Population Analysis & Breeding and Transfer Plan

Secretary Bird (*Sagittarius serpentarius*) AZA Species Survival Plan® Red Program

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PMC Population Management Center

LINCOLN PARK ZOO. ASSOCIATION OF ZOOS & AQUARIUMS

SAN DIEGO ZOO GLOBAL

This Animal Program is currently a Red SSP Program and recommendations proposed are non-binding – Participation is voluntary. Dispositions to non-AZA institutions should comply with each institution's acquisition/disposition policy.

Executive Summary

Secretary Bird (*Sagittarius serpentarius)*

The current population of secretary birds is 28 birds (13 males, 15 females) distributed among 12 AZA institutions. Raptor Taxon Advisory Group has set the target size for this population to be 35 birds (2015 Regional Collection Plan). At present, the secretary bird program qualifies as a Red SSP Program (<50 animals).

Genetic and demographic analyses of the North American Regional Studbook for Secretary Birds (current to 29 June 2017) were performed using PopLink 2.4 and PMx 1.4.20170717 resulting in the current Breeding & Transfer Plan. Recommendations contained in this plan supersede those made by previous plans.

Demography

Current Population Size (males.females.unknowns)	28 (13.15.0)
# Animals Excluded From Management	2 (1.1.0)
Population Size Following Exclusions	26 (12.14.0)
Target Population Size	35
Mean Generation Time (T; in years)	12.8
Projected Population Growth Rate (λ) – from life tables (Appendix C)	na*
Historic Population Growth Rate (average North American λ 1979-2016)	1.09
Recent Population Growth Rate (average North American λ 2012-2016)	0.99

*not accurate due to insufficient demographic data

Genetics

	2017	Current Potential
Founders	7	7 additional
Founder Genome Equivalents (FGE)	3.32	13.45
Current Gene Diversity (GD %)	84.98	96.28
Population Mean Kinship (MK)	0.1506	-----
Mean Inbreeding (F)	0.0000	-----
% Pedigree Known Before / After Assumptions and Exclusions	58 / 100	-----
% Pedigree Certain Before / After Assumptions and Exclusions	58 / 100	-----
Effective Population Size / Census Size Ratio (Ne / N)	0.18*	-----
Projections		
Years To 90% Gene Diversity	-----	-----
Years To 10% Loss of GD	18**	-----
Gene Diversity at 100 Years From Present (%)	44**	-----

*includes founders

**projections based on the current analytical population (λ = 1.09, T = 12.8 years, target size = 35 animals)

Demographic data are currently insufficient for a number of traditional analyses and projections, including predicting the number of hatches needed per year to meet demographic goals. A total of seven chicks have been hatched over the last five years (2013-2017), with three males and three females contributing to reproduction. Although low mortality rates have been observed across all age classes, deaths have outnumbered hatches in each of the three previous years (2014-2016) and resulted in an overall decline in population size. To bolster demography, nearly every female in the population has been given a breeding recommendation and genetic management is currently focused primarily on limiting inbreeding. Gene diversity in the analytical population is 84.98%, which is notably below the 90% threshold commonly thought to represent genetic vigor. A substantial reservoir of gene diversity exists in the seven potential founders still living (current potential gene diversity = ~96%). Breeding any of these potential founders would improve both current and future gene diversities, as well as reduce inbreeding in the next generation of captive-hatched birds. The primary goals of this Breeding & Transfer Plan are to 1) facilitate cooperative management by coordinating transfers and 2) ensure that birds in breeding situations are paired with genetically appropriate mates.

Summary Actions: This is a 3-year plan (2017-2019). The Program recommends nine females to breed and three transfers to establish one new breeding pair and meet institutional needs.

Table of Contents

Report and Analyses prepared by:
Jamie Ivy, Ph.D., Population Biologist – San Diego Zoo Global, jivy@sandiegozoo.org

Planning occurred at the San Diego Zoo Safari Park on 25 August 2017.
Attending: Michelle Handrus, Jamie Ivy

Cover Photo Credit: Matt McHale, Miami-Dade Zoological Park and Gardens

This plan was reviewed and distributed with the assistance of the Population Management Center.
pmc@lpzoo.org

Description of Population Status

Introduction: The secretary bird is a large, primarily terrestrial bird of prey endemic to Africa. The species belongs to the order Accipitriformes, which includes other diurnal raptors, but the secretary bird is unique in that it is the only member of the family Sagittariidea. The formally managed, captive population of secretary birds in North America is 28 birds (13 males, 15 females) distributed among 12 AZA institutions. The Raptor Taxon Advisory Group has set the target size for this population to be 35 birds (2015 Regional Collection Plan). At present, the secretary bird program qualifies as a Red SSP Program (<50 animals).

Genetic and demographic analyses of the North American Regional Studbook for Secretary Birds (current to 29 June 2017) were performed using PopLink 2.4 and PMx 1.4.20170717, resulting in the current Breeding & Transfer Plan for this species. At the time of analyses, the secretary bird studbook contained records for only 49 birds. Thus, demographic data were insufficient for a number of traditional analyses. Consequently, the primary goals of this Breeding and Transfer Plan are to 1) facilitate cooperative management by coordinating transfers and 2) ensure that birds in breeding situations are paired with genetically appropriate mates. Recommendations contained in this plan supersede those made by earlier plans.

