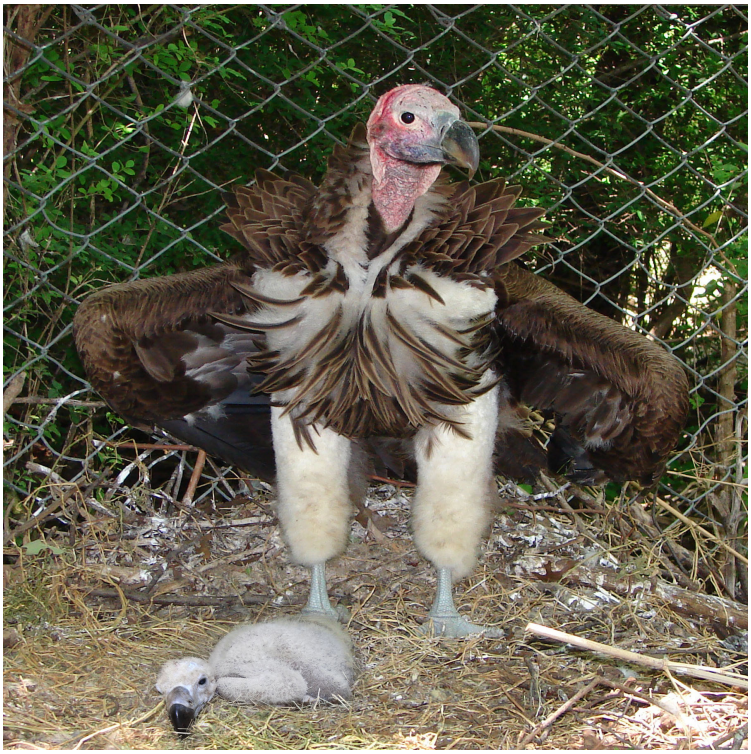
Population Analysis & Breeding and Transfer Plan
UPDATE

Lappet-faced Vulture (Torgos tracheliotus)
AZA Species Survival Plan®
Red Program



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20 November 2015

PMC Population Management Center
Lincoln Park Zoo
Association of Zoos & Aquariums

DALLAS ZOO

Executive Summary

Lappet-faced Vulture (*Torgos tracheliotus*)

This document is an update to the 8 September 2015 Breeding and Transfer Plan to address population changes and new institutional needs since that plan was finalized.

The current, managed lappet-faced vulture population includes 31 birds (16 males, 15 females, 0 unknown) held by 12 AZA institutions. The Raptor Taxon Advisory Group set a target size of 50 individuals for this population (RCP 2015 draft). At present, the Lappet-faced Vulture SSP population qualifies as a Red SSP. This is a two-year breeding and transfer plan.

Genetic and demographic analyses of the North American Regional Lappet-faced Vulture Studbook (current to 29 April 2015) were performed using PopLink 2.4 and PMx 1.2, resulting in the current breeding and transfer plan for this species. The current gene diversity in the population is 90.14% of that present in the founding population. Gene diversity at 100 years from present is projected to be 75% if the population can slowly grow (2% per year) to reach the RCP target size of 50 individuals. Increased reproduction, however, will be necessary to attain a 2% growth rate, as the population on average has experienced no growth for the past 5 years. If the population continues to experience no growth in population size, gene diversity is expected to be 69.4% in 100 years. A decrease in gene diversity below 90% of that in the founding population has been associated with reproduction increasingly compromised by, among other factors, lower hatch weights and greater neonatal mortality. At present, the best management strategy for the population is to breed potential founders, and birds with low and well-matched mean kinships.

Demography	
Current SSP population size (males.females.unknown)	31 (16.15.0)
Number of animals excluded from management	0
Population size following exclusions	31 (16.15.0)
Target population size (2015 RCP draft)	50
Mean generation time (T; in years)	20.7
Projected population growth rate (λ) from life tables	0.961
Recent population growth rate (average λ 2010-2014)	1.000

Genetics

	2015	**Current Potential**
Founders	9	9 additional
Founder genome equivalents (FGE)	5.07	17.97
Current gene diversity (GD %)	90.14	97.22
Population mean kinship (MK)	0.0929	-----
Mean inbreeding (F)	0.0000	-----
% pedigree known before assumptions and exclusions	100	-----
% pedigree known after assumptions and exclusions	100	-----
Effective population size/census size ratio (Ne / N)	na[1]	-----
Years To 90% Gene Diversity	1*	-----
Years To 10% Loss of GD	60*	-----
Gene Diversity at 100 Years From Present (%)	75.0 *	-----

[1] insufficient data to calculate Ne/N in PMx because no currently living captive-bred males have sired offspring.

