Population Analysis & Breeding and Transfer Plan

Aye-aye (*Daubentonia madagascariensis*) AZA Species Survival Plan® Red Program

AZA Species Survival Plan® Coordinator and Studbook Keeper
Dean Gibson, San Diego Zoo
(dgibson@sdzwa.org)

Species Survival Plan® Vice-Coordinator
Julie McKinney, Duke Lemur Center
(julie.mckinney@duke.edu)

Adjunct Population Advisor
Asako Chaille, San Diego Zoo Wildlife Alliance
(anavarro@sdzwa.org)

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PMC Population Management Center
LINCOLN PARK ZOO. ASSOCIATION OF ZOOS & AQUARIUMS
San Diego Zoo Wildlife Alliance

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Acknowledgments

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Dean Gibson, San Diego Zoo
Mindy Settles, San Diego Zoo
Heather Myers, San Diego Zoo
Joe Milo, San Diego Zoo
Jill Andrews, San Diego Zoo
Kim Livingstone, San Diego Zoo
Christie Eddie, Omaha's Henry Doorly Zoo and Aquarium
Ryan Sears, Omaha's Henry Doorly Zoo and Aquarium
Matt Lenyo, Denver Zoo
Kim Skelton, Denver Zoo
Julie McKinney, Duke Lemur Center
Britt Keith, Duke Lemur Center
Jenna Browning, Duke Lemur Center
Rachel Cowen, Durrell Wildlife Conservation Trust
Asako Chaille, San Diego Zoo Wildlife Alliance

Cover photo courtesy of: David Haring, Duke Lemur Center

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Description of Population Status

Species Survival Plan® for the Aye-aye (*Daubentonia madagascariensis*)

Introduction: The aye-aye (*Daubentonia madagascariensis*) is the world's largest nocturnal primate and the only extant member of the family Daubentoniidae. This species is native to Madagascar, and unlike other primates is uniquely known for its rodent-like teeth and long, thin fingers. This current SSP population consists of 24 animals (9 males, 15 females) distributed among 7 AZA facilities. The Prosimian Taxon Advisory Group has set the target population size for this population to be 30 animals (2019 Regional Collection Plan), however, every Breeding & Transfer Plan since 2011 has noted that lack of space was inhibiting continued breeding. Under AZA's current sustainability designations, this Program qualifies as a Red SSP (<50 formally managed animals; <90% gene diversity for 100 years). This is the sixth Breeding and Transfer Plan for this Program.

Analytical Assumptions and Exclusions: The pedigree of this population is 100% known before exclusions. No pedigree assumptions were necessary (Appendix A). A total of 2 animals have been excluded from the potentially breeding population due to medical concerns (Appendix C). Following exclusions, the genetically managed population included 22 animals (9 males, 13 females) with a pedigree that was 100% known and 100% certain (Appendix A).

Demography: Studbook records indicate that aye-ayes have been held in current AZA facilities since 1987, when the Duke Lemur Center acquired two wild-caught males from Madagascar. One additional wild-caught male and five wild-caught females were subsequently imported, with the last such import occurring in 1992. Transfers of captive-born animals have sporadically occurred between regions; the San Diego Zoo most recently acquired an unrelated male from Japan (SB# 176) in 2014, and seven animals have been exported to EAZA and JAZA facilities between 2011 and 2015. The first successful captive birth in current AZA facilities occurred at the Duke Lemur Center in 1992. Although yearly growth rates have varied due to a combination of continued imports and sporadic captive breeding (annual λ from 1988 – 2021 ranged from 3.00 to 0.75), the population has steadily grown in size by an average of 7.4% per year since it was founded (Figure 1; average λ 1988 – 2021 = 1.074). Declines in population size during both 2014 and 2015 were primarily due to exports, but the further decline in sizes in 2016 and 2021 were due entirely to deaths. One wild-caught animal remains, though the individual is of advanced age and has not been bred since 2017 (Figure 1). Based on the current life tables (Appendix D), the population has a projected growth rate of 2.9% per year (projected λ = 1.029).