Conservation Status: IUCN Red List – Vulnerable; USFWS – not listed; CITES – Appendix II

Analytical Population: The population size at the time of analyses was 28 birds (13 males, 15 females); the population's pedigree was 58% known/certain prior to pedigree assumptions and exclusions. Three captive-hatched birds of unknown ancestry were assumed unrelated to the remainder of the analytical population (Appendix A) and two education birds were excluded (Appendix D). Following pedigree assumptions and exclusions, the population's pedigree was 100% known/certain.

Demography: Studbook records indicate that secretary birds have been held in North American collections since 1978, but Species360 records suggest that the species has been intermittently held in low numbers since the early 1900s. This suggests that not all historical data have been entered into the studbook. Given the data that are available, studbook records indicate that the population has generally exhibited slow, but consistent, growth due to a combination of continued importations and successful captive breeding (Figures 1 and 2; average λ 1979-2016 = 1.09). A total of nine wild-caught birds are still living (Figure 2), with the most recent import occurring in 2009 (SB# 22). Current studbook records suggest that the first captive hatches in North America occurred in 2002 at the San Diego Zoo Safari Park, with four males and five females successfully producing offspring since that time. Life tables contain insufficient data to provide a projected growth rate for the population (Appendix C), but the population has declined over each of the previous three years due to the number of deaths exceeding the number of hatches (Figure 1; average λ 2014-2016 = 0.93). Thus, there is some concern about both the immediate and long-term demographic viability of this population.

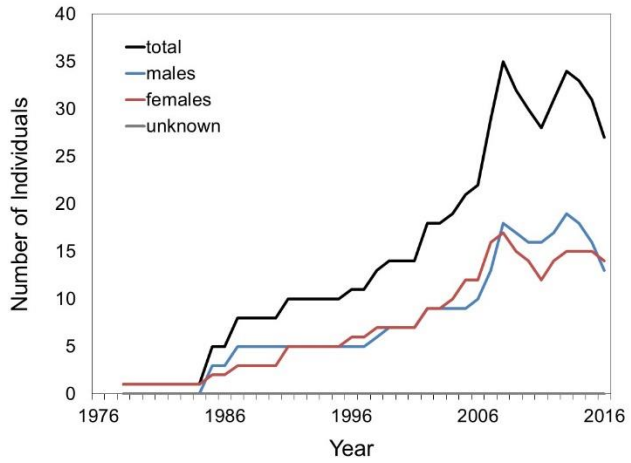

Figure 1. Census of secretary birds in North American facilities from 1976 to 2016, by sex.

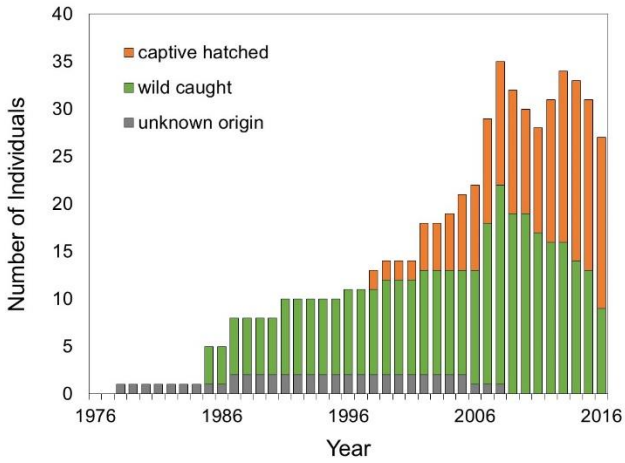

Figure 2. Census of secretary birds in North American facilities from 1976 to 2016, by hatch type.

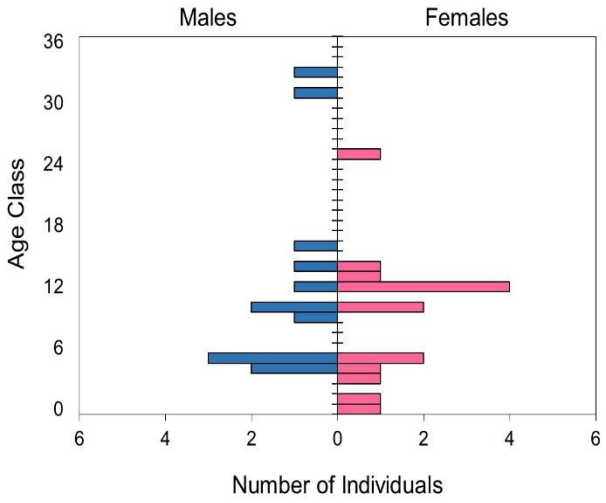

Figure 3. Age distribution of the formally managed population of secretary birds. The population currently includes 13 males and 15 females (28 birds total).

Significant numbers of secretary birds have not been held in North America (N = 49), thus demographic data do not accurately reflect species' biology and should not be used for demographic analyses or projections (Appendix C). Species360 records suggest that secretary birds regularly lives into their 20s, with some birds living into their 30s. To date, the oldest male recorded in the studbook is still living at ~33 years of age (SB# 36; approximate age of wild-caught bird) and the oldest female lived to ~34 years of age (SB# 1; approximate age of bird of unknown origin). Demographic data are insufficient for accurate estimates of hatchling mortality, but of the 22 captive hatches that have occurred in North America only a single chick died in the first year of life (note that one 2017 chick is not yet a year old). Both sexes are thought to be sexually mature at ~3 years of age, but the youngest male on record to breed was 4 years old at the time of conception (SB# 41) and the youngest female to produce offspring was 7 years of age (SB# 13). Females typically hatch one or two chicks per clutch and can double-clutch during a breeding season.

