Population Viability Analysis of the Eastern Loggerhead Shrike

(Lanius ludovicianus migrans)

prepared by

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for

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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. 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 model, simulation runs were replicated 1000 times and results are averages out of those replicate simulation runs. Absolute numbers should be interpreted with caution. Instead trends, relative importance 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 substantiated 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 Summary

This population viability analysis (PVA) for the Eastern Loggerhead Shrike is based on empirical data between 1991 and 2013 and reflects our current understanding about the status and future prospects of this small population. This PVA builds on the first PVA conducted in 2009 with an extended, consolidated and revised data set. Insights derived from this PVA benefit from recent data covering 5 more years of the field propagation and release program. These data allow for the first time to quantify effects of this conservation effort on the viability and outlook for this population. In-depth analysis and understanding of this newly compiled data set was therefore a main priority for this PVA followed by a standard population model with revised model parameter values.

The results of this PVA attest an overall positive effect of the captive breeding program in that some captive-reared adults returned after migration and continually contribute to population productivity by breeding with wild or other captive-reared adults. Therefore population size has been boosted by those captive-reared adults and the negative trend in population abundance was reduced by about 50 percent since 2005. Nevertheless, breeding pairs with captive-reared adults appear to have proportionally more nest failures and produce fewer fledglings than wild breeding pairs. This observation is based on a low sample size and may also be caused by the presence of younger and less experienced adults in mixed pairs. Still, this lower productivity for mixed breeding pairs does have a minor negative effect on the intrinsic growth rate of the population. This negative effect, however, was overcompensated by the presence of captive-reared adults in the population, therefore the net effect of this “captive-reared subsidisation” was still positive and if continued at current numbers, would reduce the extinction risk over 100 years by about 20 percent.

The results of the calibrated population model suggest a reduced extinction risk compared to the last PVA and likewise much reduced minimum viable population sizes for time horizons between 10 and 100 years. The extinction risk over 100 years is about 56 percent and the estimated time to extinction is about 88 years. These numbers indicate significant improvement over the results from the last PVA. Sensitivities of survival and fecundity on population viability remain mostly unchanged, with survival rates of hatchlings of the year and first year adults accounting for up to two thirds of the variation in simulated population abundance and extinction risk.

Overall, recent empirical data indicate a still negative intrinsic growth rate for the population most likely resulting from a net loss of adults during migration. Weak migratory connectivity might be the reason for insufficient returns of adults while helping to maintain genetic diversity in the population. Under these current circumstances, only a long-term subsidized population can be viable. The captive breeding program has shown to be effective in boosting the wild population, but it did not help quite yet to make the population self-sustainable.

Conservation efforts should consider measures to improve productivity during the breeding season. Data collection should focus on identifying reasons for the lower productivity in mixed breeding pairs, on reasons for the shift of the population distribution toward the Carden area and on the potential presence of captive-reared birds among singles in the population. Banding of wild birds should be continued only if insights gathered from re-sightings inform new or alternative conservation efforts. Re-sightings of banded birds informed the PVA about the age structure of the wild population and allowed to calibrate survival rates for the population model. It is not assumed that more re-sighting data would benefit another PVA in the future.

2 Status of the Eastern Loggerhead Shrike Population

The Eastern Loggerhead Shrike population was last assessed by COSEWIC in May 2014 and remains listed in the Species at Risk Public Registry as an endangered species (http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=26). This status reflects the fact that the population in Eastern Ontario is still declining at an average rate of about 1 breeding pair ever 4 years over the last 10 years with 22 observed breeding pairs in 2013. This rather small and declining population is accompanied by an average of about 20 percent of additional single individuals, which do not breed, but may support other breeding pairs in their nesting and feeding efforts.

Recovery efforts primarily focussed on introducing captive-reared fledglings into the wild population accompanied by substantive population surveys and habitat assessments. Between 2000 and 2013 a staggering number of 722 captive bred fledglings were released into the wild, almost doubling the accumulated productivity of the wild population of 886 fledglings over the same period. However, only 24 of those captive-reared fledglings are known to have returned from their wintering grounds as adults and bred with wild individuals. As small as this number seems, those integrated captive-reared individuals not only add to population count and productivity, but also attest some success to the captive breeding program as reported elsewhere (e.g. Lagios E.L. et al. 2014, Soorae P.S. 2013).

The question as to where most of the captive-reared fledglings remain after migrating can partly be answered by the findings of (Chabot A. 2011). A genetic analysis of Loggerhead Shrike populations across North America suggests significant mixing among migratory and non-migratory populations on the wintering grounds resulting in weak migratory connectivity. While such weak connectivity facilitates gene exchange and contributes to genetic variation and reduced potential of an Allee effect in the small Eastern Loggerhead Shrike population, it may also explain why so many individuals do not return to their breeding grounds. Further reasons for low return rates of wild and captive-reared birds are most likely limiting factors during migration and on the wintering grounds (Pruitt, L. 2000) Survival rates of released fledglings might also have been affected by the fact that at least half of the released fledglings were fitted with either radios or data loggers.

Overall, analyses of recent and consolidated data since 1991, as well as the results of this PVA reveal a reduced population decline, a reduced extinction risk and an increasing proportion of captive-reared birds in the rather small wild population. Signs of hope for the still highly endangered Eastern Loggerhead Shrike.

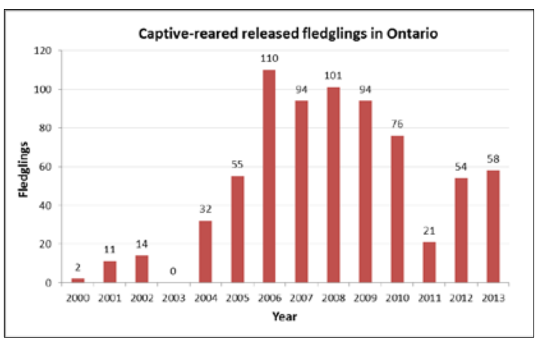
2.1 Captive Breeding Program

Captive breeding colonies were established in 1997 and 1998 in Ontario and introduction of captive-reared birds into the wild started in 2000. Over the period of 14 years, a total of 2 adults and 720 fledglings were released into the wild population (Fig. 1, Table 1). Some of the captive-reared fledglings returned to the wild population as adults and bred with wild individuals (Fig. 2). Since 2005 a total of 24 breeding pairs with captive-reared birds were observed in Ontario. These 24 mixed breeding pairs attempted 26 nests with 12 nest failures and produced a total of 47 fledglings (Table 2). One breeding pair with two captive-reared birds was observed in Carden in 2010 but failed one nest attempt and did not produce offspring.

Year / Core Area	2000	2001	2002	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Carden	2				23	62	39	43	76	33	5	24	23	330
Napanee												30	35	65
Grey-Bruce				18	32	48	55	58	18	43	16			288
Smith Falls		11	14	14										39
Total	**2**	**11**	**14**	**32**	**55**	**110**	**94**	**101**	**94**	**76**	**21**	**54**	**58**	**722**

Table 1: Number of released captive-reared fledglings into the 5 cores regions. The first 2 released birds in 2000 were adults.

Overall, the captive breeding or field propagation and release program made a difference to the Eastern Loggerhead Shrike population, measurable in returning adults, their breeding success and the added productivity to the wild population. It is therefore that this program was classified as “Successful” in the Global Re-introduction Perspectives: 2013 (Soorae P.S. 2013) as well as other recent publications (Imlay T.I. et al. 2010, Lagios E.L. et al. 2014, Nichols R.K. et al. 2010).



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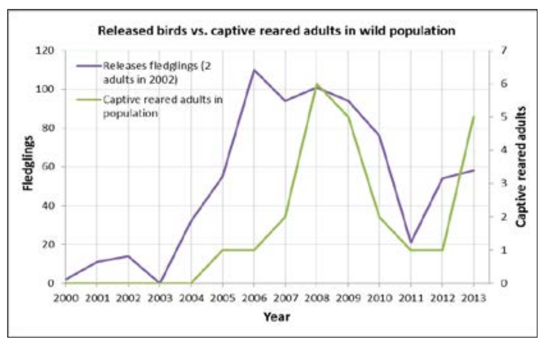

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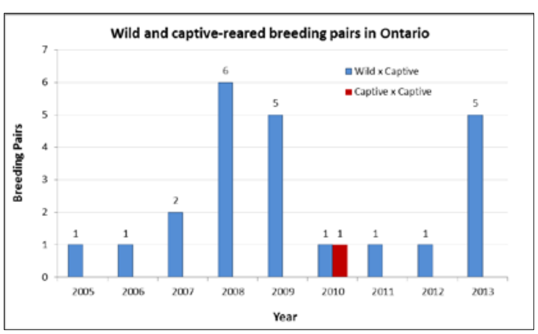

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Figure 1:
a) Number of released captive-reared birds (all fledglings except for 2 adults in 2002) into all core areas in Ontario,
b) number of released birds vs. returned captive-reared adults in wild population,
c) Number of breeding pairs with captive-reared returned adults in Ontario

year	breeding pairs	nest attempts	nest failures	nest failure rate	fledglings	fecundity
2005	1	1	0	0	6	6
2006	1	1	0	0	3	3
2007	2	3	1	0.33	7	3.5
2008	6	7	2	0.28	18	3
2009	5	7	5	0.71	6	1.2
2010	1	1	0	0	1	1
2011	1	1	0	0	3	3
2012	1	1	1	1	0	0
2013	5	4	3	0.75	3	0.6
Total / Avg.	**23**	**26**	**12**	**Avg. 0.34**	**47**	**Avg. 2.367**

Table 2: Productivity of mixed breeding pairs with wild and captive-reared adults in Ontario

2.2 Population Trend

The number of observed breeding pairs since 1991 is shown in Figure 2. This graph depicts the decline and large fluctuations in population size up to 2003 followed by a relative stabilisation of the population trend thanks in part to the presence of captive-reared birds in the population.

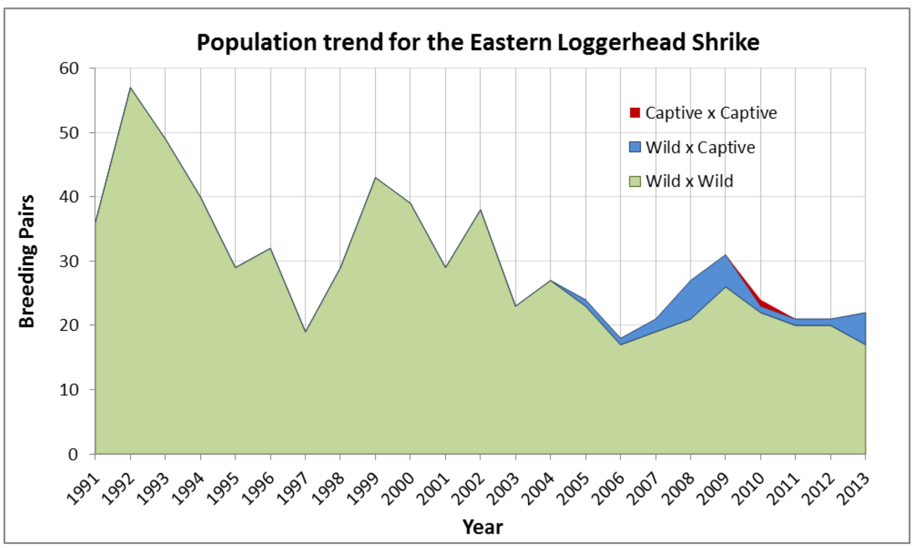
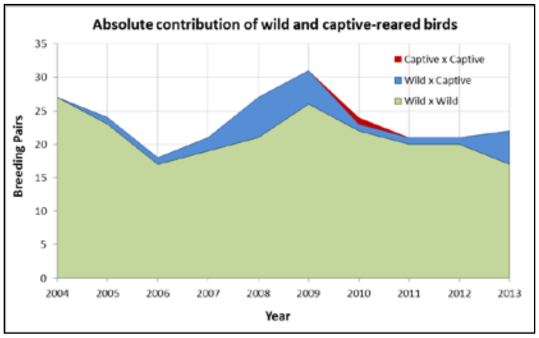


Figure 2: Population trend and contribution of captive birds to breeding pairs.