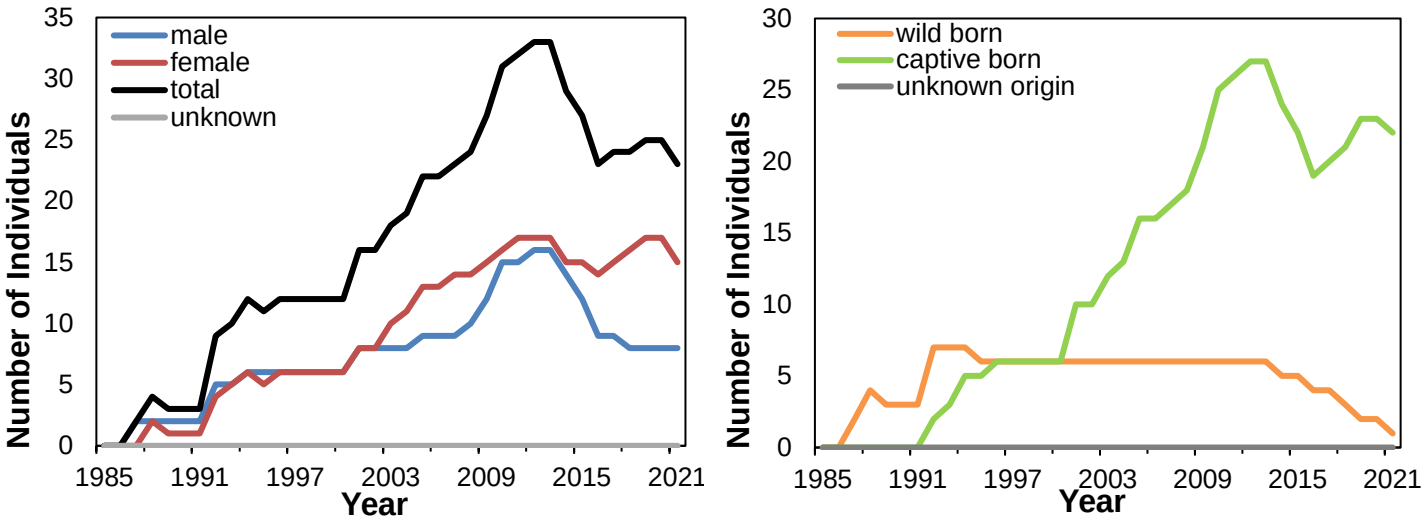

Figure 1. *Census of the Aye-aye SSP from 1985 to 2021 by sex (left) and birth type (right).*

Significant numbers of aye-ayes have been held in captivity for a short period of time relative to their potential lifespan, and demographic data for this population may not yet accurately reflect biological parameters. To date, the oldest recorded male is still living at 35 years of age (SB# 104) and the oldest recorded female lived to 38 years of age (SB# 119). It is important to note, however, both individuals are wild-caught and have approximate ages. Current life tables used for demographic analyses indicate first-year mortality is 16% for males and 14% for females, although these values

are calculated from very small sample sizes (Appendix D). Age at sexual maturity can vary depending on photoperiods and light cycles as well as the presence and proximity of same sexed adults. The youngest male on record to breed was almost 3 years of age at the time of conception (SB# 191) and the youngest female to produce offspring was 4 years of age (SB# 137). However, females can start cycling at two years of age. At this time, the oldest male on record to breed was ~30 years of age at the time of conception (SB# 104) and the oldest female to produce offspring was ~26 years of age at the time of birth (SB# 119); both individuals are wild-caught and have approximate ages. As the population ages and more individuals fill older age classes, demographic data quality will improve and values in life tables may change. Females typically produce a single offspring at a time, although a single set of twins was born in Europe in 2015 (SB# 168); the shortest interbirth interval recorded in the studbook for surviving offspring was 449 days. Unlike many other lemur species, aye-ayes are not seasonal breeders.