The age structure of the secretary bird population is scarcely populated, with gaps in many of the age classes (Figure 3). Although a columnar structure is common for long-lived species, the very small number of birds overall raises concerns about this population's demographic viability. Furthermore, although captive reproduction has occurred, the very small number of chicks hatched overall is evident by the small number of birds in the youngest age classes. The top of the age structure only approximately represents the number of birds in older age classes, as the ages of many wild-caught birds are only estimated. The sex ratio of the population is currently skewed towards females, with 1.15 females present for every male in the population. Due to this paucity of males, not every female in the population can be paired for breeding at this time.

Current life tables contain insufficient data to accurately project the number of hatches needed per year to meet demographic goals. A total of seven chicks have been hatched over the last five years (2013-2017), with three males and three females contributing to reproduction. Although low mortality rates have been observed across all age classes, deaths have outnumbered hatches in each of the three previous years (2014-2016) and resulted in an overall decline in population size. This demonstrates that a more robust reproductive rate is needed to support demographic viability.

Genetics: The studbook pedigree indicates that the analytical secretary bird population is descended from seven founders with an additional seven potential founders still remaining (Figure 4). The gene diversity of the population is 84.98%, which is equivalent to that found in approximately three unrelated animals (FGE = 3.32). Typical AZA program goals include thresholds for tolerance of gene diversity loss over time; 90% gene diversity retention for 100 years is not an uncommon management goal. Decreases in gene diversity below 90% of that in the founding population have been associated with increasingly compromised reproduction by, among other factors, lower hatch weights, smaller clutch sizes, and greater neonatal mortality. Given the uncertainty surrounding many of the parameters required to predict gene diversity retention, it is difficult to estimate how much gene diversity might be retained by the secretary bird population in the future. Given the

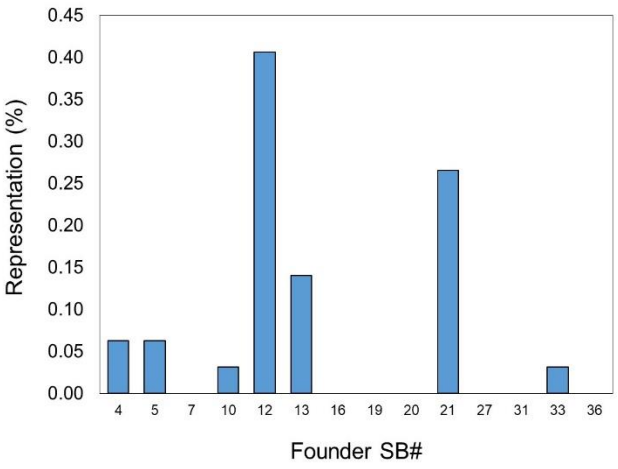

Figure 4. Distribution of founder representations in the analytical secretary bird population.

baseline parameters provided in the Genetics Summary table, gene diversity is projected to decline to ~44% over the next 100 years if the current analytical population grows at its historic growth rate of 9% to its current TAG-recommended target of 35 birds.

For demographically robust captive populations, the best management strategy for maintaining gene diversity is prioritized breeding that aims to maintain equal founder representations by breeding animals with low and well-matched mean kinships. Founder representations in the secretary bird population are currently skewed (Figure 4); more equal representations would retain more gene diversity. However, given the overall low reproductive success across the population and the recent decline in population size, more emphasis is being place on demographic management than on genetic management at this time. Thus, although mean kinships and avoidance of inbreeding were considered when developing recommendations, nearly every female in the population has been given a breeding recommendation to bolster demography. A substantial reservoir of gene diversity exists in the seven potential founders still living (current potential gene diversity = ~96%). Breeding any of these potential founders would improve both current and future gene diversities.

It is important to note that the current mean kinship in the population is 0.1506. Half-siblings have a kinship of 0.125 and full-siblings have a kinship of 0.250, which means that the average relationship in the population is somewhere between that of half and full-siblings. Furthermore, although the mean inbreeding in the population is currently 0.0000, inbreeding can be expected to notably increase in the future as related birds enter the pool of potential breeders. Thus, it is increasingly important that the remaining potential founders begin producing offspring, if at all possible, to bolster the population's long-term genetic viability.

Genetics Summary

	2013	2017	Current Potential
Number of Founders	5	7	7 additional
Founder Genome Equivalents (FGE)	3.07	3.32	13.45
Gene Diversity Retained (%)	83.73	84.98	96.28
Population Mean Kinship	0.1627	0.1506	-----
Mean Inbreeding (F)	0.0000	0.0000	-----
% Known Pedigree Before/After Assumptions and Exclusions	66 / 100	58 / 100	-----
% Certain Pedigree Before/After Assumptions and Exclusions	66 / 100	58 / 100	-----
N_e/N	0.06	0.18*	-----
Projections			
Years To 90% Gene Diversity	-----	-----	-----
Years To 10% Loss of GD	4[a]	18[b]	-----
Gene Diversity at 100 Years From Present (%)	8[a]	44[b]	-----

*includes founders
[a]projections based on the 2013 analytical population (λ = 1.03, T = 11.4 years, target size = 35 animals)
[b]projections based on the current analytical population (λ = 1.09, T = 12.8 years, target size = 35 animals)

Management Strategy: The current, formally managed population of secretary birds is 28 animals (13 males, 15 females) distributed among 12 AZA institutions. Demographic data are currently insufficient for a number of traditional analyses and projections, including predicting the number of hatches needed per year to meet demographic goals. A total of seven chicks have been hatched over the last five years (2013-2017), with three males and three females contributing to reproduction. Although low mortality rates have been observed across all age classes, deaths have outnumbered hatches in each of the three previous years (2014-2016) and resulted in an overall decline in population size. To bolster demography, nearly every female in the population has been given a breeding recommendation and genetic management is currently focused primarily on limiting inbreeding. Gene diversity in the analytical population is 84.98%, which is notably below the 90% threshold commonly thought to represent genetic vigor. A substantial reservoir of gene diversity exists in the seven potential founders still living (current potential gene diversity = ~96%). Breeding any of these potential founders would improve both current and future gene diversities, as well as reduce inbreeding in the next generation of captive-hatched birds.