Figure 3 provides a more detailed analysis of the contribution of captive-reared birds to breeding pairs of the Eastern Loggerhead Shrike. Returned captive-reared adults have been continually present in the wild population since 2005. Albeit fluctuating in numbers and in their proportional contribution, captive reared birds increased overall population size and therefore reduced the negative population trend during the last 10 years by more than 50% from about 1 breeding pair every 2 years (-0.497 slope factor in Figure 3c) to 1 breeding pair every 4 years (-0.2303 slope factor in Figure 3c).



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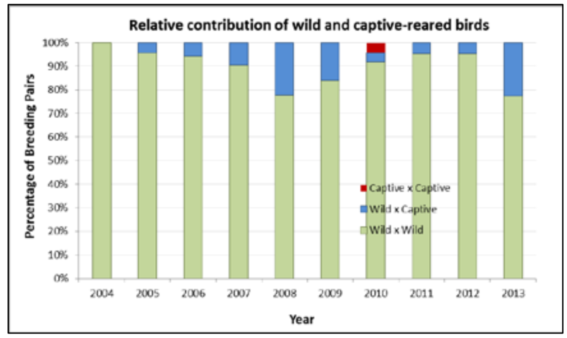

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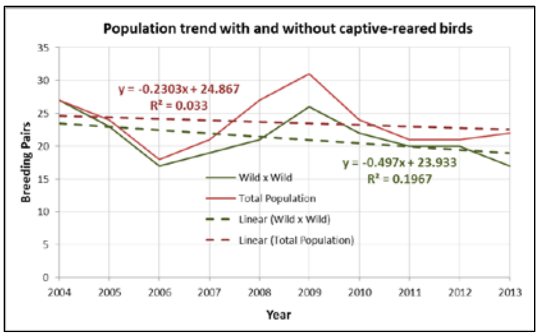

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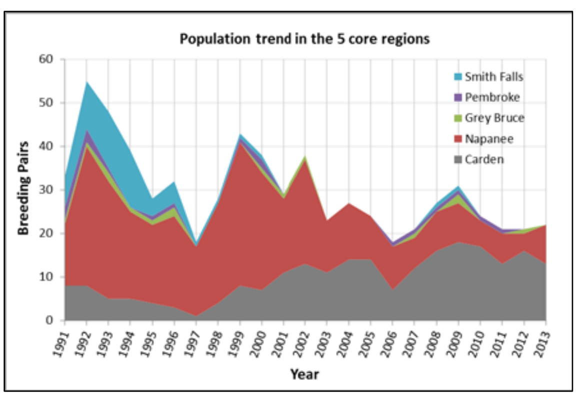
Figure 3: Contribution of captive-reared birds to breeding pairs in Ontario since 2004. a) absolute contribution, b) relative contribution, c) population trend for wild and mixed population

The distribution of the population across the 5 core areas has also changed significantly since 1991 (Fig. 4). While the area around Napanee was the breeding ground for more than 80% of the observed breeding pairs in the late ninety's, the number of breeding pairs sighted in the Carden area steadily increased over the past 15 years. The true cause of this shift cannot be determined at this point, but changes in habitat quality or observation and survey efforts could contribute to this observation.



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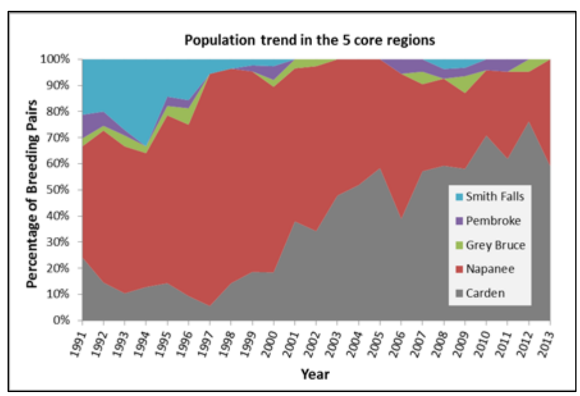

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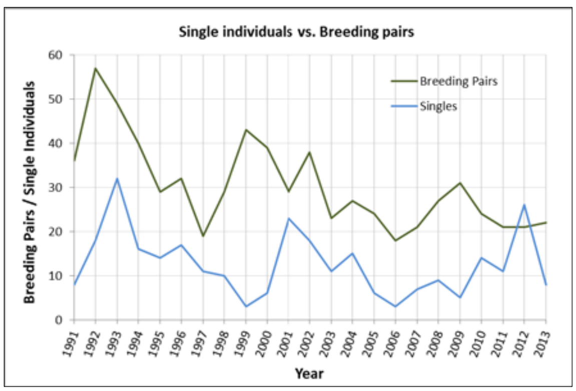
Figure 4: a) Absolute and b) relative distribution of breeding pairs across the 5 core areas in Eastern Ontario. While more than 80% of all known breeding pairs was found in Napanee between 1997 and 1999, about 60% to 70% of the population is now located in the Carden area.

It should be noted, however, that about 45% (330 of 722) of all captive-reared fledglings were released into the Carden area (see Table 1) and that 17 out of the 24 mixed breeding pairs were sighted in Carden. Therefore, the population growth in Carden is in part the result of an increasing number of captive-reared adult birds in that core region.

Finally, although the number of observed breeding pairs has been declining, sighting of breeding pairs in all major core areas within the last 5 years as well as the continuous presence of captive-reared adults could be interpreted as an encouraging sign. This is in contrast to the period between 2003 and 2005, where breeding pairs were observed in Napanee and Carden only.

2.3 Singles vs. Breeding Pairs

The Eastern Loggerhead Shrike population comprises a significant proportion of single individuals, which do not seem to be engaged in nesting and breeding activities, but may help other breeding pairs in raising their brood. Since 1991 a total of 291 singles has been observed along with 699 breeding pairs or 1398 breeding individuals. The number of singles accounts for about 21% of the entire population in terms of individual numbers. Hence about every 5th adult bird does not directly contribute to population productivity. The number of single individuals coarsely correlates with the number of breeding pairs and single individuals have been found in all major core regions. (Fig. 5)



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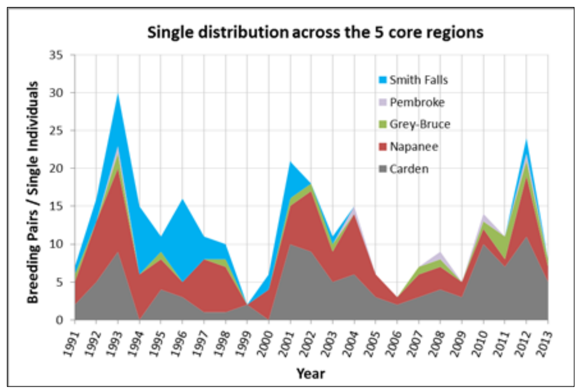

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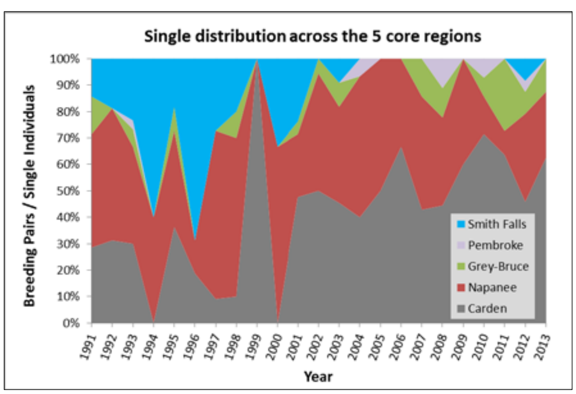

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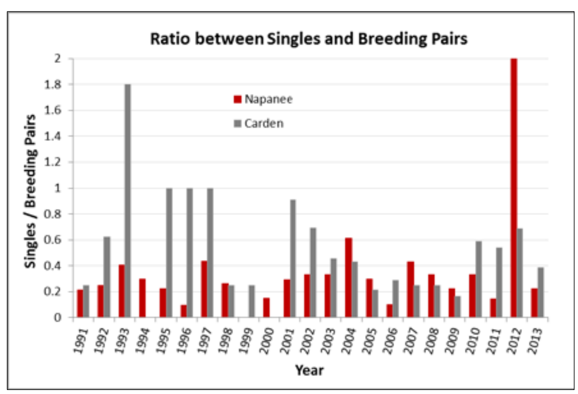

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Figure 5: Trend of single individuals a) compared to number of breeding pairs, b) distributed across core regions, c) proportion of singles in core regions and d) ratio between singles and breeding pairs in Napanee and Carden over time.

In 2012, however, the number of observed singles surpassed the number of breeding pairs for the first time since data collection began in 1991. This anomaly does not seem to coincide with any other significant irregularity or deviation and might not necessarily indicate any fundamental problem.
Furthermore, it could not be determined from the data, if captive-reared birds were among the observed singles. Therefore it is assumed that singles are wild birds.

2.4 Mating System and Breeding Behaviour

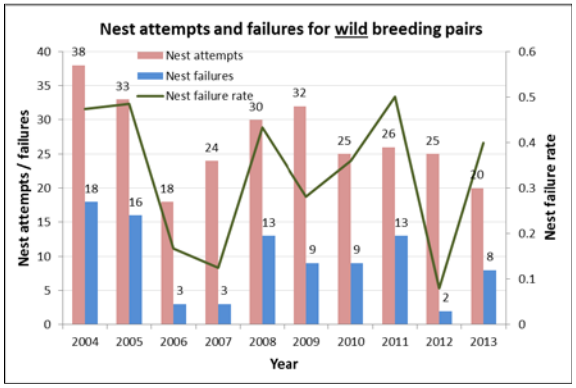
Loggerhead Shrikes generally breed as one-year old birds during the first spring after hatching. The ratio between males and females has consistently being estimated to be close to 1:1. Accordingly, Loggerhead Shrikes are believed to be monogamous. Yet, observations and genetic analyses revealed an apparent departure of Loggerhead Shrikes in Ontario from a monogamous mating system. Extra-pair copulations have been observed as well as multiple females contributing to one nest. This kind of behaviour is believed to be unique among Loggerhead Shrike populations. It is assumed that the polygynous tendency of the mating system is attributed to the lack of males or at least could compensate for the potential lack of males in Ontario's population. There is no clear evidence available yet for a biased sex ratio and the causes for this unique behaviour are not yet fully understood.

2.5 Breeding and Nest Success

The productivity or fecundity of a population is determined by the number of fledglings successfully raised by all breeding pairs during one breeding season. Successful or failed (e.g. destroyed or abandoned) nests directly contribute to a populations' productivity. We will analyse fecundity and nest success over the past 10 years (between 2004 and 2013) for wild, mixed and all breeding pairs separately.