The age structure illustrates the number of males and females in each age class (Figure 2). Based on its current age structure and growth rate, if the population continues on its current trajectory, this population is expected to increase over time. The age structure of the aye-aye population is generally columnar, with many gaps present throughout the age structure. This is typical for small populations of long-lived species with slow reproductive rates (Figure 2). The moderate numbers of animals in the younger age classes are indicative of successful reproduction, however there has been a strong skew in recent births toward females, with 1.7 females present for every male in the current total population. After exclusions, the sex ratio of the potential breeding population is closer to parity with 1.3 females present for every male. Though this species is bred in monogamous pairs and a skew in sex ratio can typically limit reproduction, space availability is currently the main factor limiting breeding in this population. Due to the long reproductive span of this species and the majority of the population currently of breeding age, there is strong potential for this population to maintain or strive towards a more stable age structure. Continuing to maintain a consistent number of births per year will also support demographic stability.

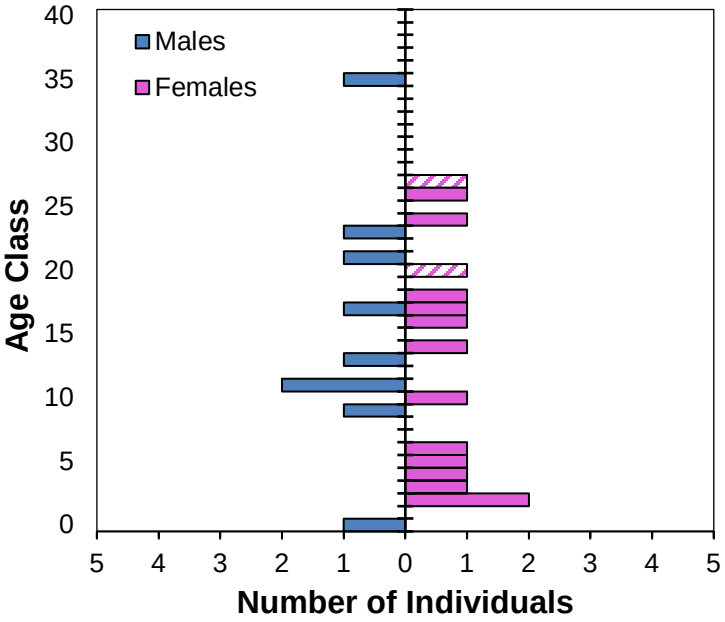

Figure 2. *Age distribution of the total population of the Aye-aye SSP, N= 24 (9.15.0). Individuals excluded from genetic analyses are represented by hashes, N= 2 (0.2.0).*

Table 1: *Demographic status of SSP population, according to studbook.*

Demography Summary		
Current size of SSP population (N) – Total (Males.Females.Unknown Sex)	24 (9.15.0)	
Number of individuals excluded from genetic analyses	2 (0.2.0)	
Population size following exclusions	22 (9.13.0)	
Target population size (Kt) from Prosimian TAG 2019 RCP	30	
Mean generation time (T, years)	12.6	
Population growth rates (λ; lambda)*: Life Table / 5–year / Projected	1.029 / 1.00 / 0.970 <> 1.002 <> 1.033	
Percentage (%) of living population born/hatched ex situ	96%	
Survival/Mortality	**Males**	**Females**
Observed first year mortality rate (Q_x)	0.16	0.14
Median life expectancy (MLE), excluding first year mortalities (years) (from PopLink Survival Statistics Report (https://www.aza.org/species-survival-statistics)) *data were not of sufficient robustness to analyze	--	--
Observed maximum longevity (L_x) (Studbook ID # of individual) *SB# 104 and 119 are wild-caught with estimated ages	35 (SB# 104)	38 (SB# 119)
Reproduction		
Observed reproductive age range	3 – 30	4 - 26
Gestation/Incubation time	172 days	
Median litter/clutch size born/hatched	1	

* Life table (AZA, 1987 – present); 5-year from studbook census; Projected from PMx stochastic 20 year projections