The primary goals of this Breeding & Transfer Plan are to 1) facilitate cooperative management by coordinating transfers and 2) ensure that birds in breeding situations are paired with genetically appropriate mates.

This is a 3-year plan (2017-2019). Although another full set of recommendations will not be produced until 2020, interim recommendations will continue to be made as needed. Please promptly report any hatches or deaths to the Program Coordinator, so that interim recommendations can be based on accurate population data. Recommendations contained in this plan supersede all previous recommendations.

At this time, the program:

1. **Recommends nine females to breed.**

2. **Recommends three transfers to establish one new breeding pair and meet institutional needs.** One new holding institution will be added through these recommendations.

Summary of Breeding and Transfer Recommendations

ID	Location	Sex	Age	Disposition	Location	Breeding	With	Notes
7	FORTWORTH	M	31	HOLD	FORTWORTH	BREED WITH	47	
10	METROZOO	F	25	HOLD	METROZOO	BREED WITH	41	
16	TORONTO	M	16	HOLD	TORONTO	DO NOT BREED		
17	SD-WAP	M	14	HOLD	SD-WAP	BREED WITH	20	
18	SD-WAP	F	13	HOLD	SD-WAP	BREED WITH	33	
19	ASHEBORO	M	12	SEE NOTES	SEE NOTES	SEE NOTES		missing
20	SD-WAP	F	12	HOLD	SD-WAP	BREED WITH	17	
21	SD-WAP	F	12	HOLD	SD-WAP	BREED WITH	25	
23	SD-WAP	F	12	HOLD	SD-WAP	DO NOT BREED		education
24	SAN ANTON	F	12	HOLD	SAN ANTON	BREED WITH	46	
25	SD-WAP	M	10	HOLD	SD-WAP	BREED WITH	21	
27	SAFARI W	M	10	HOLD	SAFARI W	BREED WITH	31	
28	SANDIEGOZ	F	10	HOLD	SANDIEGOZ	DO NOT BREED		
31	SAFARI W	F	10	HOLD	SAFARI W	BREED WITH	27	
33	SD-WAP	M	9	HOLD	SD-WAP	BREED WITH	18	
36	BIRMINGHM	M	33	HOLD	BIRMINGHM	BREED WITH	37	
37	BIRMINGHM	F	14	HOLD	BIRMINGHM	BREED WITH	36	
38	SD-WAP	M	5	HOLD	SD-WAP	DO NOT BREED		education
39	DALLAS	M	5	HOLD	DALLAS	SEE NOTES		
40	DENVER	F	5	HOLD	DENVER	DO NOT BREED		
41	METROZOO	M	5	HOLD	METROZOO	BREED WITH	10	
42	DALLAS	F	5	HOLD	DALLAS	SEE NOTES		
44	DENVER	M	4	HOLD	DENVER	DO NOT BREED		
45	ASHEBORO	F	4	SEE NOTES	SEE NOTES	SEE NOTES		missing
46	ABILENE	M	4	SEND TO	SAN ANTON	BREED WITH	24	
47	FORTWORTH	F	3	HOLD	FORTWORTH	BREED WITH	7	
48	SD-WAP	F	1	SEND TO	ABILENE	DO NOT BREED		
50	METROZOO	F	0	SEND TO	LITTLEROC	DO NOT BREED		

Recommendations By Institution

ABILENE

Abilene Zoological Gardens
Abilene, TX

Institutional Notes: F48 will be paired for breeding when a mate is available.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
46	B14086	M	4	SEND TO	SAN ANTON	BREED WITH	24	
48	816054	F	1	RECEIVE FROM	SD-WAP	DO NOT BREED		

ASHEBORO

North Carolina Zoo
Asheboro, NC

Institutional Notes: Please continue to update the SSP Coordinator on the status of this pair.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
19	23925	M	12	SEE NOTES	SEE NOTES	SEE NOTES		
45	23998	F	4	SEE NOTES	SEE NOTES	SEE NOTES		

BIRMINGHM

Birmingham Zoo
Birmingham, AL

Institutional Notes: This pair produced infertile eggs in 2012, but no eggs have been produced since. At this time, the best option is to leave this pair together even though they may ultimately be unsuccessful.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
36	207026	M	33	HOLD	BIRMINGHM	BREED WITH	37	
37	207027	F	14	HOLD	BIRMINGHM	BREED WITH	36	

DALLAS

Dallas Zoo
Dallas, TX

Institutional Notes: This full-sibling pair can be bred to bolster the demography of the population and should not be discouraged from breeding.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
39	13M127	M	5	HOLD	DALLAS	SEE NOTES		
42	13M128	F	5	HOLD	DALLAS	SEE NOTES		

DENVER

Denver Zoological Gardens
Denver, CO

Institutional Notes: This full-sibling pair is for exhibit, per institutional request.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
40	A12284	F	5	HOLD	DENVER	DO NOT BREED		
44	A13196	M	4	HOLD	DENVER	DO NOT BREED		