Nest attempts and failures are shown in Figure 6. Nest failure rates do vary greatly between the years for wild and mixed breeding pairs. It appears that mixed breeding pairs fail more nest attempts than wild breeding pairs (see Figure 6d). This situation is also confirmed by comparing the accumulated nest failures. Between 2004 and 2013 all known wild breeding pairs attempted 233 nests and failed 76 of those nest attempts, which sets the wild nest failure rate to 32.62 percent. By comparison, mixed breeding pairs produced a nest failure rate of 46.15 percent by attempting 26 nests and failing 12 of those during the same period. While this mixed nest failure rate is about 40% higher than the wild nest failure rate, the total nest failure rate was only increased by about 6% due to the smaller number of mixed nest attempts.

Nevertheless, it should be noted that mixed breeding pairs have so far failed proportionally more nests than wild breeding pairs and attention should be paid to that performance indicator in the future. Low sample size and a higher proportion of younger and less experienced adults may contribute to this observation.



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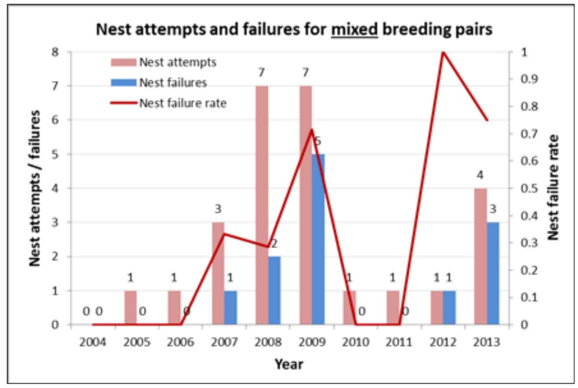

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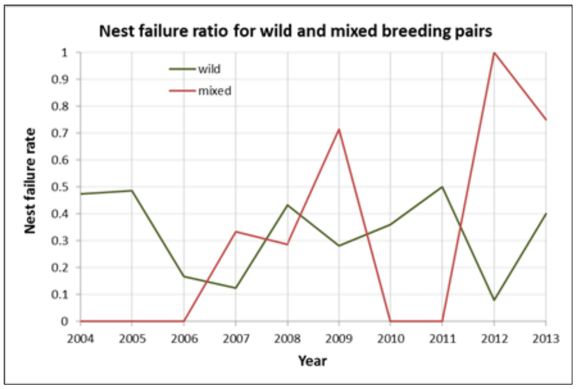

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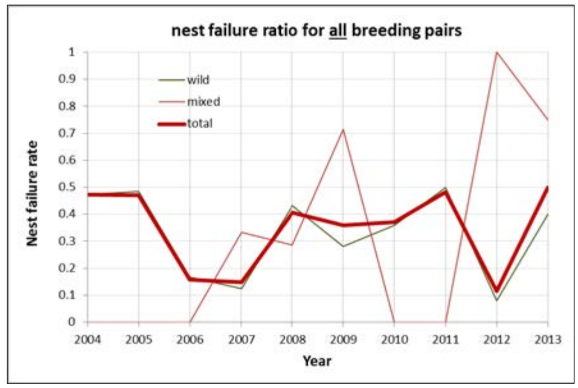

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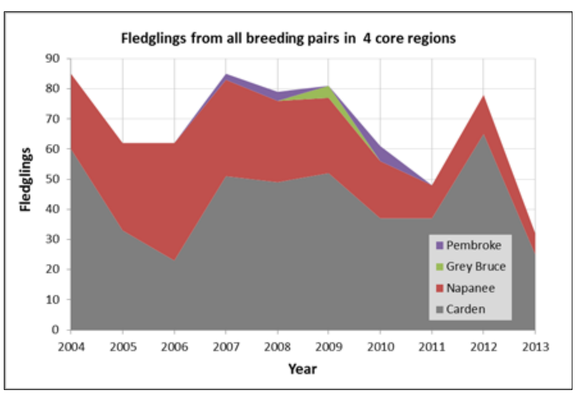
Figure 6: Nest attempts and failures for wild, mixed and total number of breeding pairs

The productivity or fecundity of a population is usually defined by the number of successfully raised fledglings per breeding pair at the end of a breeding season. Nest success as shown in Figure 6 is a major factor in raising a brood but other factors, such as initial clutch size, hatching success and fledgling mortality impact the effective fecundity of a breeding pair and population. The number of fledglings produced by all breeding pairs in 4 core regions is shown in Figure 7.



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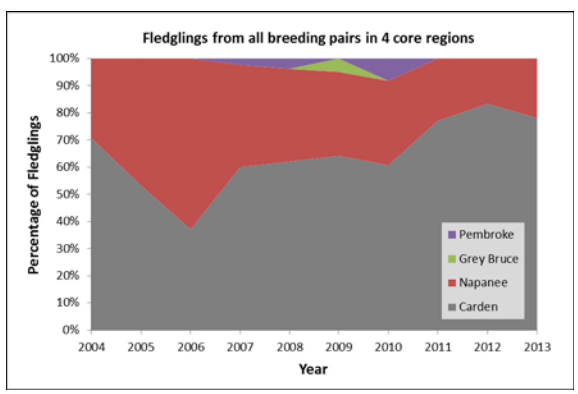

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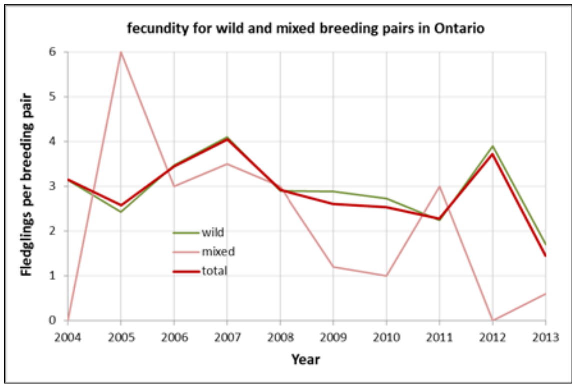
Figure 7: a) Number of fledglings produced in 4 out of the 5 core regions. (Note, no fledglings have been observed in Smith Falls during that period). b) Fledgling proportions across the 4 core regions.

The numbers reflect a negative trend in fledglings per year between 2004 and 2013 and a shift of population productivity toward Carden. Between 2011 and 2013 about 75% to 80% of all fledglings were counted in the Carden area.



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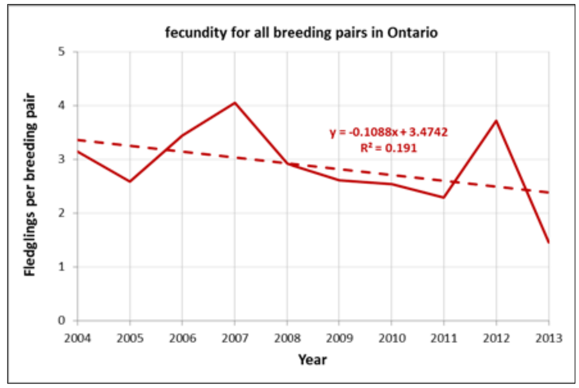

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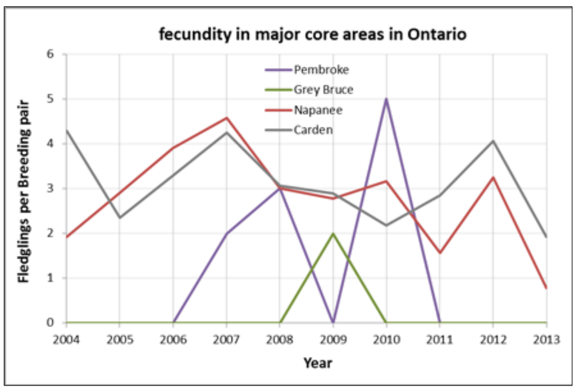


Figure 8: a) Fecundity compared for wild and mixed breeding pairs with the resulting fecundity for the all breeding pairs.
b) Fecundity trend for the entire population. Fecundity has been declining at a rate of 1 fledgling every 10 years or 0.1 fledgling per year since 2004.
c) Fecundity per core area in Ontario.

c)

Fecundity for mixed and wild breeding pairs is shown in Figure 8. These graphs reveal that fecundity for mixed breeding pairs appears to be lower and more variable across years than fecundity for wild breeding pairs. The trend for both is negative with a ratio of about minus 0.1 fledglings per year.

In numbers, mixed breeding pair fecundity averages about 2.367 fledglings per breeding pair with a standard deviation of about 75 percent. Wild breeding pairs produced about 2.931 fledglings per breeding pair with a standard deviation of about 25 percent. This comparison reveals that the productivity of mixed breeding pairs lags about 9 percent of that observed in wild breeding pairs. The net negative effect on the total fecundity is about 3 percent.

One remaining question is if fecundity is related to the number of nest attempts and failures. As Figure 9 shows, average seasonal fecundity per breeding pair is not correlated to nest attempts or failures, hence other factors, such as predation or hatching success might have a stronger influence on net productivity.

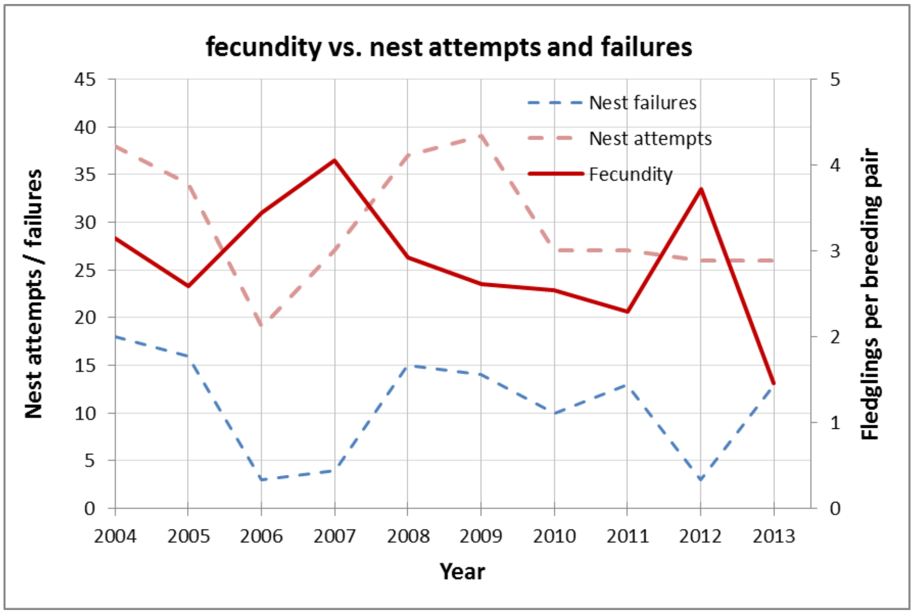


Figure 9: Nest attempts, failures and fecundity for all breeding pairs

In summary, key indicators of population productivity are declining and mixed breeding pairs appear to produce more nest failures and fewer fledglings than their wild counterparts. More emphasis should be paid to these particular facts of population productivity in future observation efforts.