Genetics: Based on pedigree assumptions and exclusions, the studbook pedigree indicates that the analytical Aye-aye SSP population is descended from eight founders, with no potential founders still remaining (Figure 3). The mean kinship in the population is 0.1045. Half-siblings have a kinships of 0.125 and first-cousins have a kinship of 0.0625, which means that the average relationship across the population is between that of second and third-order relatives. The gene diversity of the analytical population is 89.55%, which is equivalent to that found in approximately 4 to 5 founders (FGE = 4.79). Typical AZA program goals include thresholds for tolerance of gene diversity loss over time; 90% gene diversity retention for 100 years is a common management goal. Decreases in gene diversity below 90% of that in the founding population have been associated with reproduction increasingly compromised by, among other factors, lower birth weights, smaller litter sizes, and greater neonatal mortality in some species.

Gene diversity in the analytical aye-aye population is projected to decline to ~65% over the next 100 years if the population grows at its projected growth rate of 2.9% (λ = 1.029) to a size of 30 animals. The parameters used for projections are generally quite reasonable and its unlikely long-term gene diversity retention can be markedly improved through management alone. The population's Ne/N ratio is already quite high and the gains in gene diversity that might be achieved by breeding animals with low and well-matched mean kinships are small (as evidenced by the small difference between current and potential gene diversity). As more demographic data accumulate, the use of a longer generation length for projections may be warranted but also is unlikely to notably change long-term gene diversity retention; increasing generation length to 15 years only increased gene diversity retention at 100 years to ~72%. Although markedly increasing the population's target size is currently unrealistic, analyses suggest increasing this parameter is likely to have the greatest positive impact on projections; doubling the population's target size to 60 animals increased gene diversity retention at 100 years to nearly 76%. Given the population's low current gene diversity and small size, additional imports of unrelated animals ultimately will be necessary to support long-term gene diversity maintenance. As an example benchmark—given the TAG's recommended target size of 30 animals—approximately two new founders would need to be acquired and successfully bred every six to seven years to retain 90% founding gene diversity for 100 years (T = 12.6 years; λ = 1.029; Ne/N = 0.52; starting GD = 89.55).

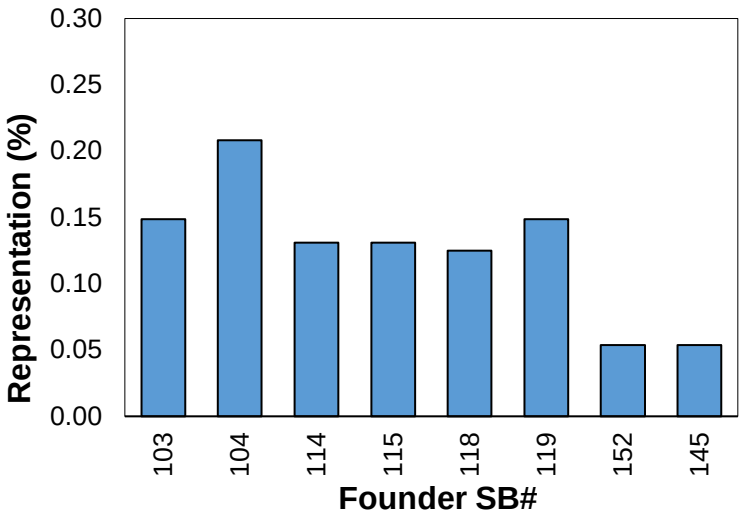

Figure 3. *Founder representation distribution of the analytical Aye-aye SSP population.*

The best genetic management strategy to maximize a population's long-term gene diversity retention is typically managed breeding targeted at equalizing founder representations, by breeding animals with low and well-matched mean kinships. Founder representations in the aye-aye population are currently relatively equally distributed (Figure 3). The only factors contributing to the population's skewed founder representations is the under-represented founder lineages of SB# 152 and SB# 145; there are four living descendants remaining in the population (SB# 176, 228, 244, and 252). If these descendants produce more offspring through careful management, we would expect their founder representations to increase over time. Due to the small founder base, new sources for potential founders from collections outside the SSP should be investigated.