FORTWORTH

Fort Worth Zoological Park
Ft Worth, TX

Institutional notes: Please continue to update the SSP Coordinator on the compatibility of this pair and a description of any mating behaviors and/or egg laying that may be observed.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
7	207201	M	31	HOLD	FORTWORTH	BREED WITH	47	
47	208832	F	3	HOLD	FORTWORTH	BREED WITH	7	

LITTLEROC

Little Rock Zoo
Little Rock, AR

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
50	17B017	F	0	RECEIVE FROM	METROZOO	DO NOT BREED		

METROZOO

Miami Metrozoo
Miami, FL

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
10	B40200	F	25	HOLD	METROZOO	BREED WITH	41	
41	13B035	M	5	HOLD	METROZOO	BREED WITH	10	
50	17B017	F	0	SEND TO	LITTLEROC	DO NOT BREED		

SAFARI W

Safari West
Santa Rosa, CA

Institutional notes: Please provide the SSP Coordinator information on the compatibility of your birds and a description of any mating behaviors and/or egg laying that may have ever been observed.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
27	208042	M	10	HOLD	SAFARI W	BREED WITH	31	
31	210013	F	10	HOLD	SAFARI W	BREED WITH	27	

SAN ANTON

San Antonio Zoological Gardens & Aquarium
San Antonio, TX

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
24	J14003	F	12	HOLD	SAN ANTON	BREED WITH	46	
46	B14086	M	4	RECEIVE FROM	ABILENE	BREED WITH	24	

SANDIEGOZ

San Diego Zoo
San Diego, CA

Institutional Notes: The SSP has noted that you would like a hand-reared male. Future offspring hatched at the San Diego Zoo Safari Park will be considered for hand-rearing.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
28	311128	F	10	HOLD	SANDIEGOZ	DO NOT BREED		

SD-WAP

San Diego Zoo Safari Park
Escondido, CA

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
17	802272	M	14	HOLD	SD-WAP	BREED WITH	20	
18	804014	F	13	HOLD	SD-WAP	BREED WITH	33	
20	812268	F	12	HOLD	SD-WAP	BREED WITH	17	
21	811089	F	12	HOLD	SD-WAP	BREED WITH	25	
23	805051	F	12	HOLD	SD-WAP	DO NOT BREED		education
25	808261	M	10	HOLD	SD-WAP	BREED WITH	21	
33	810284	M	9	HOLD	SD-WAP	BREED WITH	18	
38	812102	M	5	HOLD	SD-WAP	DO NOT BREED		education
48	816054	F	1	SEND TO	ABILENE	DO NOT BREED		

TORONTO

Toronto Zoo
Scarborough, Ontario

Institutional Notes: M16 was reported as an education animal during plan development and will be formally excluded from the breeding population and genetic analyses in future plans.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
16	41006	M	16	HOLD	TORONTO	DO NOT BREED		

Appendix A
Analytical Assumptions

SB#	Sire	New Sire	Dam	New Dam	Notes
10	UNK	WILD	UNK	WILD	hatched at HOUT BAY; believed unrelated to rest of founding population
12	UNK	WILD	UNK	WILD	hatched at WALSR-KG and imported with SB# 13 as a breeding pairs; believed unrelated to rest of founding population
13	UNK	WILD	UNK	WILD	hatched at WALSR-KG and imported with SB# 12 as a breeding pairs; believed unrelated to rest of founding population

Appendix B
Summary of Data Exports

Report compiled under PopLink V. 2.4 and PMx 1.4.20170717
Project: BirdSecretary_August2017
Created: 2017-08-25

Studbook information:
Data compiled by: Michelle Handrus
Data current thru: 2017-06-29
Scope of data: North America

Primary data file:
XXBirdSecretary_August2017.ped
Filter conditions:
Dates: 1978-01-01 to 2017-08-25
Locations: N.AMERICA
Other Filters: Status = Living

Moves data files:
XXBirdSecretary_August2017genetics.csv
XXBirdSecretary_August2017demog.csv
Filter conditions:
Dates: 1978-01-01 to 2017-08-25
Locations: N.AMERICA
Other Filters: Status = Living

There are 22 hatches in the demographic window. Of these:
20 hatches are attributed to known parents with a known age (91%).
2 hatches are attributed to known parents with an unknown age.
0 hatches are attributed to unknown parents.