2.6 Re-sightings, age structure, sex ratio and over-winter survival

Re-sightings of banded individuals provide valuable information about the age structure of a population and to some extend about over-winter survival or return rates between age classes. Tables 3 and 4 provide re-sighting numbers and survival estimates for the entire population between 1999 and 2013. Accumulated numbers over 13 and 14 years seem sufficient for deriving at least a credible age class distribution (Figure 10) and guidance for survival estimates.

years / age	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
HY	50	126	102	97	81	66	41	0	0	0	0	20	4	11	0	598
1 year (SY)	5	17	10	26	6	12	8	17	0	9	13	6	7	8	7	151
2 year (ASY)	0	15	13	9	10	2	9	1	0	13	14	27	17	7	15	152
3 year (TY)	0	6	6	5	2	4	4	1	0	1	3	4	10	4	3	53
4	0	0	0	5	4	4	2	2	1	3	0	1	3	0	3	28
5	0	0	2	1	0	1	1	0	1	0	1	0	0	0	3	10
6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Total	**55**	**164**	**133**	**143**	**103**	**89**	**65**	**21**	**2**	**27**	**31**	**58**	**41**	**30**	**31**	**993**

Table 3: Age structure based on re-sightings and fledgling counts in Ontario

It should be noted that the numbers for age classes 1 and higher in Table 3 represent amalgamations of e.g. 1 and 1+ classification (see Figure 11b for an example). It is often not possible to determine the exact age of re-sighted birds, but merely the minimum possible age. In those situations the age class is defined as “age+”, meaning that the bird could be older. For the sake of practicability and consistency with the model (these data just help to calibrate the model parameters, see 4.1.2), “age+” and “age” class numbers were amalgamated into one age group.

Year banded	HY banded (wild)	# surviving 1+ years	SY banded	# surviving 1+ years	ASY banded	# surviving 1+ years	AHY banded	# surviving 1+ years
1999	50	19	5	3	25	10	3	1
2000	126	13	14	2	12	10	3	0
2001	102	21	9	1	6	3	0	0
2002	97	8	11	3	6	0	1	0
2003	81	12	3	2	3	5	0	0
2004	66	11	3	1	1	0	0	0
2005	41	1	2	0	1	0	0	0
2006	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0
2008	0	0	9	3	13	5	0	0
2009	0	0	9	9	10	6	0	1
2010	20	2	7	10	8	13	0	0
2011	4	0	4	3	6	3	0	0
2012	11	1	1	4	2	1	0	0
Total	598	88	77	41	93	56	7	2
(%)		14.72%		53.25%		60.22%		28.57%

Table 4: Over-winter survival estimates per age class based on re-sightings of banded birds in Ontario

These data confirm that adult individuals my live up to 6 years (although one 9 year old banded male individual was re-sighted 2006) in in the wild and the big drop in individuals between HY and one year adults (see Figure 10) indicates a high mortality or “lack-of-return” rate for first year adults. While this age structure shows similarity to age class distributions of similar species, it seems unlikely that age class one and two are equally represented in a population.

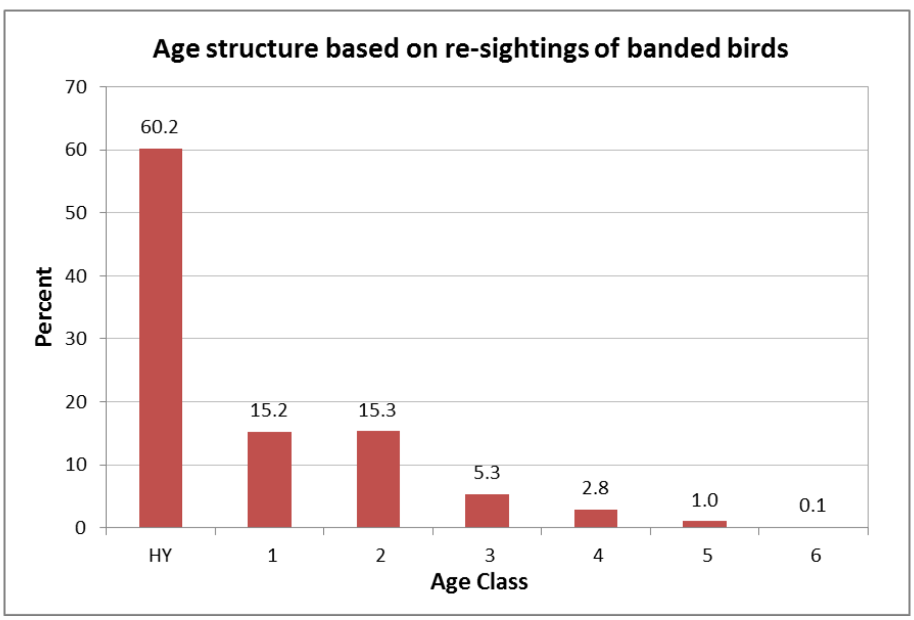
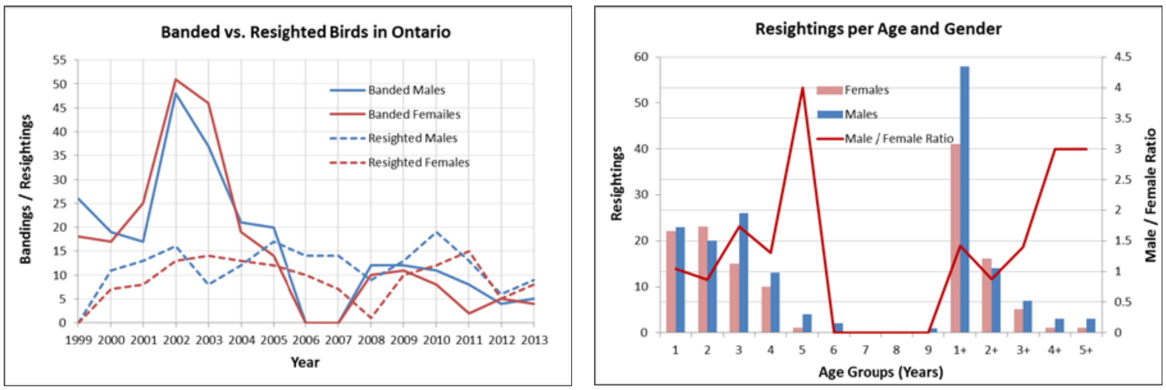


Figure 10: Age class distribution based on re-sightings between 1999 and 2013

Another insight from re-sights of banded individuals relates to the sex-ratio and potential differences in return rates or survival of the population. Figure 11 shows the number of banded and re-sighted birds since 1999. Overall, a total of 230 female and 240 male birds were banded between 1999 and 2013. During that time period 135 re-sights of females and 174 re-sights of males in different age groups were recorded. These numbers indicate that chances to re-sight males were higher than those for females (72.5% vs. 58.6%). A breakdown into age groups reveals that the males of all age groups (except for 2 year olds) are more likely to be re-sighted than females. There could be multiple reasons for this difference, such as a difference in detection probability, a difference in return rates of banded birds or a difference in over-winter survival rates or a combination of those factors.



a) b)

Figure 11: a) Numbers of banded and re-sighted individuals in Ontario. b) Number of all re-sighted individuals per age group between 2000 and 2013. The data suggest that more males than females have been re-sighted in most years and for almost all age groups.

2.7 Potential for an Allee Effect

The low population size paired with a significant proportion of singles in the population raises concerns about the potential for an Allee effect by which the population would most likely experience an accelerated decline due to low population density effects, such as inbreeding, mate finding issues or breakdowns of social structures. There are currently 3 indicators that this population has most likely not been affected by an Allee effect.

First of all, the results from Chabot A. 2011 reveal a weak migratory connectivity and significant mixing of resident and migratory populations on the wintering grounds, which should facilitate gen flow into the Ontario population and reduce the risk of inbreeding. Second, if social aspects of the population were affected, the number of singles should increase with decreasing population size. This has mostly not been the case except for 2010 until 2012 when the number of observed singles rose above the number of breeding pairs (Figure 12). This trend, however, did not continue in 2013. Third, the observed fecundity did not decline with population size (Figure 12), but showed a rather positive trend between 2002 and 2012 despite a low population size.

All these observations cannot exclude the risk of an Allee effect or low density depression of the population in the future and, if the population continues to decline, it might well become another threat to the Eastern Loggerhead Shrike population.

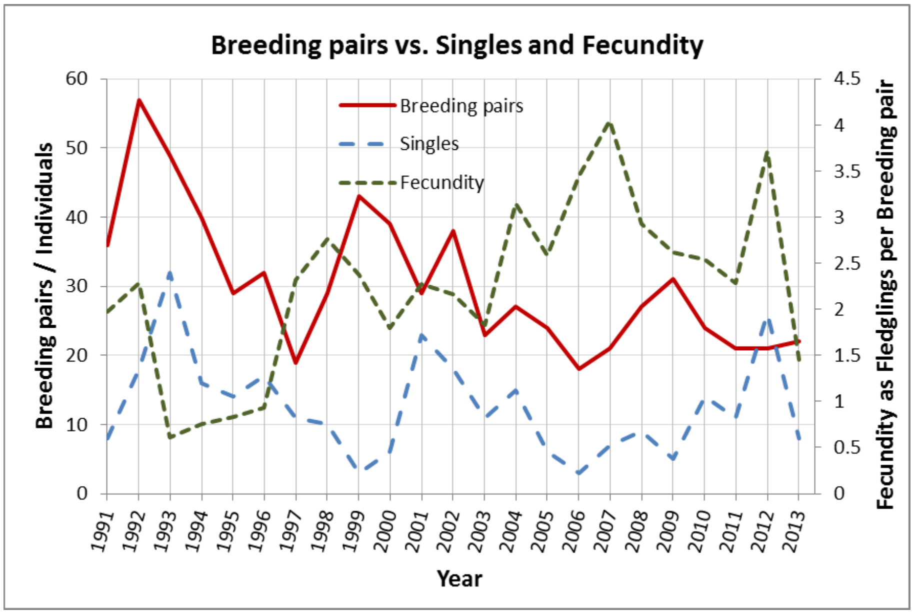


Figure 12: Relationships between breeding pairs, singles and productivity. Fecundity was higher during the last 10 years and singles mostly correlated with breeding pairs, except for 2012, when observed singles exceeded the number of breeding pairs.

2.8 Summary

The status and fate of the Eastern Loggerhead Shrike has been captured and documented by many volunteers and staff members over the past 24 years. The collected data support the following conclusions:

1. the population is small and continues to decline with 22 breeding pairs accounted for in 2013
2. the population distribution across the 5 major core areas has shifted with approximately 60-70 percent of all observed breeding pairs now located in the Carden region
3. captive-reared birds returned to the wild population after migration and have continuously contributed to productivity in mixed breeding pairs since 2005
4. captive-reared adults increased population size and reduced the negative population trend
5. mixed breeding pairs are somewhat less productive than wild breeding pairs, they are likely to exhibit proportionally more nest failures and produce fewer fledglings than wild breeding pairs
6. population productivity is declining and consequences of this trend have been partially offset by captive-reared adults boosting adult population size
7. single and non-productive individuals continue to account for about 20 percent of the total population
8. accumulated data from re-sightings attest that individuals may live up to 6 years in the wild and provide valuable insight into the age structure of the population
9. weak migratory connectivity and unknown fates during migration and on the overwintering grounds most likely contribute to the ongoing population decline

3 Population Model

The following sections describe the structure of the population model as well as the underlying assumptions and sources for model parameter values. The model represents an age-structured population of females based on the demographic fingerprint of the Eastern Loggerhead Shrike population in Ontario as outlined in section 2. The model was implemented using Ramas©MetaPop (Akçakaya and Root 2002).