*projections based on the breeding population growing to the RCP target size of 50 birds (λ = 1.020, Ne/N = 0.30)

Analyses suggest that 2 hatches are needed over the next two years (1 per year) to maintain the current population size, while 5 hatches are needed over the next two years (2 - 3 per year) if a growth rate of 2.0% can be maintained to grow toward the RCP target size of 50 birds. The breeding recommendations are intended to produce sufficient offspring to increase the population to the target size, fill new institutions if recruited, and replace individuals as needed. As with most managed AZA populations, breeding groups are prioritized to maintain or increase gene diversity through considerations of mean kinship, avoidance of inbreeding, differences in sire and dam mean kinships, and the degree of uncertainty within a pedigree.

Summary Actions: The Program recommends 11 females to be placed in breeding situations and 12 transfers to create new breeding pairs and meet institutional needs.

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Cover Photo Courtesy of Debbie Milligan, Dallas Zoo

Report and Analyses prepared by:
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Planning occurred on June 24th, 2015 via video conference at the San Diego Safari Park and was attended by Debbie Milligan (Dallas Zoo), Harrison Edell (Dallas Zoo) and Andrea Putnam (San Diego Zoo Global), Mike Taylor (Jacksonville Zoo), Tricia Emrich (Disney's Animal Kingdom).

This plan was reviewed and distributed with the assistance of the Population Management Center.
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Description of Population Status

Lappet-faced Vulture (*Torgos tracheliotus*)

Introduction: The current, managed lappet-faced vulture population includes 31 birds (16 males, 15 females, 0 unknown) held by 12 AZA institutions. The Raptor Taxon Advisory Group set a target size of 50 individuals for this population (RCP 2015 draft). At present, the Lappet-faced Vulture SSP population qualifies as a Red SSP Program. This is a two-year breeding and transfer plan.

Genetic and demographic analyses of the North American Regional Lappet-faced Vulture Studbook (current to 29 April 2015) were performed using PopLink 2.4 and PMx 1.2, resulting in the current breeding and transfer plan for this species.

This document is an update to the 8 September 2015 Breeding and Transfer Plan to address population changes and new institutional needs since that plan was finalized.

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

Analytical Population: No analytic assumptions were necessary as the pedigree of the current, living population can be traced to documented founders. No birds were excluded from genetic analyses (Appendix D). A total of 31 birds (16 males, 15 females, 0 unknown) were included in the breeding population.

Demography: Lappet-faced vultures were first seen in North American zoos in 1920, when one male was brought to the Philadelphia Zoo. The population relied on imports for decades as the reported first zoo hatch did not occur until 1991. Since that time, the population size has remained between 25 – 35, with small numbers of zoo hatches replacing older wild caught individuals as they aged out of the population (Figures 1 and 2). The average growth rate for the past 20 years has been 0.2% (λ = 1.002). Based on the current life tables (Appendix C) and age structure (Figure 3), the population has a negative projected growth rate of -5.9% per year (projected λ = 0.941).

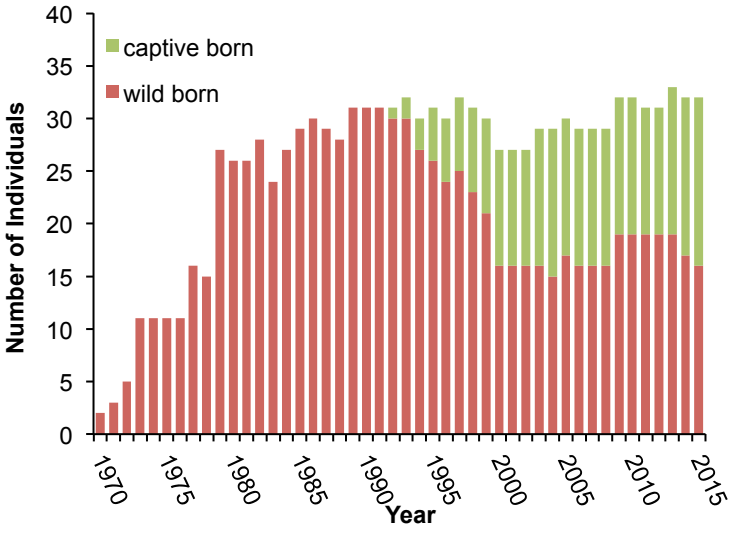

Figure 1. Census of lappet-faced vultures in North America from 1970 to 2015, by birth type.

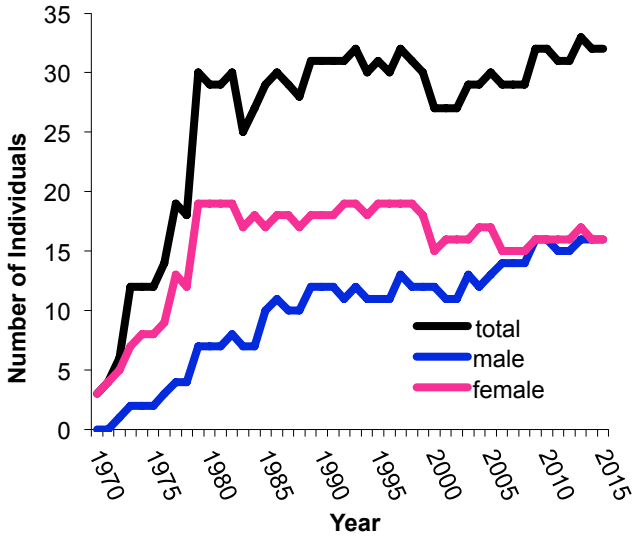

Figure 2. Census of lappet-faced vultures in North America from 1970 to 2015, by sex.