Non-AZA Institutions: none

Appendix C
Life Tables

MALES											
Age	**Px**	**Mid Px**	**Qx**	**Risk Qx**	**Lx**	**Mid Lx**	**Mx**	**Risk Mx**	**Ex**	**Vx**	**Cx**
0	1.00	1.00	0.00	10.9	1.00	1.00	0.00	10.9	---	1.00	0.05
1	1.00	0.97	0.00	16.0	1.00	1.00	0.00	15.9	---	1.00	0.05
2	0.93	0.95	0.07	18.6	1.00	0.97	0.00	18.6	---	1.04	0.05
3	0.96	0.95	0.04	18.6	0.93	0.91	0.00	18.6	---	1.11	0.04
4	0.94	0.94	0.06	17.9	0.89	0.87	0.03	17.9	---	1.17	0.04
5	0.94	0.97	0.06	14.5	0.84	0.82	0.00	14.5	---	1.21	0.04
6	1.00	0.98	0.00	13.4	0.79	0.79	0.00	13.4	---	1.26	0.04
7	0.95	0.96	0.05	13.0	0.79	0.77	0.00	13.0	---	1.29	0.04
8	0.97	0.94	0.03	12.2	0.75	0.74	0.14	12.2	---	1.35	0.04
9	0.92	0.96	0.08	11.1	0.73	0.70	0.05	11.1	---	1.29	0.03
10	1.00	1.00	0.00	9.7	0.67	0.67	0.12	9.7	---	1.31	0.03
11	1.00	1.00	0.00	8.8	0.67	0.67	0.00	8.8	---	1.19	0.03
12	1.00	1.00	0.00	7.7	0.67	0.67	0.08	7.7	---	1.19	0.03
13	1.00	1.00	0.00	7.0	0.67	0.67	0.08	7.0	---	1.12	0.03
14	1.00	1.00	0.00	7.0	0.67	0.67	0.08	7.0	---	1.05	0.03
15	1.00	1.00	0.00	7.0	0.67	0.67	0.00	7.0	---	0.97	0.03
16	1.00	1.00	0.00	6.2	0.67	0.67	0.00	6.2	---	0.97	0.03
17	1.00	0.90	0.00	5.9	0.67	0.67	0.22	5.9	---	0.98	0.03
18	0.80	0.89	0.20	4.9	0.67	0.60	0.73	4.9	---	0.85	0.03
19	1.00	0.99	0.00	4.1	0.53	0.53	0.14	4.1	---	0.14	0.02
20	0.97	0.96	0.03	4.0	0.53	0.53	0.00	4.0	---	0.00	0.02
21	0.94	0.94	0.06	4.0	0.52	0.51	0.00	4.0	---	0.00	0.02
22	0.94	0.94	0.06	4.0	0.49	0.48	0.00	4.0	---	0.00	0.02
23	0.94	0.94	0.06	4.0	0.46	0.45	0.00	4.0	---	0.00	0.02
24	0.93	0.96	0.07	4.0	0.43	0.42	0.00	4.0	---	0.00	0.02
25	0.99	1.00	0.01	3.1	0.40	0.40	0.00	3.1	---	0.00	0.02
26	1.00	1.00	0.00	3.0	0.40	0.40	0.00	3.0	---	0.00	0.02
27	1.00	1.00	0.00	3.0	0.40	0.40	0.00	3.0	---	0.00	0.02
28	1.00	1.00	0.00	3.0	0.40	0.40	0.00	3.0	---	0.00	0.02
29	1.00	1.00	0.00	3.0	0.40	0.40	0.00	3.0	---	0.00	0.02
30	1.00	1.00	0.00	3.0	0.40	0.40	0.00	3.0	---	0.00	0.02
31	1.00	0.78	0.00	3.0	0.40	0.40	0.00	3.0	---	0.00	0.02
32	0.57	0.68	0.43	2.2	0.40	0.31	0.00	2.1	---	0.00	0.01
33	0.88	0.94	0.12	1.1	0.23	0.21	0.00	1.1	---	0.00	0.01
34	1.00	1.00	0.00	0.0	0.20	0.20	0.00	0.0	---	0.00	0.01
35	---	---	---	---	---	---	---	---	---	---	---

Px = survival; Qx = mortality; lx = cumulative survivorship; Mx = fecundity
Ex = life expectancy; Vx = reproductive value; Cx = stable age distribution
At Risk (Qx and Mx) = number of animals corresponding values are estimated from
r = 0.004; lambda = 1.004; T = 14.8

Ex not calculated because oldest male in demographic selection (SB# 36) is still living.

FEMALES											
Age	**Px**	**Mid Px**	**Qx**	**Risk Qx**	**Lx**	**Mid Lx**	**Mx**	**Risk Mx**	**Ex**	**Vx**	**Cx**
0	1.00	1.00	0.00	11.6	1.00	1.00	0.00	11.6	24.86	1.00	0.05
1	1.00	1.00	0.00	11.5	1.00	1.00	0.00	11.5	23.86	1.01	0.05
2	1.00	1.00	0.00	13.4	1.00	1.00	0.00	13.4	22.86	1.02	0.05
3	1.00	1.00	0.00	13.7	1.00	1.00	0.00	13.7	21.86	1.03	0.05
4	1.00	1.00	0.00	12.5	1.00	1.00	0.00	12.5	20.86	1.04	0.04
5	1.00	1.00	0.00	10.1	1.00	1.00	0.00	10.1	19.86	1.06	0.04
6	1.00	1.00	0.00	10.6	1.00	1.00	0.00	10.6	18.86	1.07	0.04
7	1.00	0.95	0.00	11.0	1.00	1.00	0.35	11.0	17.86	1.08	0.04
8	0.91	0.95	0.09	10.4	1.00	0.95	0.22	10.4	17.67	0.77	0.04
9	1.00	1.00	0.00	10.0	0.91	0.91	0.17	10.0	17.50	0.59	0.04
10	1.00	1.00	0.00	9.3	0.91	0.91	0.00	9.3	16.50	0.43	0.04
11	1.00	1.00	0.00	9.1	0.91	0.91	0.06	9.1	15.50	0.43	0.04
12	1.00	1.00	0.00	8.5	0.91	0.91	0.15	8.5	14.50	0.38	0.04
13	1.00	0.80	0.00	5.8	0.91	0.91	0.09	5.8	13.50	0.23	0.04
14	0.60	0.75	0.40	4.7	0.91	0.73	0.00	4.7	15.63	0.18	0.03
15	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	19.50	0.24	0.02
16	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	18.50	0.24	0.02
17	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	17.50	0.25	0.02
18	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	16.50	0.25	0.02
19	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	15.50	0.25	0.02
20	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	14.50	0.25	0.02
21	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	13.50	0.26	0.02
22	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	12.50	0.26	0.02
23	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	11.50	0.26	0.02
24	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	10.50	0.27	0.02
25	1.00	1.00	0.00	2.0	0.55	0.55	0.27	2.0	9.50	0.27	0.02
26	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	8.50	0.00	0.02
27	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	7.50	0.00	0.02
28	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	6.50	0.00	0.02
29	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	5.50	0.00	0.02
30	1.00	1.00	0.00	2.0	0.55	0.55	0.00	2.0	4.50	0.00	0.02
31	1.00	1.00	0.00	1.2	0.55	0.55	0.00	1.2	3.50	0.00	0.02
32	1.00	1.00	0.00	1.0	0.55	0.55	0.00	1.0	2.50	0.00	0.02
33	1.00	0.50	0.00	1.0	0.55	0.55	0.00	1.0	1.50	0.00	0.02
34	0.00	0.00	1.00	0.0	0.55	0.27	0.00	0.0	1.00	0.00	0.01