3.1 Model expectation

The age structure and the parameter values of a population model should be defined by quantified empirical observations and guided by expert knowledge. However, some of the data requirements cannot always be satisfied with empirical data or even expert knowledge. Therefore, conducting a quantitative PVA in the presence of data gaps requires postulating assumptions or best guesses in conjunction with creative model calibration strategies.

One possible strategy is to compare simulated results against empirical data and to use this comparison for calibrating unknown or uncertain model parameter values. The first goal should therefore be a population model, which reproduces empirical facts, such as known population trajectories or age class distributions. Such a calibrated model may then be used to quantify viability measures, such as extinction risk or minimum viable population size, but also to explore consequences of scenarios in a quantitative manner. It is exactly this kind of information, which is generally more trustworthy and consistent then predicting population sizes for a future point in time.

3.1.1 Population Trend

As presented in section 2.2., the population model should reproduce a negative population trend with a growth rate of about -1 breeding pairs every 4 years.

3.1.2 Age Structure

The observed maximum life expectancy of Loggerhead Shrike's in the wild is about 6 years, although only one bird at the age of 6 years has been re-sighted in Ontario between 2000 and 2013 (see Table 3 and Figure 10 in section 2.6). The population model should produce an age class distribution similar to Figure 10.

3.2 Model parameters and assumptions

3.2.1 Time Step

The model uses a time step of one year and a time span of 10 to 100 years. All simulation runs were repeated 1000 times unless noted otherwise.

3.2.2 Age Classes

The population is divided into 6 age classes as follows:

- Juvenile - fledglings or hatchlings of the year
- Adult_1 – first year adults
- Adult_2 – second year adults
- Adult_3 – third year adults
- Adult_4 – fourth year adults
- Adult_5 – fifth plus year adults

These age classes allow for accounting juveniles up to 5 plus year adults whereas individuals older than 5 years remain part of the Adult_5 age class.

3.2.2.1 Fecundity

Fecundity in the population model refers to the number of fledglings per adult female during one breeding season. It is assumed that all females of all adult age classes produce on average the same number of fledglings throughout their simulated life.

Year	# breeding pairs	# fledglings	#fledglings/#breeding pairs
2004	27	85	3.1481
2005	24	62	2.5833
2006	18	62	3.4444
2007	21	85	4.0476
2008	27	79	2.9259
2009	31	81	2.6129
2010	24	61	2.5416
2011	21	48	2.2857
2012	21	78	3.7142
2013	22	32	1.4545
Total/Avg.	**236**	**673**	**Avg. 2.8758**

Table 5: Breeding pairs and fledglings in Ontario.

Fecundity was calculated based on the reported number of fledglings per breeding pair in Ontario between 2004 and 2013 (see Table 5).

The average ratio between fledglings and breeding pairs (2.8758) as well as the corresponding standard deviation of 25% has been used as fecundity values for the population model. Since the population model tracks females only, the fecundity was divided by 2 based on the assumption of a balanced sex ratio.

The period of consideration for calculating fecundity was consciously chosen based on the belief that breeding conditions for the Loggerhead Shrike in Eastern Ontario over those ten years represent current and near future conditions and reflect current population productivity.

3.2.2.2 Survival

Survival in the population model refers to an annual survival rate, i.e. the proportion of the age class in the population surviving from one year to the next. Since survival rates are practically unknown (as outlined in section 2.6) assumptions had to be made here. It was assumed that survival of juveniles was about 50% of adults and that 5 plus year adults experienced a lower survival rate then younger adults. Survival rates were then calibrated until the simulated population trajectory matched its empirical counterpart and until the simulated age class distribution resembled the empirically determined age structure of the population. Survival rates per age class are shown in Table 6, section 3.2.2.3. A 10 percent standard deviation around survival rates was used in the model (see Table 7).

3.2.2.3 Stage Matrices

Table 6 shows the stage matrix with fecundity values in the upper row and survival values in the diagonal row. Table 7 shows the corresponding standard deviation matrix for fecundity and survival values.

age class	juvenile	adult_1	adult_2	adult_3	adult_4	adult_5
juvenile	0.0	1.4379	1.4379	1.4379	1.4379	1.4379
adult_1	0.306	0	0	0	0	0
adult_2	0	0.65	0	0	0	0
adult_3	0	0	0.56	0	0	0
adult_4	0	0	0	0.41	0	0
adult_5	0	0	0	0	0.3	0.2

Table 6: Stage matrix for Loggerhead Shrike population model

age class	juvenile	adult_1	adult_2	adult_3	adult_4	adult_5
juvenile	0	0.3574	0.3574	0.3574	0.3574	0.3574
adult_1	0.0306	0	0	0	0	0
adult_2	0	0.065	0	0	0	0
adult_3	0	0	0.056	0	0	0
adult_4	0	0	0	0.041	0	0
adult_5	0	0	0	0	0.03	0.02

Table 7: Standard Deviation matrix for values shown in Table 6

3.2.3 Sex structure and Mating System

The Loggerhead Shrike population model is a female only model.

3.2.4 Density Dependence

No density dependence was used in this model. There appears to be no evidence for an Allee effect and population sizes are too small and unlikely to be constrained by limited habitat amount.

3.2.5 Stochasticity

Demographic stochasticity was used in the model as well as stochasticity originating from the standard deviations around fecundity and survival rates. The model was set so that fecundity and survival were not correlated based on the assumption that over-winter survival is uncorrelated to breeding success.

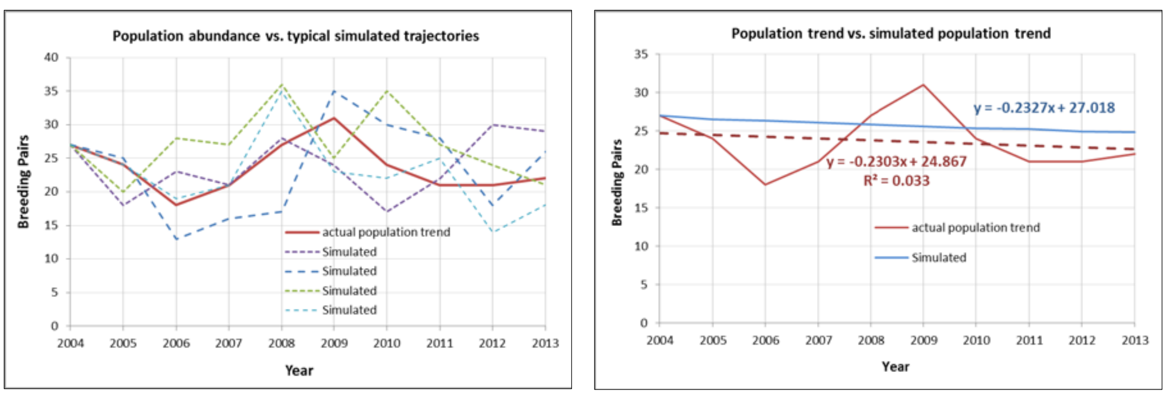
4 Results

4.1 Model Calibration

This section compares simulated results to empirical data as a way of calibrating the population model and establishing some confidence into the structure and parameterisation of the model.

4.1.1 Population Trend / Growth Rate

Figure 13 depicts a comparison of exemplary simulated population sizes over 10 years with the real population count as well as compares the empirical trend with the simulated trend.



a) b)

Figure 13: a) Simulated population trajectories and b) the simulated average population trend compared to the actual population counts and trend between 2004 and 2013.

These results confirm that the population model produces quite realistic population sizes over time and that the average population size over 1000 replicate simulation runs declines similar to the trend based on currently observed population counts.

4.1.2 Age Structure

Figure 14 compares the simulated age class distribution against the empirically determined age structure of the population. Both age class distributions are very similar and differ mostly in Age classes 1 and 2. As already pointed out in section 2.6, it appears unlikely that two age classes share the same proportion of individuals within a population. A steady decline of individuals in higher age classes seems more realistic and survival rates were fine tuned to produce an age structure as close as possible to the empirical distribution.

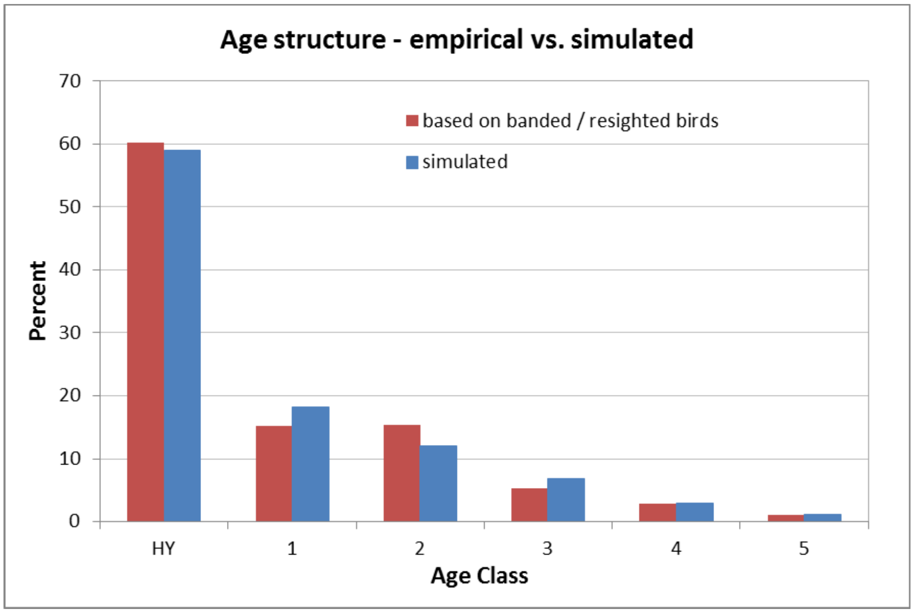
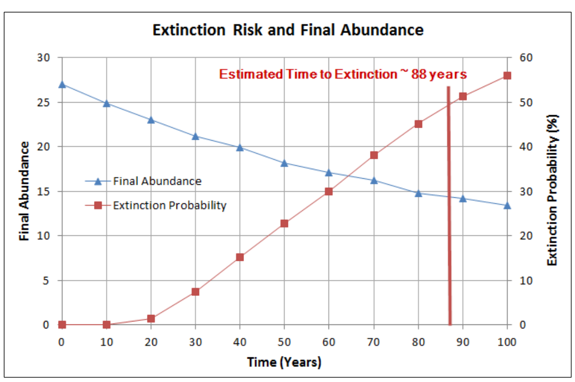


Figure 14: Observed age structure vs. simulated age class distribution

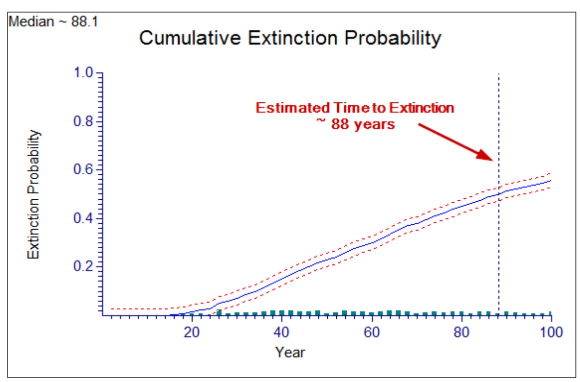
4.2 Probability of Extinction

The probability of extinction is calculated as the proportion of the 1000 replicate simulation runs in which the population abundance becomes zero during one simulation run. For example, an extinction risk of 10 corresponds to 100 out of 1000 simulation runs with a simulated zero population size over the course of 100 years. The extinction risk is a function of time and tends to increase over time.