Table 2: *Population size, genetic status, and projections for the Aye-aye SSP population.*

Genetics Summary*					
	2011	*2015*	*2019*	**2022**	**Potential**
Founders	*6*	*8*	*8*	8	0
Founder genome equivalents (FGE)	*4.58*	*4.76*	*4.81*	4.79	6.31
Gene diversity (GD %)	*89.08*	*89.50*	*89.60*	89.55	92.08
Population mean kinship (MK)	*0.1092*	*0.1050*	*0.1040*	0.1045	--
Mean inbreeding (F)	*0.0104*	*0.0125*	*0.0030*	0.0030	--
Effective population size (N_e/N)	*0.53*	*0.34*	*0.53*‡	0.52‡	--
Percentage of pedigree known before / after assumptions and exclusions	*100 / 100*	*100 / 100*	*100 / 100*	*100 / 100*	--
Percentage pedigree certain after assumptions and exclusions	100	100	100	100	--
Projections					
Years to 90% gene diversity	NA <90%	NA <90%	NA <90%	NA <90%	--
Years to 10% loss of gene diversity	75	42	46	43	--
Gene diversity at 100 Years (%)	76	70	69	65	--
Parameters for analysis: growth rate (λ), target size (Kt), generation length (T), starting population size (n)	Assuming λ = 1.03, Kt = 50, T = 13.1, n = 30	Assuming λ = 1.05, Kt = 50, T = 13.0, n = 23	Assuming λ = 1.04, Kt = 30, T = 12.7, n = 25	Assuming λ = 1.03, Kt = 30, T = 12.6, n = 22	--

*Genetic statistics may not be comparable across years due to changes in software and parameters used for projections from year to year.
‡ Calculation known to include founders

Recommendation Outcomes: The website PMCTrack calculates the outcomes fo SSP recommendations by comparing Breeding and Transfer Plan recommendations to births/hatches and transfers recorded in the studbook (Figure 4). There are many reasons that recommendations might not be fulfilled, including interim recommendations issued by the SSP Coordinator; these reasons can be captured using PMCTrack Outcomes Surveys. Note that starting in 2022, SSP Coordinators directly add interim recommendations to PMCTrack to improve the accuracy of recommendation outcomes. The fulfillment rates of any plan that had outcomes calculated in 2022 or after may reflect inclusion of these interim rates; in the graph, this may include the last plan before 2022, such as a 2021 plan, plus any plans with a date of 2022 or after.

Of the recommendations proprosed in the 2019 Breeding and Transfer Plan, 14% of the BREED WITH recommendations were fulfilled, and 0% of SEND TO recommendations were fulfilled as requested by 05/11/22. SSP participants are always encouraged to attempt to fulfill recommendations and communicate sucesses and challenges to the SSP Coordinator.