Px = survival; Qx = mortality; lx = cumulative survivorship; Mx = fecundity
Ex = life expectancy; Vx = reproductive value; Cx = stable age distribution
At Risk (Qx and Mx) = number of animals corresponding values are estimated from
r = 0.011; lambda = 1.011; T = 10.7

Appendix D

Individuals Excluded from Genetic Analyses

Studbook ID	Location	Sex	Age	Reason for Exclusion
23	SD-WAP	F	12	education
38	SD-WAP	M	5	education

Appendix E

Ordered Mean Kinships

Note: This list is current to August 2017 and based on an analytical studbook. Values are subject to change with any birth, death, import, export, inclusion, or exclusion. **Average Population MK = 0.1506**

MALES					FEMALES				
SB#	**MK**	**% Known**	**Age**	**Location**	**SB#**	**MK**	**% Known**	**Age**	**Location**
36	0.0000	100	33	BIRMINGHM	20	0.0000	100	12	SD-WAP
7	0.0000	100	31	FORTWORTH	31	0.0000	100	10	SAFARI W
16	0.0000	100	16	TORONTO	10	0.0156	100	25	METROZOO
19	0.0000	100	12	ASHEBORO	28	0.0469	100	10	SANDIEGOZ
27	0.0000	100	10	SAFARI W	48	0.1035	100	1	SD-WAP
33	0.0156	100	9	SD-WAP	50	0.1191	100	0	METROZOO
25	0.0469	100	10	SD-WAP	21	0.1328	100	12	SD-WAP
17	0.1523	100	14	SD-WAP	37	0.1523	100	14	BIRMINGHM
39	0.1836	100	5	DALLAS	24	0.1523	100	12	SAN ANTON
44	0.1836	100	4	DENVER	18	0.1602	100	13	SD-WAP
46	0.1836	100	4	ABILENE	40	0.1836	100	5	DENVER
41	0.1914	100	5	METROZOO	42	0.1836	100	5	DALLAS
					45	0.1836	100	4	ASHEBORO
					47	0.1836	100	3	FORTWORTH

Appendix F
Definitions

Management Terms

Green Species Survival Plan® (Green SSP) Program – A Green SSP Program has a population size of 50 or more animals and is projected to retain 90% gene diversity for a minimum of 100 years or 10 generations. Green SSP Programs are subject to AZA's Full Participation and Non–Member Participation Policies.

Yellow Species Survival Plan® (Yellow SSP) Program – A Yellow SSP Program has a population size of 50 or more animals but cannot retain 90% gene diversity for 100 years or 10 generations. Yellow SSP participation by AZA institutions is voluntary.

Red Species Survival Plan® (Red SSP) Program – A Red SSP has a population size of greater than 20 but fewer than 50 animals, at least three AZA member institutions, and a published studbook. Animal Programs that manage species designated as Extinct in the Wild, Critically Endangered, or Endangered (IUCN) do not need to meet minimum population size and number of participating institution criteria to be designated as an SSP Program. Red Program participation by AZA institutions is voluntary.

Full Participation – AZA policy stating that all AZA accredited institutions and certified related facilities having a Green SSP animal in their collection are required to participate in the collaborative SSP planning process (e.g., provide relevant animal data to the AZA Studbook Keeper, assign an Institutional Representative who will communicate institutional wants and needs to the SSP Coordinator and comment on the draft plan during the 30-day review period, and abide by the recommendations agreed upon in the final plan).

All AZA member institutions and Animal Programs, regardless of management designation, must adhere to the AZA Policy on Responsible Population Management and the AZA Code of Professional Ethics. For more information on AZA policies, see http://www.aza.org/board-policies/.

Demographic Terms

Age Distribution – A two-way classification showing the numbers or percentages of individuals in various age and sex classes.

Ex, Life Expectancy – Average years of further life for an animal in age class x.

Lambda (λ) or Population Growth Rate – The proportional change in population size from one year to the next. Lambda can be based on life-table calculations (the expected lambda) or from observed changes in population size from year to year. A lambda of 1.11 means an 11% per year increase; lambda of 0.97 means a 3% decline in size per year.

lx, Age-Specific Survivorship – The probability that a new individual (e.g., age 0) is alive at the *beginning* of age *x*. Alternatively, the proportion of individuals which survive from birth to the beginning of a specific age class.

Mean Generation Time (T) – The average time elapsing from reproduction in one generation to the time the next generation reproduces. Also, the average age at which a female (or male) produces offspring. It is not the age of first reproduction. Males and females often have different generation times.

