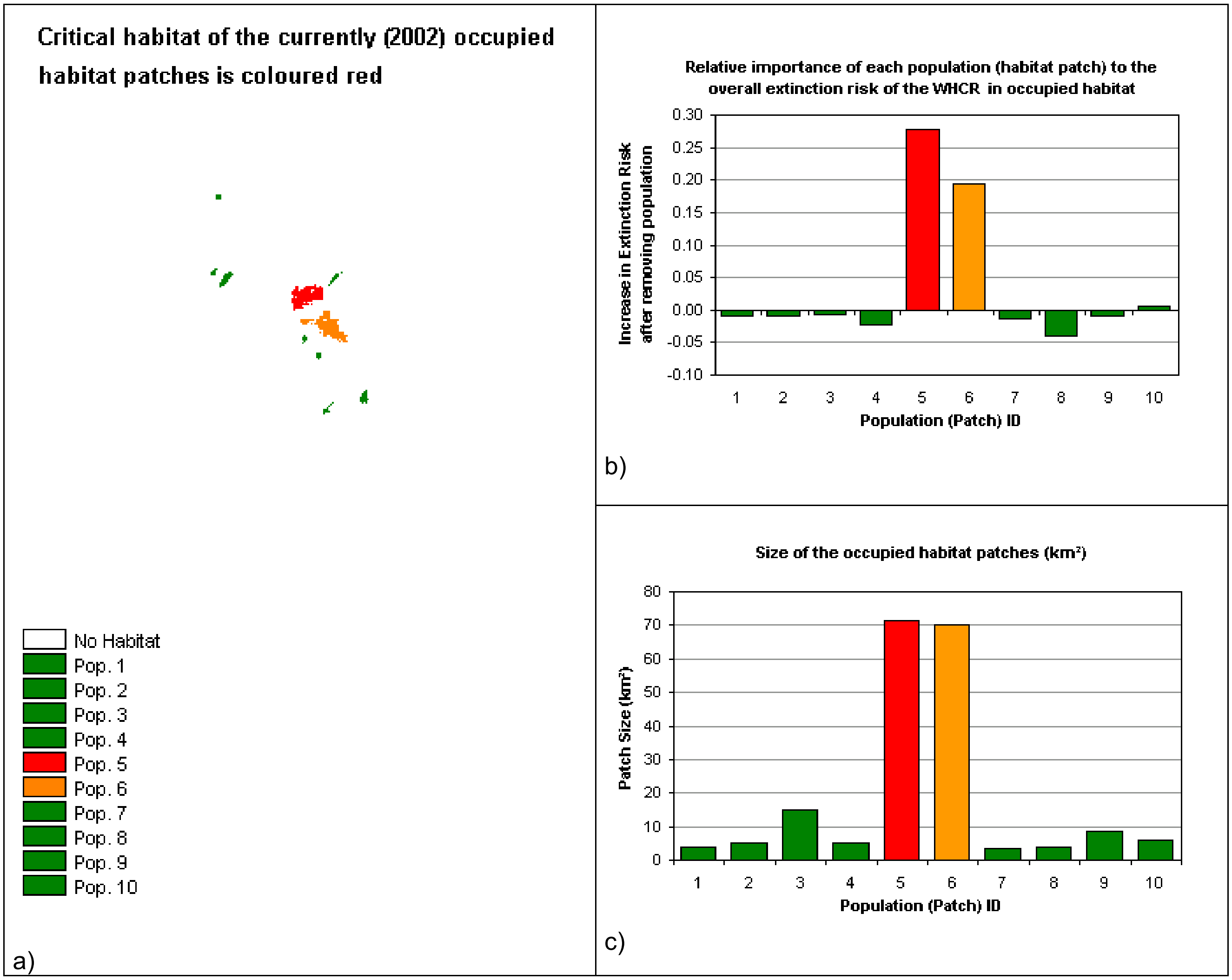


Figure 6: Relative importance of <u>occupied</u> habitat patches to the extinction risk of the WHCR populations. a) Most critical habitat patches are marked in red colours in the critical habitat map. b) Relative importance of the habitat patches to the extinction risk. c) Sizes of the habitat patches.