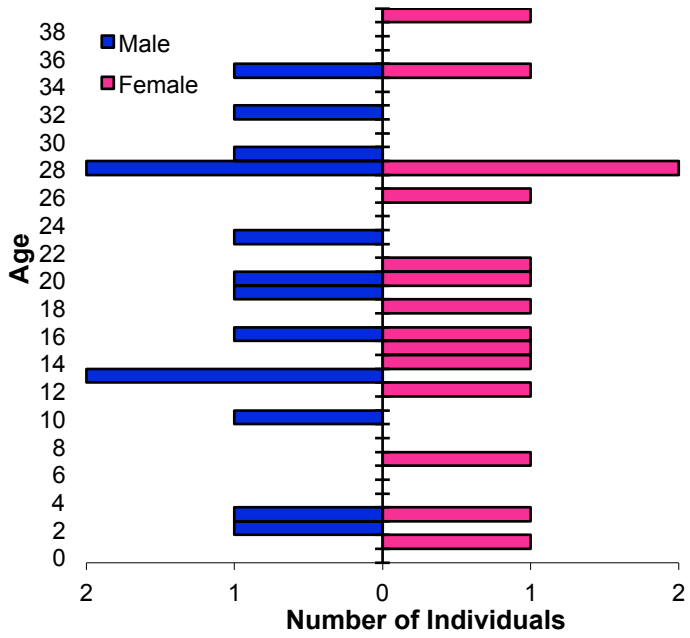

Figure 3. Age distribution of the current population of lappet-faced vultures in N. America.

The age structure of the managed lappet-faced vulture population has gaps in a number of the age classes reflecting sporadic reproductive success in captivity (Figure 3). Although the species is long-lived, consistent reproduction will be necessary to maintain a stable age distribution and growth potential. The sex ratio is currently equal.

Because a relatively small number of lappet-faced vultures have been held in North America, demographic data for this population may not yet accurately reflect the true biology of the species. Based on the studbook, the oldest captive hatched male and female are 21 and 23 years old, respectively, and still living. Wild-hatched males and females (with estimated hatch dates) have survived through their mid- to late-thirties. First year mortality is 42% for males and 38% for females. Data for lappet-faced vultures were not sufficiently robust to calculate formal survival statistics (see www.aza.org/survival-stats/ for the complete report). However, current life tables (Appendix C) indicate that median life expectancy is 3.1 years for males and 10.1 years for females (50% of males and females die before these ages and 50% die after). Males in N. America have reproduced between the ages of 8 and 27, and females between the ages of 10 and 29. It is likely that they have a longer reproductive span than this; data is currently deficient for birds in many of the age classes. Average clutch size is one offspring.

Analyses suggest that 2 hatches are needed over the next two years (1 per year) to maintain the current population size, while 5 hatches are needed over the next two years (2 - 3 per year) if a growth rate of 2.0% can be maintained to grow toward the RCP target size of 50 birds. The population has been averaging 1.4 hatches per year for the last 5 years, thus reproduction must be increased to grow the population toward the target size. Successful reproduction, not institutional holding capacity, is the limiting factor in population growth for this SSP.

Genetics: The studbook pedigree indicates that the managed lappet-faced vulture population is descended from 9 founders with 9 potential founders remaining (Figure 4). Breeding the potential founders to increase gene diversity is a priority for this SSP Program. The gene diversity of the population is currently 90.14%, which is equivalent to that found in ~5 unrelated animals (FGE = 5.07). However, the potential gene diversity is 97.22%.

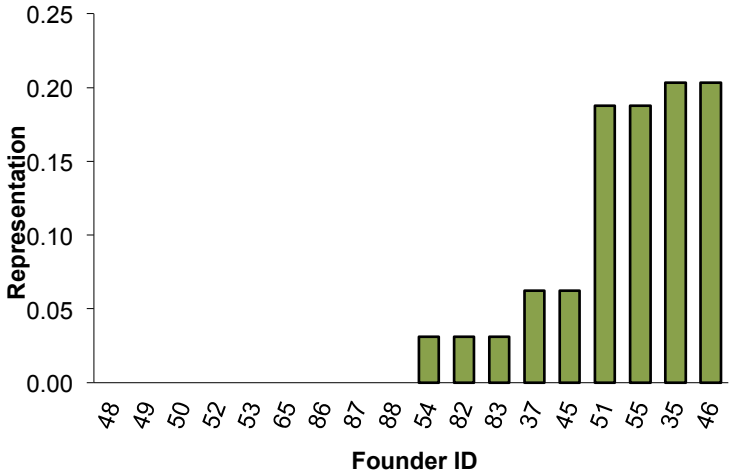

Figure 4: Founder representation, including the 9 potential founders in the managed lappet-faced vulture population in N. America.