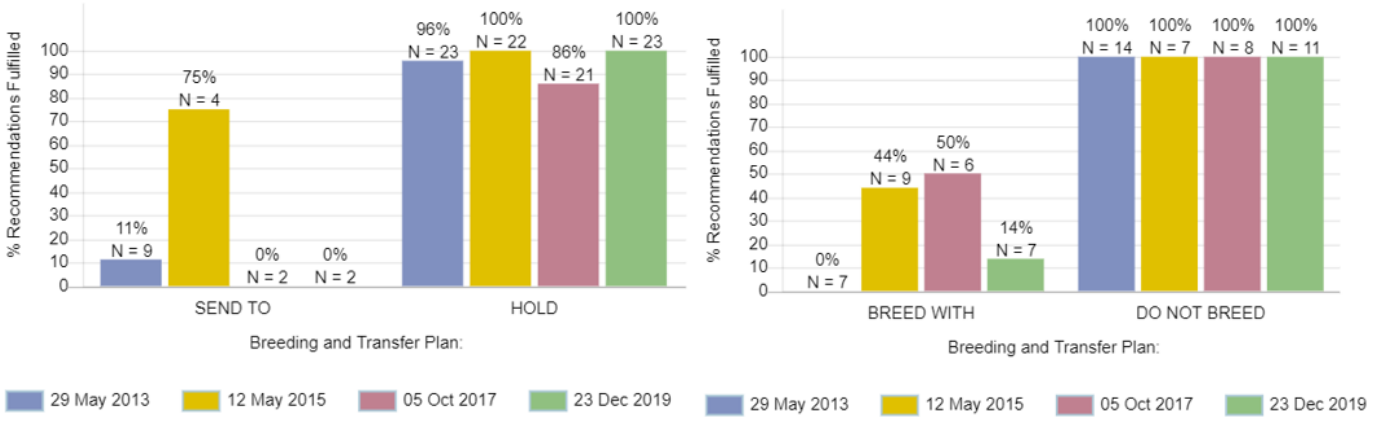

Figure 4. Recommendation outcomes by transfers (left) and breeding (right) for the past Aye-aye SSP Breeding and Transfer Plans. *N* represents the number of recommendations scored for each recommendation type, per plan, and the number represents the percentage recommendations fulfilled. Please visit PMCTrack.org or contact pmctrack@lpzoo.org for more information or with any questions.

Management Strategies: The current, formally managed population of aye-aye includes 24 animals (9 males, 15 females) distributed among seven AZA facilities. Demographic analyses indicate that approximately 3 to 4 births are needed over the next three years (~1 birth per year) to maintain the population at its current size. If the population grows at its projected rate of 2.9% (life table λ = 1.029), then approximately 6 births are needed over the next three years (2 births per year) for the population to reach 26 animals in three years or to reach a target size of 30 animals in a relatively short time frame of roughly eight years. The population has been averaging 1.2 births per year over the last five years (2017-2021), but recent reproduction has purposefully been limited due to lack of space. Although the population's TAG-recommended five-year target size is 30 animals, every Breeding & Transfer Plan since 2011 has noted that lack of space was inhibiting continued breeding. Historical rates of reproduction indicate that the population has the reproductive potential to confidently grow the population towards a larger size, and could be increased to slowly fill additional space if it becomes available.

Gene diversity in the analytical population is 89.55%, which is just below the 90% threshold commonly thought to represent genetic vigor. Gene diversity is projected to decline to ~65% over the next 100 years (see above), suggesting additional imports of unrelated animals ultimately will be necessary to support long-term gene diversity maintenance. Given that the parameters used for genetic projections are generally quite reasonable, its unlikely long-term gene diversity retention can be notably improved through management alone and additional imports of unrelated animals ultimately will be necessary to support long-term gene diversity maintenance. **Given that the population is generally demographically robust and not all females require breeding recommendations, animals with low and well-matched mean kinships have been prioritized for breeding to support gene diversity retention and slow gene diversity loss across the population.** As with most AZA-managed programs, breeding recommendations also aim to limit inbreeding and minimize differences between sire and dam kinships. **Although additional exports to Europe are possible, exports are no longer being considered as the primary means of demographic management to regularly create space for additional breeding.** Thus, at this time, the number of breeding recommendations is intended to maintain the population's current size of 24 animals. In order to prevent exceeding carrying capacity, breeding facilities are asked to breed once every 3 years ONLY if they are able to hold offspring long-term.

This is a 3-year plan (2022-2025). Interim recommendations will continue to be made as needed until another full set of recommendations are produced. Recommendations contained in this plan supersede all previous recommendations.

Table 3: Historic reproduction and future population goals.

Current Reproductive Goals Summary		
	Number of Births Needed per Year over the next 3 Years	**Target Population Size**
To maintain current population size (λ = 1.00)	1	24
To grow to the RCP target population size in 8 years (Kt = 30; λ = 1.029)	2	30
Reproductive Goals Summary from the Last BTP (2019)		
Number of females recommended to breed	7	
Number of births since then (12/23/19 –5/24/22)	2	
Average Number of Births/Hatches in the SSP Population		
Average number of births per year, from the past five years (range)	1.2 (0 – 2)	

At this time, the SSP:

1. **Recommends four females to breed at three facilities.** An additional four females were given multiple breeding options pending space availability. One of the recommended four females has previously produced offspring. Each female recommended to breed is expected to produce a maximum of one offspring over the next three years. Because space for placing offspring is currently very limited, institutions with breeding recommendations should **only** breed their animals at their discretion if they have space to house mature offspring long-term.