The negative growth rate of the simulated Loggerhead Shrike population leads to a predicted extinction risk of about 56 percent within 100 years and an estimated time to extinction (median of the distribution of annual extinction probabilities) of about 88 years. The risk of extinction is primarily driven by a continually decreasing population size as shown in Figure 15.



a)



b)

Figure 15: Cumulative probability of extinction over 100 years and estimated time to extinction of about 88 years. a) extinction risk is inversely related to population size due to the negative growth rate. b) probability of extinction distribution over time with accumulated extinction probability reaching about 56 percent after 100 years.

4.3 Minimum viable population size

The minimum viable population size (MVP) was simulated for time horizons between 10 and 100 years under consideration of a final extinction probability of less than 1 percent (Figure 16).

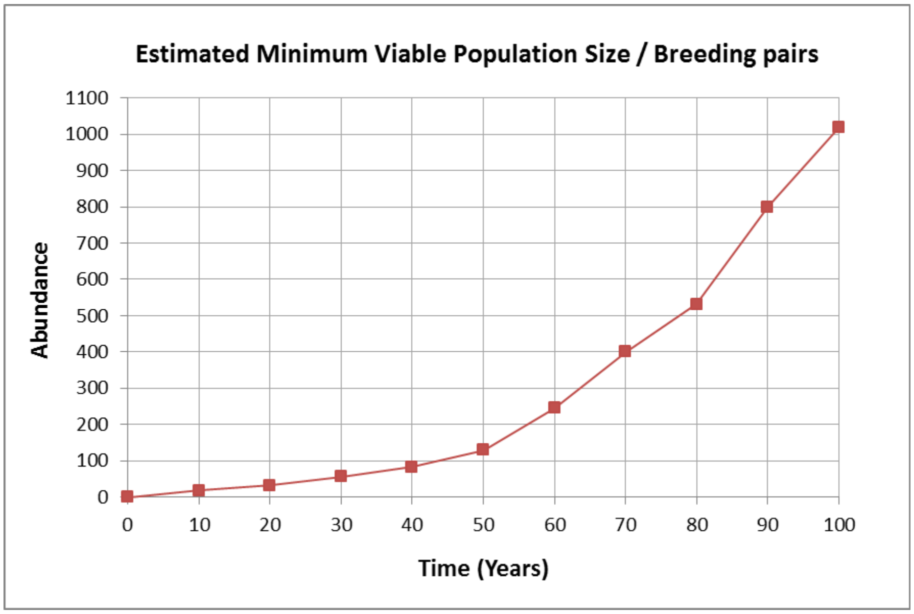


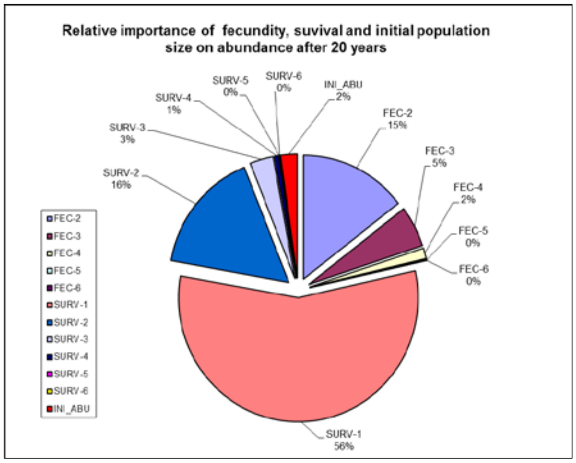
Figure 16: MVP as a function of time. At least 800 breeding pairs would be necessary to ensure a less than 1 percent extinction risk over 90 years if the current population trend continued.

4.4 Sensitivity analysis

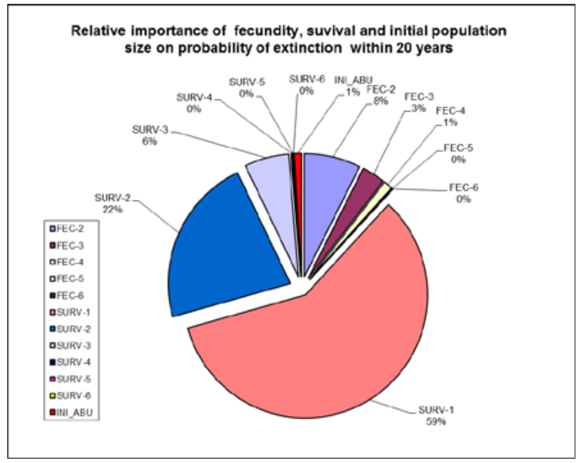
The relative importance or sensitivity of all model parameters for population abundance and extinction risk was analysed using GRIP (Curtis and Naujokaitis-Lewis 2008). GRIP varies model parameter values randomly and executes Ramas@Metapop for each randomized parameter value combination, therefore executing an automated sensitivity analysis based on randomized parameter variations of the initial population model.

A slightly modified version of GRIP was used to vary the model parameter values for fecundity, survival and initial abundance by drawing random numbers from normal distributions with a standard deviation of 10 percent.

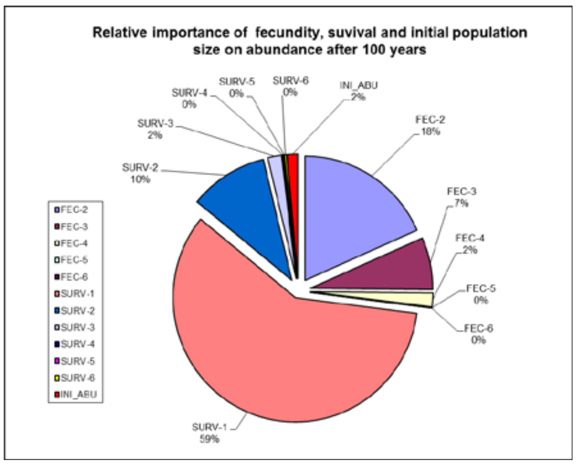
GRIP ran 1000 model parameter variations based on the initial population model whereas each simulation run was internally repeated 1000 times resulting in 1 million actual simulation runs. The resulting data set was analyzed by means of ANOVA (using Statistica 2001) and the relative importance of each significant model parameter was then determined using Type III Sums of Squares. The results are shown in Figures 17.



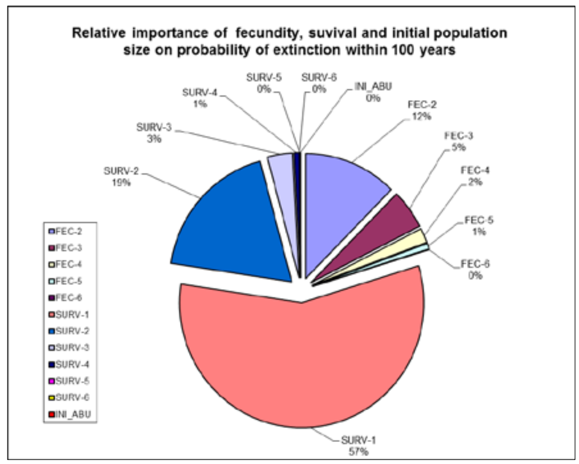
a)



b)



c)



d)

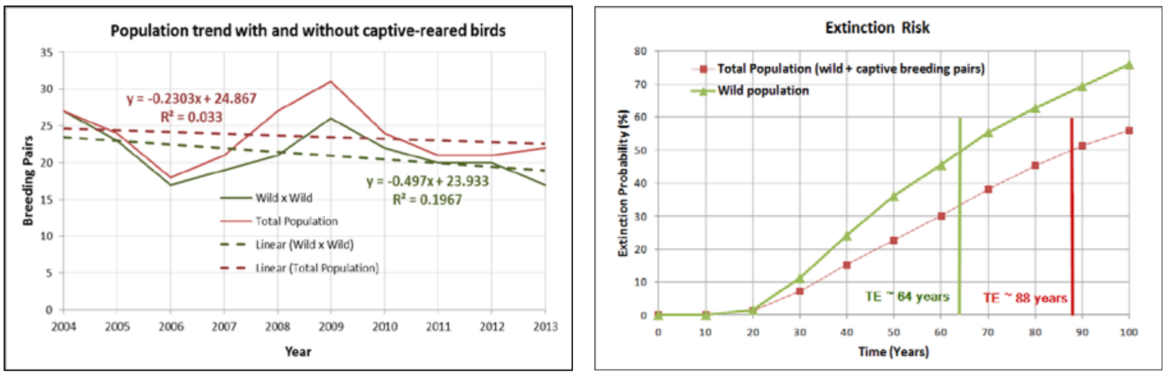
Figure 17: Relative importance of model parameters to a) abundance after 20 years, b) extinction risk after 20 years, c) abundance after 100 years and d) extinction risk after 100 years. "FEC" and "SURV" refer to fecundity and survival rates of age classes respectively. INI_ABU refers to the initial abundance of females in the model.

Relative importance of model parameters was analysed against 4 response variables – abundance and extinction risk after 20 and 100 years. As all 4 graphs in Figure 17 reveal, overwinter survival rates of the first two age classes or juveniles and first year adults account for roughly two thirds of the variation in all 4 response variables. These results closely resemble those from the first PVA conducted in 2009 even though demographic rates were adjusted to updated empirical data in the current population model. This similarity confirms that relative simulation results are more robust and generally more trustworthy than absolute numbers.

4.5 The effect of captive-reared adults on extinction risk

Analysis of the data in section 2 revealed that the presence of captive-reared adults in mixed breeding pairs affects population dynamics in two ways. First, mixed breeding pairs seem somewhat less productive than wild breeding pairs. Second, that negative effect on population growth is offset by a continuous presence of captive reared adults in the population. In order to analyse these effects on the probability of extinction, the initial population model was modified to reflect the situation of wild breeding pairs only. Fecundity was increased based on wild breeding pairs and their produced fledglings between 2004 and 2013. Survival rates were lowered so that the simulated population trend matched that of the wild population in Ontario (see Figure 18a).

The difference in extinction risk between the wild and total population is shown in Figure 18b. It is reasonable to assume that the current presence of captive-reared adults in the population does reduce the extinction risk over 100 years by about 20 percent (from 76 to 56 percent) and the estimated time to extinction by about 24 years. These predictions, however, extrapolate the positive effects of a “captive-reared subsidised” population or, in other words, rely on the influx of “external” productive adults to the wild population.



a) b)

Figure 18: a) albeit lower productivity in mixed breeding pairs, the growth rate or population trend for wild breeding pairs is lower than for the entire population b) extinction risk and estimated time to extinction compared for wild only and total population.

5 Future Data Requirements

Key insights of this analysis are based on recent observations but also raise some new questions, which should help to focus observation and data collection efforts in the near future.

1. The causes for the shift in the population distribution toward the Carden region should be understood. Do the data reflect some bias in observation efforts or are other reasons possible?
2. Are there any captive-reared birds among the singles in the population? If so, what is their role or observed behavior?
3. Mixed breeding pairs exhibit a somewhat lower productivity than wild breeding pairs. A better understanding of this difference and the main causes would help guiding conservation efforts in support of boosting productivity.
4. If low migratory connectivity prevents adults from returning to Ontario, some banded captive-reared birds should be sighted elsewhere. Collaboration with teams working on the overwintering grounds and data sharing could potentially help to better understand the fate of “emigrated” birds.
5. The continuation of banding wild birds of this small population should only be considered if new insights can be expected from future re-sightings. Accumulated re-sightings until 2013 provided valuable information on the age structure of the wild population and some guidance on return or survival rates. It is not expected that further banding and potential re-sightings will add much new information for another PVA. Therefore, unless future conservation efforts are expected to benefit from continued banding, it seems

unnecessary and could be replaced by paying more attention to some of the data requirements mentioned above.