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, and greater neonatal mortality. The lappet-faced vulture pedigree yields a current gene diversity of ~90%, which is projected to decline to 75% over the next 100 years if the current population can maintain a 2% growth rate and reach its target size of 50

birds. Increased reproduction, however, will be necessary to attain a 2% growth rate, as the population on average has experienced no growth for the past 5 years. If the population continues to experience no growth in population size, gene diversity is expected to be 69.4% in 100 years.

Genetics Summary

	2015	Current Potential
Founders	9	9 additional
Founder genome equivalents (FGE)	5.07	17.97
Current gene diversity (GD %)	90.14	97.22
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Years To 10% Loss of GD	60*	-----
Gene Diversity at 100 Years From Present (%)	75.0 *	-----

[1] insufficient data to calculate Ne/N in PMx because no currently living captive-bred males have sired offspring.
*projections based on the breeding population growing to the RCP target size of 50 birds (λ = 1.020, Ne/N = 0.30)

Management Strategy: The current population of managed lappet-faced vultures in North America includes 31 individuals (16 males, 15 females, 0 unknown) held by 12 AZA institutions. Demographic analyses indicate that 2 hatches are needed over the next two years (1 per year) to maintain the current population size, while 5 hatches are needed over the next two years (2 - 3 per year) if a growth rate of 2.0% can be maintained to reach the RCP target size of 50 birds.

As many genetically valuable birds that have not reproduced may soon be lost to attrition, several recommendations were made to create new breeding pairs with the hope to stimulate breeding behavior.

This is a 2-year plan. Interim recommendations will continue to be made as needed.

At this time, the SSP Program:

1. Recommends 12 females to breed.

2. Recommends 11 transfers to meet institutional needs and establish new breeding pairs.

3. Recommends contacting the Studbook Keeper with information on egg production, regardless of hatching success.

Summary of Breeding and Transfer Recommendations

SB ID	Location	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
37	SD-WAP	808251	F	39	HOLD	SD-WAP	BREED WITH	45	
45	SD-WAP	808250	M	32	HOLD	SD-WAP	BREED WITH	37	
49	DALLAS	854531	M	35	HOLD	DALLAS	BREED WITH	71	
50	KANSASCTY	A00044	F	28	SEND TO	CINCINNAT	BREED WITH	65	
51	DALLAS	906887	M	28	HOLD	DALLAS	BREED WITH	55	
52	COLUMBIA	9671	M	28	HOLD	COLUMBIA	BREED WITH	53	
53	COLUMBIA	9672	F	28	HOLD	COLUMBIA	BREED WITH	52	
54	PHOENIX	10772	M	29	HOLD	PHOENIX	BREED WITH	60	
55	DALLAS	906686	F	26	HOLD	DALLAS	BREED WITH	51	See Inst. Note
58	JACKSONVL	695070	M	23	HOLD	JACKSONVL	BREED WITH	91	
60	PHOENIX	7243	F	21	HOLD	PHOENIX	BREED WITH	54	See Inst. Note
62	DISNEY AK	100788	F	20	HOLD	DISNEY AK	SEE NOTES		See Inst. Note
64	BATONROUG	7932	M	19	HOLD	BATONROUG	BREED WITH	75	
65	KANSASCTY	203676	M	20	SEND TO	CINCINNAT	BREED WITH	50	
66	DETROIT	6029	F	18	HOLD	DETROIT	BREED WITH	77	
71	JACKSONVL	607337	F	16	SEND TO	DALLAS	BREED WITH	49	
75	DETROIT	7757	F	15	SEND TO	BATONROUG	BREED WITH	64	
76	RIO GRAND	B10037	M	13	SEND TO	ATLANTA	BREED WITH	78	
77	DETROIT	10759	M	13	HOLD	DETROIT	BREED WITH	66	
78	ATLANTA	B00075	F	12	HOLD	ATLANTA	BREED WITH	76	
82	DISNEY AK	40433	F	14	HOLD	DISNEY AK	BREED WITH	83	
83	DISNEY AK	40434	M	16	HOLD	DISNEY AK	BREED WITH	82	
84	ATLANTA	A80040	M	10	SEND TO	RIO GRAND	DO NOT BREED		
86	DALLAS	14P385	F	--	HOLD	DALLAS	BREED WITH	87	
87	DALLAS	14P386	M	--	HOLD	DALLAS	BREED WITH	86	
88	DALLAS	14P387	M	--	HOLD	DALLAS	DO NOT BREED		
91	DALLAS	08H981	F	7	SEND TO	JACKSONVL	BREED WITH	58	See Inst. Note
94	CINCINNAT	214094	M	2	SEND TO	KANSASCTY	DO NOT BREED		See Inst. Note
95	CINCINNAT	214093	F	1	SEND TO	KANSASCTY	DO NOT BREED		
96	DISNEY AK	120125	F	3	HOLD	DISNEY AK	SEE NOTES		
98	PHOENIX	11968	M	3	SEND TO	DISNEY AK	DO NOT BREED		See Inst. Note