Mx, **Fecundity** – The average number of same-sexed young born to animals in that age class. Because studbooks typically have relatively small sample sizes, studbook software calculate Mx as 1/2 the average number of young born to animals in that age class. This provides a somewhat less "noisy" estimate of Mx, though it does not allow for unusual sex ratios. The fecundity rates provide information on the age of first, last, and maximum reproduction.

Px, Age-Specific Survival – The probability that an individual of age *x* survives one time period; is conditional on an individual being alive at the beginning of the time period. Alternatively, the proportion of individuals which survive from the beginning of one age class to the next.

Qx, Mortality – Probability that an individual of age *x* dies during time period. Qx = 1-Px. Alternatively, the proportion of individuals that die during an age class. It is calculated from the number of animals that die during an age class divided by the number of animals that were alive at the beginning of the age class (i.e.-"at risk").

Risk (Qx or Mx) – The number of individuals that have lived during an age class. The number at risk is used to calculate Mx and Qx by dividing the number of births and deaths that occurred during an age class by the number of animals at risk of dying and reproducing during that age class.

Vx, **Reproductive Value** – The expected number of offspring produced this year and in future years by an animal of age x.

Genetic Terms

Allele Retention – The probability that a gene present in a founder individual exists in the living, descendant population.

Current Gene Diversity (GD) -- The proportional gene diversity (as a proportion of the source population) is the probability that two alleles from the same locus sampled at random from the population will not be identical by descent. Gene diversity is calculated from allele frequencies, and is the heterozygosity expected in progeny produced by random mating, and if the population were in Hardy-Weinberg equilibrium.

Effective Population Size (Inbreeding N_e) -- The size of a randomly mating population of constant size with equal sex ratio and a Poisson distribution of family sizes that would (a) result in the same mean rate of inbreeding as that observed in the population, or (b) would result in the same rate of random change in gene frequencies (genetic drift) as observed in the population. These two definitions are identical only if the population is demographically stable (because the rate of inbreeding depends on the distribution of alleles in the parental generation, whereas the rate of gene frequency drift is measured in the current generation).

Founder – An individual obtained from a source population (often the wild) that has no known relationship to any individuals in the derived population (except for its own descendants).

Founder Genome Equivalents (FGE) – The number wild-caught individuals (founders) that would produce the same amount of gene diversity as does the population under study. The gene diversity of a population is 1 - 1 / (2 * FGE).

Founder Representation -- Proportion of the genes in the living, descendant population that are derived from that founder.

Inbreeding Coefficient (F) -- Probability that the two alleles at a genetic locus are identical by descent from an ancestor common to both parents. The mean inbreeding coefficient of a population will be the proportional decrease in observed heterozygosity relative to the expected heterozygosity of the founder population.

Mean Kinship (MK) – The mean kinship coefficient between an animal and all animals (including itself) in the living, captive-born population. The mean kinship of a population is equal to the proportional loss of gene diversity of the descendant (captive-born) population relative to the founders and is also the mean inbreeding coefficient of progeny produced by random mating. Mean kinship is also the reciprocal of two times the founder genome equivalents: MK = 1 / (2 * FGE). MK = 1 - GD.

Percent Known – Percent of an animal's genome that is traceable to known founders. Thus, if an animal has an UNK sire, the % Known = 50. If it has an UNK grandparent, % Known = 75.

Percent Certain -- The percentage of the living individuals' pedigree that can be completely identified as *certain:* (exact identity of both parents is known) and traceable back to known founders. Individuals that are 100% *certain* do not have any MULTs or UNKs in their pedigree. *Certainty* represents a higher degree of knowledge than *Known* and therefore is always less than or equal to *Known*.

Prob Lost – Probability that a random allele from the individual will be lost from the population in the next generation, because neither this individual nor any of its relatives pass on the allele to an offspring. Assumes that each individual will produce a number of future offspring equal to its reproductive value, Vx.

Appendix G

Directory of Institutional Representatives

Contact Name (IR)	Institution	Phone Number	Email Address
Denise Ibarra	ABILENE Abilene Zoological Gardens	325- 280-1939	denise.ibarra@abilenetx.com
Debbie Zomback	ASHEBORO North Carolina Zoo	336-879-7605	dzpmback@nczoo.org
Alan Yester	BIRMINGHM Birmingham Zoo	205-879-0409 x211	ayester@birminghamzoo.com
Sprina lu	DALLAS Dallas Zoo	469-554-7240	sprina.liu@dallaszoo.com
John Azua	DENVER Denver Zoological Gardens	720-337-1514	jazua@denverzoo.org
Shelly Collinsworth	FORTWORTH Fort Worth Zoological Park	817-759-7170	scollinsworth@fortworthzoo.org
Fran Lyon	LITTLEROC Little Rock Zoo	501-661-7242	flyon@littlerock.gov
Jim Dunster	METROZOO Miami Metrozoo	305-251-0400 x5084965	jdun@miamidade.gov
Marie Barbera	SAFARI W Safari West	707-579-2551	mbarbera@safariwest.com
Josef San Miguel	SAN ANTON San Antonio Zoological Gardens	210-734-7184	josef.sanmiguel@sazoo.org
Dave Rimlinger	SANDIEGOZ San Diego Zoo	619-557-3978	drimlinger@sandiegozoo.org
Michelle Handrus	SD-WAP San Diego Zoo's Safari Park	760-747-8702 x5108	mhandrus@sandiegozoo.org
Kevin Kerr	TORONTO Toronto Zoo	416-392-5972	kkerr@torontozoo.ca