6 Conclusions

The following conclusions can be derived from the results of this PVA:

1. the ongoing field propagation of captive-reared juvenile birds led to a continuous presence of captive-reared adults in the wild population since 2005
2. captive-reared adults bred with wild adults and those mixed breeding pairs exhibit proportionally more nest failures and raised fewer fledglings resulting in a lower overall productivity compared to wild breeding pairs
3. captive-reared adults have boosted productive population size and reduced the negative population trend by about 50 percent since 2005.
4. the overall net effect of captive-reared adults or mixed breeding pairs in the population on extinction risk is positive, reducing predicted probability of extinction over 100 years by about 20 percent to 56 percent and extending estimated time to extinction by about 24 years to 88 years
5. despite positive and encouraging effects and results of the captive breeding program, the intrinsic growth rate of the population is still negative and the current population persistence depends on an influx of captive-reared or external adults, therefore population viability cannot be considered to be self-sustainable
6. single individuals continue to account for a stable 20 percent of total population size, it is not known if captive-reared adults were among observed singles since 2005
7. the distribution of the population has shifted primarily from Napanee to Carden, but also to all other core regions within the past 5 years
8. survival of juveniles and young adults are again the most sensitive model parameters and account for two thirds of the variation in extinction risk and future population abundance, they are therefore the most important but also least controllable variables for population viability
9. in comparison to the PVA conducted in 2009, extinction risk has been reduced, the decline of the population has been slowed, although population sizes have been comparatively low, ranging from 18 to 31 between 2005 and 2013

8 General Feedback and Issues raised by recovery team members

Several comments addressed the observation that mixed breeding pairs exhibit lower productivity than wild breeding pairs. While the data currently support such a conclusion, it should be noted that the very small sample size for mixed breeding pairs (23 breeding pairs over 9 years) and the fact that mixed breeding pairs might involve younger and less experienced captive-reared adults could play a role here. More data are necessary to better understand if experience, age or simply sample size are responsible for this difference in productivity.

It was also noted that the shift in observed population size from Napanee to Carden could be attributed to changes in survey efforts over time and between those core regions. The Napanee population has supposedly seen a recovery in recent years. If this is indeed the case, the data available at this point do not support either of these comments.

The rather low population size raised concerns about a potential Allee effect and a resulting low density depression of the population in Ontario. A new section 2.7 was added to address this issue. It appears unlikely that the population suffers from Allee effects at this time, but an unprecedented spike in singles in 2012 could be the result of low density problems. Fortunately, the proportion of singles vs. breeding pairs was back to normal in 2013.

Some reviewers questioned the time period for data analysis and model parameterization. These decisions were indeed arbitrary and guided by two considerations. First, it was considered that overall conditions for the Eastern Loggerhead Shrike but also for resident shrike populations on the wintering grounds might have changed since 1991. Since these environmental and climatic conditions have not been recorded, it was assumed that the last 10 years might provide a more realistic context for predicting the next 10 and more years. Second, captive-reared birds have been breeding in mixed pairs since 2005, which provides 9 years of data. Since the evaluation of the field propagation program was a major focus of this PVA, the time frame of 10 years seemed appropriate.

Finally, one important observation and recommendation was made with regard to release times of captive bred juveniles. It was suggested that a spring release might be more effective for population productivity, because of the inherent elimination of juvenile overwinter mortality.

9 References

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Uncited References / Further Readings

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10 Appendix

10.1 List of documents attached to this report

- tbl_birdstation_info_Nov 26_pva version_JS_RS-Summaries.xls
  (by Hazel Wheeler, Nov. 26, 2014)
- ON_LOSH_banding_summaries_PVA_Nov 2014.xlsx
  (by Amy Chabot, Nov. 6, 2014)
- ELOSH_wild banding and resights_master_November 6 2014.xls
  (by Amy Chabot, Nov. 6, 2014)

10.2 Ramas@Metapop - Model Summaries

10.2.1 Non-spatial, single population model

Program: RAMAS Metapop version 4.0
Title: Eastern Loggerhead Shrike PVA
Comments: nonspatial, single population base model, uses fecundity calculated for wild birds only... calibrated on population trend between 1991 and 2013 without captive bred birds...
Replications: 1000
Duration: 100 time steps (100.0 years)

Stage structure
There are 6 stages

Stage matrix

default	juvenile	adult_1	adult_2	adult_3	adult_4	adult_5
juvenile	0.0	1.4379	1.4379	1.4379	1.4379	1.4379
adult_1	0.306	0.0	0.0	0.0	0.0	0.0
adult_2	0.0	0.65	0.0	0.0	0.0	0.0
adult_3	0.0	0.0	0.56	0.0	0.0	0.0
adult_4	0.0	0.0	0.0	0.41	0.0	0.0
adult_5	0.0	0.0	0.0	0.0	0.3	0.2

Constraints
Proportion of each stage matrix element that is survival (as opposed to fecundity)

	juvenile	adult_1	adult_2	adult_3	adult_4	adult_5
juvenile	0.0	0.0	0.0	0.0	0.0	0.0
adult_1	1.0	1.0	1.0	1.0	1.0	1.0
adult_2	1.0	1.0	1.0	1.0	1.0	1.0
adult_3	1.0	1.0	1.0	1.0	1.0	1.0
adult_4	1.0	1.0	1.0	1.0	1.0	1.0
adult_5	1.0	1.0	1.0	1.0	1.0	1.0

Stochasticity
Demographic stochasticity is used
Environmental stochasticity distribution: Lognormal
Extinction threshold for metapopulation = 0
Explosion threshold for metapopulation = 0
When abundance is below local threshold: count in total
Within-population correlation: All uncorrelated (F, S, K)
(F = fecundity, S = survival, K = carrying capacity)

Standard deviations matrix

default	juvenile	adult_1	adult_2	adult_3	adult_4	adult_5
juvenile	0.0	0.357462	0.357462	0.357462	0.357462	0.357462
adult_1	0.0306	0.0	0.0	0.0	0.0	0.0
adult_2	0.0	0.065	0.0	0.0	0.0	0.0
adult_3	0.0	0.0	0.056	0.0	0.0	0.0
adult_4	0.0	0.0	0.0	0.041	0.0	0.0
adult_5	0.0	0.0	0.0	0.0	0.03	0.02

Catastrophes
There are no catastrophes.

Initial abundances

	juvenile	adult_1	adult_2	adult_3	adult_4	adult_5
Pop 1	38	**12**	**8**	**4**	**2**	**1**

Populations

General
Population is Pop 1
Initial abundance is 65 (27 adults)
Local threshold is 0.0
The population is included in the summation

Density dependence
Density dependence type is Exponential

Population management
Population management is not used

10.3 Comments by Jean-Pierre Savard

Nevertheless, breeding pairs with captive-reared adults appear to have proportionally more nest failures and produce fewer fledglings than wild breeding pairs.

JP: "would be expected if mixed pairs are younger that wild pairs which is likely the case"

LT: I agree, but this cannot be verified, because age of breeding pair members was not available

This negative effect, however, was overcompensated by the presence of captive-reared adults in the population, therefore the net effect of this "captive-reared subsidisation" was still positive and if continued at current numbers, would reduce the extinction risk over 100 years by about 10 percent.

JP: *"Nice useful result; would be interesting to have a graph or a statement indicating what doubling or tripling the number of released birds would produce as effect"*

LT: we don't know what it would take to multiply the number of captive-reared adults in the population, since that number greatly depends on returns after migration, but yes, more captive-reared adults in productive breeding pairs would most likely reduce the extinction risk further.

The captive breeding program has shown to be effective in boosting the wild population, but it did not help quite yet to make the population self-sustainable.

JP: "This is in part because of the low number of released birds in recent years. This will improve as the number of released birds is increased. This reduction was due in great part to EC gradual withdrawal from the program."

LT: This could be the case. See new Figure 1b. The number of adult captive-reared birds seems to be related to the number of released birds in previous years.

Conservation efforts should consider measures to improve productivity during the breeding season.

JP: "Not sure this should be the main focus. In part the lower productivity of the mixed pairs could be due to the fact that most captive birds are at their first breeding experience whereas wild birds cohort likely includes older more experienced birds."

LT: I did not mean this to be the main focus, but one possible consideration. We need more data to better understand if and why mixed breeding pairs show a lower productivity.

Further reasons for low return rates of wild and captive-reared birds are most likely limiting factors during migration and on the wintering grounds (Pruitt, L. 2000).

JP: "Another point (that should be raised in the text somewhere is the fact that at least half of the released fledglings were fitted with either radios or data loggers which may have slightly affected their survival. "

LT: This was added to the text.

Figure 6: Trend of single individuals a) compared to number of breeding pairs, b) distributed across core regions and c) proportion of singles in core regions over time.

JP: "This figure is a bit misleading and possibly not appropriate because survey efforts differed greatly among years and between areas. I would only trust the data from Carden and Napanee. The figure gives the impression of comparability between areas and years."

LT: I was not aware of different survey and observation efforts or changes therein over time. If that's the case, we would need some data to correct for that. Without additional information, the data as provided indicate what is shown in these graphs and the base assumption was that data are comparable between core areas and years.

Nevertheless, it should be noted that mixed breeding pairs have so far failed proportionally more nests than wild breeding pairs and attention should be paid to that performance indicator in the future

JP: "Possibly state also that it is possible that the small sample size (of mixed pairs) could explain at least part of the difference"
"Also the y axis label is a bit confusing; possibly and instead of / would be better. As it reads now we have the impression that the value of the y axis is the number of nest attempts divided by the number of nest failure."

The numbers reflect a negative trend in fledglings per year between 2004 and 2013 and a shift of population productivity toward Carden. Between 2011 and 2013 about 75% to 80% of all fledglings were counted in the Carden area.

JP: "Caution needed here because of the great differences in survey efforts between years and between regions"

LT: again, this is not reflected in the data

These graphs reveal that fecundity for mixed breeding pairs appears to be lower and more variable across years than fecundity for wild breeding pairs.

JP: "Again a warning about small sample sizes for mixed pairs is needed here. It is unlikely that sample sizes are large enough to compare variation between years."

More emphasis should be paid to these particular facts of population productivity in future observation efforts.

JP: "If this lower performance is true then it could be important to determine whether this is due to something inherent to captive breeding or just a reflexion of the younger age and inexperienced of first breeding birds which are likely more prominent in mixed pairs than in wild ones."

the population distribution across the 5 major core areas has shifted with approximately 60-70% of all observed breeding pairs now located in the Carden region

JP: "In the last few years there was a recovery of the Napanee population"

LT: not reflected in the data

mixed breeding pairs are somewhat less productive than wild breeding pairs, they exhibit proportionally more nest failures and produce fewer fledglings than wild breeding pairs

JP: "This statement is too categorical for the data available. It should be qualified as a possibility."

accumulated data from re-sightings attest that individuals may live up to 6 years in the wild and provide valuable insight into the age structure of the population

JP: "May be pertinent to add that the re-sighting of individual not seen in year +1 but seen in subsequent years suggest that a portion of the birds released avoid detection when present or used areas outside the surveyed area some years."