Recommendations by Institution

ATLANTA

Zoo Atlanta
Atlanta, GA

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
78	B00075	F	12	HOLD	ATLANTA	BREED WITH	76	
84	A80040	M	10	SEND TO	RIO GRAND	DO NOT BREED		
76	B10037	M	13	RECEIVE FROM	RIO GRAND	BREED WITH	78	

BATONROUG

Baton Rouge Zoo
Baton Rouge, LA

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
64	7932	M	19	HOLD	BATONROUG	BREED WITH	75	
75	7757	F	15	RECEIVE FROM	DETROIT	BREED WITH	64	

CINCINNAT

Cincinnati Zoo & Botanical Garden
Cincinnati, OH

Institutional Note: Your institution is recommended to receive male SB# 65 and female SB# 50 who are a very genetically valuable breeding pair. Any reproduction from this pair is considered a success for the SSP. If imports of birds unrelated to the SSP are pursued, they could be paired with either SB# 50 or SB# 65.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
94	214094	M	2	SEND TO	KANSASCTY	DO NOT BREED		Immature
95	214093	F	1	SEND TO	KANSASCTY	DO NOT BREED		Immature
50	A00044	F	28	RECEIVE FROM	KANSASCTY	BREED WITH	65	
65	203676	M	20	RECEIVE FROM	KANSASCTY	BREED WITH	50	

COLUMBIA

Riverbanks Zoo
Columbia, SC

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
52	9671	M	28	HOLD	COLUMBIA	BREED WITH	53	
53	9672	F	28	HOLD	COLUMBIA	BREED WITH	52	

DALLAS

Dallas Zoo
Dallas, TX

Institutional Note: In the MateRx below, please prioritize breeding pairs rated as 1, 2, 3, and 4.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
49	854531	M	35	HOLD	DALLAS	BREED WITH	71	
51	906887	M	28	HOLD	DALLAS	BREED WITH	55	
55	906686	F	26	HOLD	DALLAS	BREED WITH	51	Pinioned (left wing)
86	14P385	F	--	HOLD	DALLAS	BREED WITH	87	
87	14P386	M	--	HOLD	DALLAS	BREED WITH	86	
88	14P387	M	--	HOLD	DALLAS	DO NOT BREED		
71	607337	F	16	HOLD	DALLAS	BREED WITH	49	

	Females >	86	55	71
Males V	Location	DALLAS	DALLAS	DALLAS
88	DALLAS	1	4	6
87	DALLAS	1	4	6
49	DALLAS	1	4	6
51	DALLAS	4	4	-

DETROIT

Detroit Zoo
Royal Oak, MI

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
66	6029	F	18	HOLD	DETROIT	BREED WITH	77	
75	7757	F	15	SEND TO	BATONROUG	BREED WITH	64	
77	10759	M	13	HOLD	DETROIT	BREED WITH	66	

DISNEY AK

Disney's Animal Kingdom
Bay Lake, FL

Institutional Note: Male SB# 98 and female SB# 96 are a future breeding pair. If health status of 62 and 96 improves please contact the Program Leader regarding an interim breeding recommendations for them at DISNEY AK.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
62	100788	F	20	HOLD	DISNEY AK	SEE NOTES		Partial wing amputee; See Inst. Note.
82	40433	F	14	HOLD	DISNEY AK	BREED WITH	83	
83	40434	M	16	HOLD	DISNEY AK	BREED WITH	82	
96	120125	F	3	HOLD	DISNEY AK	SEE NOTES		See Inst. Note.
98	11968	M	3	RECEIVE FROM	PHOENIX	DO NOT BREED		

JACKSONVL

Jacksonville Zoo and Gardens
Jacksonville, FL

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
58	695070	M	23	HOLD	JACKSONVL	BREED WITH	91	
91	08H981	F	7	HOLD	JACKSONVL	BREED WITH	58	Partial wing amputation (right wing)

KANSASCTY

Kansas City Zoo
Kansas City, MO

Institutional Note: Male SB# 65 and female SB# 50 will be recommended to re-pair with future imports at CINCINNAT to stimulate breeding behavior.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
50	A00044	F	28	SEND TO	CINCINNAT	BREED WITH	65	
65	203676	M	20	SEND TO	CINCINNAT	BREED WITH	50	
94	214094	M	2	RECEIVE FROM	CINCINNAT	DO NOT BREED		
95	214093	F	1	RECEIVE FROM	CINCINNAT	DO NOT BREED		