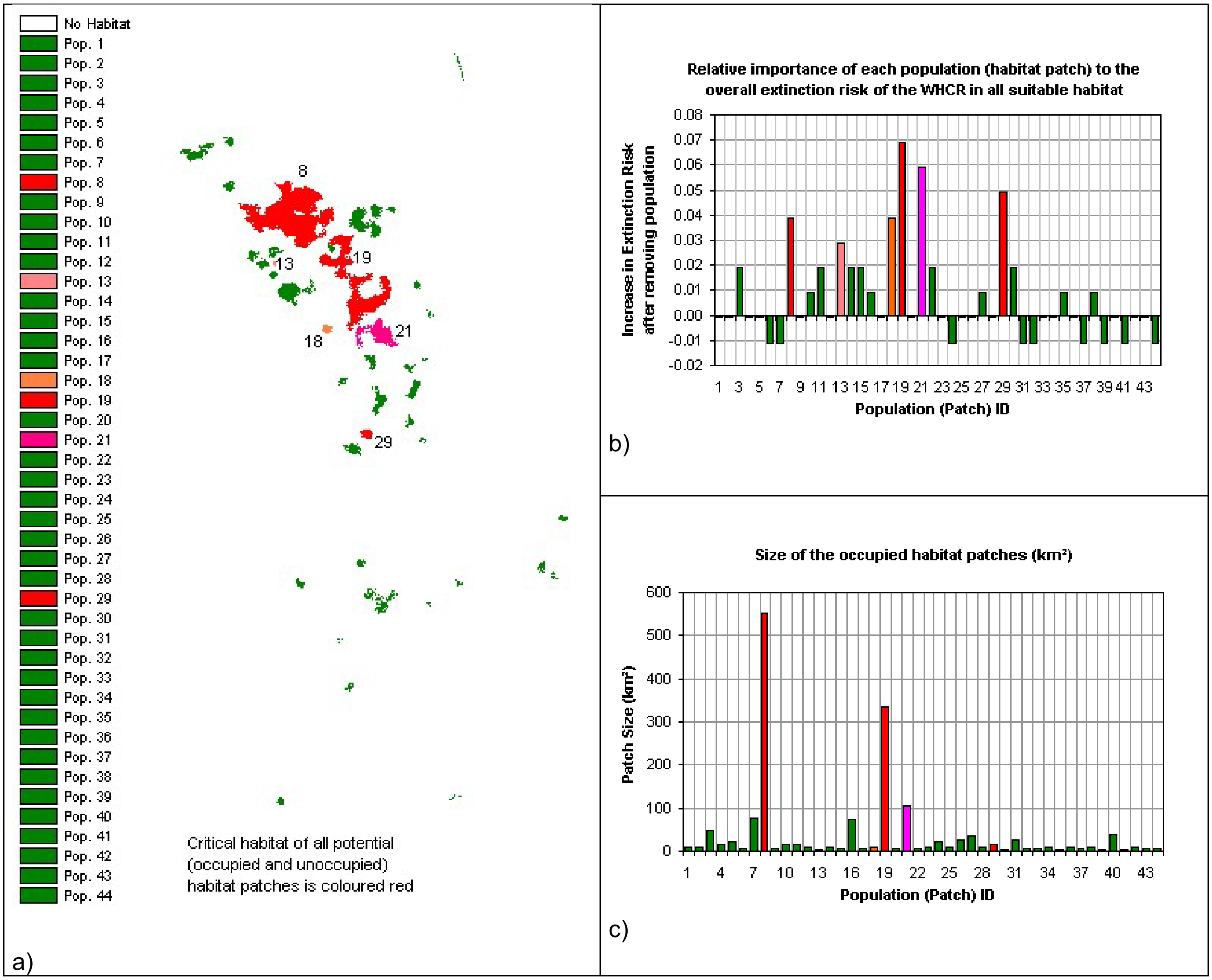


Figure 7: Relative importance of <u>all</u> habitat patches to the extinction risk of the WHCR populations. a) Critical habitat patches are marked in red colours in the critical habitat map, b) relative importance of each habitat patch to the extinction risk, c) Sizes of the habitat patches.

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Tables

Figures