JP: "The importance of survival in the first year suggests that it may be wise in the near future to experiment with spring release rather than fall release of juveniles. If successful this would avoid first winter mortality so that return rates would be basically 100 percent"

10.4 Comments by Amy Chabot

AC: "Summary (page 4) – is it worthwhile to continue banding and quantifying resighting of captive reared and released birds in Napanee in particular to quantify impact of newly initiated captive releases in this population as we are now able to see in Carden?"

2.0 Status of the population

AC: "While it is discussed later, it sounds from this section as if the decline is steady rather than an erratic trend of up and down for both breeding pairs and singles. To provide a more clear picture, maybe an idea of the range of singles per year and some quantification of trend would be possible? E.g. over the past N years, the population has increased up to X pairs and decreased as low as X pairs?"

LT: I think the fluctuations in population and single individual numbers are all presented in the graphs, which are raw data. Box charts would be redundant.

AC: "I don't think recovery has focused primarily on captive breeding – population survey work and habitat assessment have been on-going during the same time frame and were substantive efforts. Perhaps worthwhile to note other 'core' activities?"

LT: I adjusted the wording and mention these other core activities.

AC: "2.3 Should be able to tell if singles were banded or not and thus if wild or captive? Possibly also determine sex of singles by banding data?"

LT: data were not available at this time.

AC: "Break out singles vs. pairs by core to see if they are more prevalent in e.g. Napanee than Carden where population size/trend differs?"

LT: Figure 5d has been added.

AC: "2.4 Also in one case a male (banded and thus sex known) was found to act as a helper to a nearby pair after loss of his mate. See Etterson for only published empirical comparison if desired."

LT: This seems anecdotal and has very little relevance for this PVA.

AC: "Look at return rates of banded birds by sex and age?"

LT: Figure 11 was added.

AC: 2.5 Is it possible to indicate what fecundity rate is required by pair or overall for a sustainable population?

LT: This would be possible, but since survival or return rates are the most uncertain and variable demographic variables, focusing on fecundity is only marginally helpful.

AC: "Can nest failure data and/or fledgling per pair be partitioned by core area as well? Figure 8 gives overall numbers, but as the number of pairs differs, it is hard to compare among areas."

LT: Figure 8c has been added.

AC: "2.6 Where noted as Figure 10 should be Figure 11?"

LT: This has been corrected.

AC: "Table 3 – ASY is 2 OR MORE years – we can't say for sure how old an ASY bird is, only that it is at least 2 years old. This is not the case for the other age classes – we know for sure SY is in first breeding season (i.e. 1 year old). I assume that 3, 4, 5, and 6 is based on birds first banded as SY or does it include ASY? In which case, it should be <3, <4, etc."

LT: Age groups were amalgamated as described in a new paragraph in section 2.6.

AC "Page 14, first paragraph: Not sure what 'age class one and two' refers to – is this Figure 11, 1 year and 2 year birds? If '2' refers to ASY versus actual known age (2 year old) birds, then the reason that 1 and 2 year are equal proportions could be that a bird aged as ASY could be 2, 3, 4 years old."

LT: Wording has been adjusted. In this PVA age class numbers refer to the age of an individual. 0 or HY are fledglings, 1 is one year old, 2 is two year old and so on.

AC: "Might be worth some clarification of the degree to which shrikes can be aged when first in hand i.e. HY, SY vs ASY, versus being able to quantify age structure thereafter based on band resights of birds first banded as HYor SY?"

LT: This clarification should be provided by the recovery team experts.

AC: "Is it possible to include references to other species for further reading?"

LT: I added "uncited references" for further reading.

AC: "3.2.2.1 Is the assumption that females of all adult age classes produce the same number of fledglings annually? Can we not test with the data – e.g. look at # fledglings per year and nest failure rate for SY females vs. ASY? Ideally we'd look at SY M X SY F couples versus ASY M x SY F, etc. but we may not have enough data."

LT: Yes, in light of the limited data and lack of age of breeding pairs, it was assumed that females of all age groups produce on average the same number of fledglings per year. However, fecundity per female age class per year is drawn from a normal distribution with a standard deviation as outlined in the model section. Therefore, during each model run, each age class produces a different number of fledglings per year.

AC: "If there are differences in number of fledglings produced, then would this not impact population trajectory/size of sustainable population as population age structure changes? Or is this getting too complex for modeling?

LT: We have insufficient data for that. Still, the fecundity average and standard deviation is based on productivity of all pairs over 10 years and incorporates this variability. Still, we are limited by data here and a breakdown of fecundity into age classes (if possible) would result in very small sample sizes.

AC: "3.2.2.2 Should survival rates not mirror that of Table 4, in which survival rate of HY is much less than 50% of adults?"

LT: It should, but then the model should reproduce to the best possible degree all empirical data available - fecundity, age structure, abundance trend and survival. Since empirical data are incomplete and biased, it cannot be expected that the output of a population model can match all of those data. The current model represents the best possible compromise based on my understanding and interpretation of the data provided.

AC: "MVP – How do MVP and geographic distribution of a population relate? i.e. does it matter that the ON population is in different geographic areas?"

LT: I don't understand. MVP as "simulated" by the population model reflects the situation for the Ontario population and would therefore be much different for populations in other geographic areas.

AC: "WRT lower reproductive success rate of captive birds – could this be due to differences in reproductive success based on age? Are most captive birds SY, i.e. first breeding season? If SY birds generally have lower success, then is this the effect being noted, rather than captive vs. wild origin?"

LT: I addressed this issue in the discussion section. I don't speculate about the reasons for the observed lower productivity in mixed breeding pairs, but it is likely that low sample size and / or younger birds with less experience in mixed pairs contribute to this observed difference.

AC: "WRT 'emigrated bird' – the one 'return' of an ON bird based on genetic data from Chabot 2011 was in Louisiana – this bird was considered as a 'resident' based on stable isotope signatures. This could mean she molted her P1 on the wintering ground, which is atypical, or that she was in fact resident."

LT: This seems an interesting, but anecdotal and not significant for the results of this PVA.

AC: "WRT shift to Carden, work in progress to compare landscape characteristics (e.g. percent suitable habitat, patch size) among core areas may provide a better understanding. For example, habitat fragmentation may differ among areas, which has impacts on reproductive success, etc."

LT: JP mentioned changes in survey and observation efforts as one reason for this observed shift.

AC: "Question – is there a relationship between number of captive birds released and number in population in subsequent year? This would assume most captive birds sited area SY, which I'm not sure is the case."

LT: I added Figure 1b.

AC: "Question – can you investigate the relationship between population size/trend and age structure (simply SY versus ASY birds)? Ideally, also by sex – so male ASY versus female ASY, male SY versus female SY. If over-wintering survival varies by age or sex, then this could be important to understand."

LT: This would be interesting, but I cannot investigate this relationship based on the data I have.

10.5 Comments by Jessica Steiner

JS: "With regards to the nest success of "mixed pairs", sample size is very low, especially when you look at annual figures (in many years the rate is based on only 1-2 pairs). Lutz was provided with data from 1991-2013, and summaries on the number of pairs and counts of nest outcomes by core and by year. I agree that proportion of pairs that ultimately failed/were successful would be a valuable stat – that will require some further data summarizing (which I'm not volunteering to do at this point! But the data is all there!)"

LT: no comment.

JS: "Table 1 – Grey-Bruce and Dyer's Bay represent the same site"

LT: This has been corrected.

JS: "Origin of single birds – we should be able to tell from the banding data and our records whether singles are wild/captive/unknown. So the status of single birds can be confirmed in a good proportion of instances I believe."

LT: work in progress

10.6 Comments by John MacCracken

JMC: "Why are a bunch of the analyses based on only the 2004-2013 time period, rather than the entire time series? On the bottom of page 10, Lutz seems to imply that this yields a 10-year trend. Actually, for a 10-year trend, you need to have 11 years. Even so, a 10-year trend isn't nearly as good as one that's based on more years."

LT: Primary focus of the analysis was to gain insight into the effect of released captive birds and returning adults to population abundance and fecundity. Therefore the time frame was deliberately chosen from 2004 to 2013 with the assumption that environmental conditions and observation efforts and data collection protocols were relatively stable and consistent during that period. Reasons for the larger fluctuations in population abundance between 1991 and 2003 are less well understood and could be the result of various factors, which may be no longer relevant or present. Using a 10 year time frame of historical recent data to parameterize the population model seems a reasonable compromise considering uncertainties and potential inconsistencies in earlier data.

JMC: "On page 11, he suggests that the mixed breeding pairs showed reduced nesting success compared to the wild pairs (67% vs 54% success). However, this is based on only 26 nests of mixed birds, which isn't a very good sample size. It also doesn't seem to incorporate the fact that some of the pairs that had failed nests probably went on to attempt a 2^nd^ or 3^rd^ nesting. The important demographic statistic here is what proportion of ***pairs*** *had a successful nest at some point during the breeding season, not what proportion of nests were successful. The nest success rates are also not all that horribly bad in my opinion. I don't find the evidence for his conclusion very convincing."*

LT: This is not a conclusion, but a mere observation and should be reported. It was argued also that lower fecundity in mixed breeding pairs is caused by a higher proportion of less experienced younger adults in those breeding pairs, which might be true, but the data provided in support of this PVA do not allow analysing the effect of age in breeding pairs on reproductive success. Age of breeding pairs or pair members was not reported.

JMC: "On page 12 (Figure 9b), he concludes that there has been a negative "trend" in fecundity. However, this "trend" is based on a short time series (2004-2014) and is clearly being driven by the low success event seen in the end point year (2013). I don't find his "trend" conclusion at all convincing."

LT: Yes, a trend is always dependent on the starting point and the end point of a time series. But in the end we have to work with the data at hand and 2013 was a low year. The starting point was chosen for 3 reasons. Firstly, to coincide with the first wild-captive breeding pairs in the population and second with the assumption or belief that overall environmental and climatic conditions over the last 10 years are more representative and relevant for a current viability assessment than those from earlier years. Third, that observation efforts and data collection protocols were more consistent during the last 10 years in light of the captive breeding program and intensive conservation efforts.

JMC: "In section 3.2.4, he states that there doesn't appear to be any evidence for an Allee effect. Doesn't the mere fact that there are so many single birds in the population point to evidence for an Allee effect? If so, then it seems that density dependence should be incorporated into the model, though I have no idea on how that sort of thing is actually done."

LT: I added a new section 2.7 to address this concern.

JMC: "In Figure 13 and elsewhere, he refers to HY birds as part of the age structure of the breeding population. HY birds shouldn't be used should they, as they're not mature individuals? Perhaps he means to refer to SY birds (i.e., one-year old birds)? If so, the age values in the tables and charts should be adjusted accordingly."

LT: Very good point and thank you for this observation. I included HY into the population counts of the model, which was not correct. I repeated the entire viability analysis without Juveniles / HY in population count.

JMC: "This is a moot point, but we'd almost certainly have reached somewhat different conclusions re: the efficacy of the release program if we had also been releasing adult birds. It might be worth emphasizing somewhere that the conclusions are based on the release of fledglings, and that they could be different had adults been incorporated into the mix."

LT: Of course, this analysis is based on the release of fledglings and could be different, if adults were released, see also JP's comment about potential benefits of spring releases of juveniles to avoid first winter mortality.

10.7 Comments by Elaine Williams

EW: "I saw Lutz has 2 birds released in 2000 in Carden. These were adult females released into a male's territory, not juveniles as the table indicates"

LT: This was corrected in Table 1.