PHOENIX

Phoenix Zoo
Phoenix, AZ

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
54	10772	M	29	HOLD	PHOENIX	BREED WITH	60	
60	7243	F	21	HOLD	PHOENIX	BREED WITH	54	Pinioned (right wing)
98	11968	M	3	SEND TO	DISNEY AK	DO NOT BREED		

RIO GRAND

Rio Grande Zoo
Albuquerque, NM

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
76	B10037	M	13	SEND TO	ATLANTA	BREED WITH	78	
84	A80040	M	10	RECEIVE FROM	ATLANTA	DO NOT BREED		

SD-WAP

San Diego Zoo Safari Park
Escondido, CA

Institutional Note: Your institution is a priority for receiving a replacement breeding pair when necessary.

ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
37	808251	F	39	HOLD	SD-WAP	BREED WITH	45	
45	808250	M	32	HOLD	SD-WAP	BREED WITH	37	

Appendix A
Analytical Assumptions

No analytical assumptions were used for this plan.

Appendix B
Summary of Data Exports

Report compiled under PopLink V. 2.4 and Population Management x, V. 1.2.
PMx Vulture_Lappet_faced_2015
Report compiled under Population Management x, version 1.2

Studbook information:
Data compiled by: Debbie Milligan
Data current thru: 4/29/2015
Scope of data: North America

Demographic data from:
Demographic data from: C:\Documents and Settings\asputnam\My Documents\PMx\PMx_Projects\ Vulture_Lappet_faced _2015\PMx Export\ Vulture_Lappet_faced _2015.csv

Demographic filter conditions:
Locations: N. America, During 1/1/1980-6/8/2015
Census file: Exchcens.txt

Genetic data from:
C:\Documents and Settings\asputnam\My Documents\PMx\PMx_Projects\ Vulture_Lappet_faced _2015\PMx Export\ Vulture_Lappet_faced _2015.ped
Genetic filter conditions:
Locations: N. America, During 1/1/1980-6/8/2015

Appendix C
Life Tables

MALES								
Age	**Qx**	**Px**	**lx**	**Mx**	**Vx**	**Ex***	**Risk (Qx)**	**Risk (Mx)**
0	0.42	0.58	1.00	0.000	1.27	---	9.6	9.6
1	0.08	0.92	0.58	0.000	1.72	---	12.0	12.0
2	0.06	0.94	0.54	0.000	1.78	---	16.1	16.1
3	0.02	0.98	0.50	0.000	1.79	---	20.8	20.8
4	0.01	0.99	0.49	0.000	1.75	---	20.0	20.0
5	0.01	0.99	0.48	0.000	1.70	---	20.6	20.6
6	0.00	1.00	0.48	0.000	1.64	---	22.0	22.0
7	0.07	0.93	0.48	0.000	1.63	---	21.7	21.7
8	0.00	1.00	0.45	0.049	1.62	---	20.5	20.5
9	0.00	1.00	0.44	0.024	1.51	---	20.5	20.5
10	0.00	1.00	0.44	0.024	1.43	---	20.2	20.2
11	0.03	0.97	0.44	0.051	1.37	---	19.5	19.5
12	0.07	0.93	0.43	0.083	1.34	---	18.6	18.6
13	0.00	1.00	0.40	0.061	1.25	---	16.7	16.7
14	0.00	1.00	0.40	0.065	1.15	---	15.5	15.5
15	0.10	0.90	0.40	0.097	1.09	---	15.1	15.1
16	0.00	1.00	0.36	0.110	1.01	---	13.3	13.3
17	0.00	1.00	0.36	0.077	0.86	---	13.0	13.0
18	0.15	0.85	0.36	0.045	0.82	---	11.2	11.2
19	0.00	1.00	0.30	0.050	0.81	---	10.4	10.4
20	0.00	1.00	0.30	0.100	0.73	---	10.0	10.0
21	0.00	1.00	0.30	0.111	0.60	---	9.2	9.2
22	0.11	0.89	0.30	0.125	0.50	---	8.2	8.2
23	0.14	0.86	0.27	0.063	0.41	---	7.6	7.6
24	0.00	1.00	0.23	0.000	0.36	---	6.0	6.0
25	0.00	1.00	0.23	0.083	0.35	---	6.0	6.0
26	0.00	1.00	0.23	0.167	0.25	---	6.0	6.0
27	0.00	1.00	0.23	0.083	0.08	---	6.0	6.0
28	0.00	1.00	0.23	0.000	0.00	---	6.0	6.0
29	0.00	1.00	0.23	0.000	0.00	---	4.8	4.8
30	0.07	0.93	0.23	0.000	0.00	---	3.8	3.8
31	0.29	0.71	0.22	0.000	0.00	---	3.0	3.0
32	0.00	1.00	0.15	0.000	0.00	---	2.0	2.0
33	0.00	1.00	0.15	0.000	0.00	---	2.0	2.0
34	0.00	1.00	0.15	0.000	0.00	---	1.8	1.8
35	0.00	1.00	0.15	0.000	0.00	---	1.0	1.0
36	0.00	1.00	0.15	0.000	0.00	---	1.0	1.0
37	0.00	1.00	0.15	0.000	0.00	---	1.0	1.0
38	0.00	1.00	0.15	0.000	0.00	---	1.0	1.0

Qx = mortality; Px = survival; lx = cumulative survivorship; Mx = fecundity; Vx = reproductive value; Ex = life expectancy;
At Risk (Qx and Mx) = number of animals corresponding values are estimated from:
r =-0.041; lambda =0.960; T = 18.8
*Ex is blank because the oldest male is currently living.

FEMALES								
Age	**Qx**	**Px**	**lx**	**Mx**	**Vx**	**Ex***	**Risk (Qx)**	**Risk (Mx)**
0	0.38	0.62	1.00	0.000	1.24	---	13.2	13.2
1	0.05	0.95	0.62	0.000	1.60	---	20.4	20.4
2	0.04	0.96	0.59	0.000	1.61	---	25.8	25.8
3	0.02	0.98	0.56	0.000	1.60	---	29.5	29.5
4	0.01	0.99	0.55	0.000	1.56	---	30.0	30.0
5	0.01	0.99	0.55	0.000	1.51	---	29.6	29.6
6	0.03	0.97	0.54	0.000	1.48	---	32.0	32.0
7	0.05	0.95	0.53	0.000	1.48	---	29.9	29.9
8	0.00	1.00	0.50	0.000	1.46	---	27.7	27.7
9	0.00	1.00	0.50	0.000	1.41	---	27.5	27.5
10	0.03	0.97	0.50	0.027	1.38	---	27.5	27.5
11	0.04	0.96	0.48	0.029	1.35	---	25.6	25.6
12	0.04	0.96	0.47	0.000	1.33	---	24.9	24.9
13	0.00	1.00	0.45	0.062	1.30	---	23.5	23.5
14	0.09	0.91	0.45	0.000	1.25	---	21.0	21.0
15	0.05	0.95	0.41	0.107	1.29	---	20.1	20.1
16	0.03	0.97	0.39	0.041	1.18	---	17.4	17.4
17	0.11	0.89	0.38	0.000	1.18	---	16.9	16.9
18	0.00	1.00	0.33	0.049	1.21	---	15.0	15.0
19	0.00	1.00	0.33	0.052	1.12	---	14.3	14.3
20	0.00	1.00	0.33	0.056	1.03	---	12.7	12.7
21	0.00	1.00	0.33	0.121	0.94	---	12.0	12.0
22	0.00	1.00	0.33	0.000	0.79	---	11.1	11.1
23	0.12	0.88	0.33	0.197	0.81	---	10.4	10.4
24	0.15	0.85	0.29	0.240	0.68	---	9.2	9.2
25	0.13	0.87	0.25	0.090	0.49	---	8.2	8.2
26	0.02	0.98	0.22	0.102	0.42	---	7.2	7.2
27	0.00	1.00	0.21	0.118	0.31	---	6.4	6.4
28	0.00	1.00	0.21	0.000	0.18	---	6.1	6.1
29	0.00	1.00	0.21	0.174	0.17	---	4.8	4.8
30	0.00	1.00	0.21	0.000	0.00	---	4.0	4.0
31	0.00	1.00	0.21	0.000	0.00	---	4.0	4.0
32	0.25	0.75	0.21	0.000	0.00	---	3.5	3.5
33	0.00	1.00	0.16	0.000	0.00	---	3.0	3.0
34	0.09	0.91	0.16	0.000	0.00	---	3.0	3.0
35	0.27	0.73	0.14	0.000	0.00	---	2.5	2.5
36	0.00	1.00	0.11	0.000	0.00	---	2.0	2.0
37	0.00	1.00	0.11	0.000	0.00	---	2.0	2.0
38	0.00	1.00	0.11	0.000	0.00	---	2.0	2.0

Qx = mortality; Px = survival; lx = cumulative survivorship; Mx = fecundity; Vx = reproductive value; Ex = life expectancy
At Risk (Qx and Mx) = number of animals corresponding values are estimated from
r = -0.039; lambda = 0.962; T = 22.0
*Ex is blank because the oldest female is currently living.

Appendix D
Individuals Excluded from Genetic Analyses

No individuals were excluded from genetic analyses.

Appendix E
Ordered Mean Kinships

Note: This list is current to April 29th 2015. Values are subject to change with any birth, death, import, export, inclusion, or exclusion. **Average Population MK = 0.0986.**

MALES

SB#	MK	% Known	Age	Location
87	0	100	--	DALLAS
88	0	100	--	DALLAS
49	0	100	35	DALLAS
52	0	100	28	COLUMBIA
65	0	100	20	KANSASCTY
54	0.0156	100	29	PHOENIX
83	0.0156	100	16	DISNEY AK
45	0.0313	100	32	SD-WAP
77	0.0469	100	13	DETROIT
98	0.0859	100	3	PHOENIX
51	0.0938	100	28	DALLAS
76	0.1094	100	13	RIO GRAND
84	0.1094	100	10	ATLANTA
94	0.1094	100	2	CINCINNAT
58	0.1172	100	23	JACKSONVL
64	0.1172	100	19	BATONROUG

FEMALES

SB#	MK	% Known	Age	Location
86	0	100	--	DALLAS
50	0	100	28	KANSASCTY
53	0	100	28	COLUMBIA
82	0.0156	100	14	DISNEY AK
37	0.0313	100	39	SD-WAP
96	0.0313	100	3	DISNEY AK
75	0.0469	100	15	DETROIT
55	0.0938	100	26	DALLAS
71	0.1094	100	16	JACKSONVL
91	0.1094	100	7	DALLAS
95	0.1094	100	1	CINCINNAT
62	0.1172	100	20	DISNEY AK
66	0.1172	100	18	DETROIT
78	0.1172	100	12	ATLANTA
60	0.125	100	21	PHOENIX

Appendix F
Definitions

Management Terms (as of September 2014)

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 Acquisitions, Transfers, and Transitions 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 SPARKS is typically using relatively small sample sizes, SPARKS calculates 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

Institution	Contact (IR)	Phone	Email
ATLANTA – Zoo Atlanta	James Ballance	404-624-5691	jballance@zooatlanta.org
BATONROUG – Baton Rouge Zoo	Sam Winslow	225-775-3877 ext 213	swinslow@brzoo.org
CINCINNAT – Cincinnati Zoo & Botanical Garden	Robert Webster	513-475-6153	robert.webster@cincinnatizoo.org
COLUMBIA – Riverbanks Zoo	Colleen Lynch	803-602-0913	clynch@riverbanks.org
DALLAS – Dallas Zoo	Sprina Liu	469-554-7240	sprina.liu@dallaszoo.com
DETROIT – Detroit Zoo	Tom Schneider	248-541-5717 ext 3128	tschneider@detroitzoo.org
DISNEY AK – Disney's Animal Kingdom	Scott Tidmus	407-938-2105	scott.tidmus@disney.com
JACKSONVL – Jacksonville Zoo and Gardens	Mike Taylor	904-757-4463 ext 138	taylorm@jacksonvillezoo.org
KANSASCTY – Kansas City Zoo	Dale Frerking	816-595-1368	dalefrerking@fotzkc.org
PHOENIX – Phoenix Zoo	John Sills	602-273-1341 ext 7625	jsills@thephxzoo.com
RIO GRAND – Rio Grande Zoo	Peter Shannon	505-764-6258	pshannon@cabq.gov
SD-WAP – San Diego Zoo Safari Park	Michael Mace	760-738-5077	mmace@sandiegozoo.org

Appendix H
Explanation of MateRx

Recommendations Provided from MateRx

MateRx is analytical software developed jointly by the National Zoological Park and Lincoln Park Zoo. The primary output is a matrix of genetic ratings (Mate Suitability Indices = MSI) for every possible breeding pair in a population. MSIs allow managers to quickly discover how the genetic status of animals in their collections compare to the rest of a managed population.

Each MSI represents the genetic consequences for the population if a given pair was to produce offspring. There are seven values for MSIs: offspring of pairs rated 1, 2, or 3 would benefit the population's genetic situation; pairs rated 4, 5, or 6 would be detrimental to the population's genetic situation. Pairs without an MSI value (i.e., a dash [--]) should not be considered under any circumstances without consulting an advisor. These MSI values are defined as:

1 – very beneficial
2 – moderately beneficial
3 – slightly beneficial
4 – slightly detrimental
5 – moderately detrimental
6 – very detrimental

Whenever possible, managers should encourage pairings with MSIs of 1, 2, or 3 and discourage pairings of 5, 6, or "—". Pairings with MSIs of 4 are neither encouraged nor discouraged and will likely be necessary in order to meet demographic goals.

MateRx integrates four genetic factors to produce the Mate Suitability Index (MSI). These four components are currently used to develop pairing recommendations for SSPs. In decreasing order of "importance," they are:

1. the expected change in genetic diversity (increase, decrease) that would result if an offspring of a pair is added to the population;
2. the relative rareness or commonness of the parents genetic information (i.e., the relative dissimilarity of parental mean kinships);
3. the inbreeding coefficient of offspring that would be produced by a pair; and
4. the proportion, if any, of the dam and/or sire's pedigree that is of unknown origin.

Analysis Note: The "breakpoint" and "no way" values for inbreeding used average MK values and were set to 0.0986 and 0.25, respectively. The mean kinship difference method was changed to 'Balanced Ranks'.