2. **Recommends five transfers to establish new breeding pairs.** One institution will be temporarily lost through these transfers.

Breeding and Transfer Recommendations by Facility

CINCINNAT

Cincinnati Zoo & Botanical Gardens
Cincinnati, OH

Facility Note: The transfer of F228 (Fady) can only occur after her current infant (M252) is independent (in approximately 2 years) and only if DUKE is able to receive Medea at that time. Please check with the SSP Coordinator before completing transfers. Space for placing new offspring currently continues to be very limited. Breed the recommended pair at your discretion, **only** if you have space to house mature offspring.

ID	Local ID	Sex	Age	Name	Disposition	Location	Breeding	With	Notes
175	111024	F	17	Medea	SEND TO	DUKE PRIM	DO NOT BREED		
191	112022	M	13	Nify	HOLD	CINCINNAT	BREED WITH	228	
228	7339	F	6	Fady	RECEIVE FROM	DUKE PRIM	BREED WITH	191	

CLEVELAND

Cleveland Metroparks Zoo
Cleveland, OH

ID	Local ID	Sex	Age	Name	Disposition	Location	Breeding	With	Notes
134	111102	F	27	Caliban	HOLD	CLEVELAND	DO NOT BREED		excluded

DENVER

Denver Zoological Gardens
Denver, CO

Facility Note: Space for placing new offspring is currently very limited; this pair is not recommended to breed at this time.

Please place both females on contraception and update the SSP Coordinator & Vice-Coordinator on the social dynamics of this trio, as it will provide valuable information on potential social groupings for this species.

ID	Local ID	Sex	Age	House Name	Disposition	Location	Breeding	With	Notes
188	A14272	F	14	Bellatrix	HOLD	DENVER	DO NOT BREED		contracept
202	A15122	M	11	Smeagol	HOLD	DENVER	DO NOT BREED		
242	A18173	F	3	Tonks	HOLD	DENVER	DO NOT BREED		contracept

DUKE PRIM

Duke Lemur Center
Durham, NC

Facility Note: Space for placing new offspring is currently very limited. Breed the recommended pairs at your discretion, only if you have space to house mature offspring. Two sets of pairings have been provided: Priority one includes the three animals from San Diego Zoo; Priority two includes your current holding.

Priority one pairs for current space

1) M176 x F183 (or see note below for alternative pairing)
2) M201 x F244

Priority two pairs if additional space becomes available

1) M104 x F169
2) M201 x F137
3) M252 x F169

*If there are concerns that F237 (Agatha) and F245 (Melisandre) have not yet bred, either female or both (pending space) may breed with M176 instead of F183 (Claudia).

ID	Local ID	Sex	Age	Name	Disposition	Location	Breeding	With	Notes
104	6202	M	35	Poe	HOLD	DUKE PRIM	SEE NOTES		founder
137	6674	F	26	Ardrey	HOLD	DUKE PRIM	SEE NOTES		
158	6786	F	20	Lucrezia	HOLD	DUKE PRIM	DO NOT BREED		excluded
169	6821	F	18	Medusa	HOLD	DUKE PRIM	SEE NOTES		
176	514134	M	17	Nirina	RECEIVE FROM	SANDIEGOZ	SEE NOTES		Genetic priority
183	100032	F	16	Claudia	RECEIVE FROM	SANDIEGOZ	SEE NOTES		Genetic priority
201	6975	M	11	Grendel	HOLD	DUKE PRIM	SEE NOTES		
228	7339	F	6	Fady	SEND TO	CINCINNAT	BREED WITH	191	SEE NOTES
237	7279	F	4	Agatha	HOLD	DUKE PRIM	SEE NOTES		
244	100068	M	2	Aloka	RECEIVE FROM	SANDIEGOZ	SEE NOTES		Genetic priority
245	7336	F	2	Melisandre	HOLD	DUKE PRIM	SEE NOTES		
252	7413	M	0	Binx	HOLD	DUKE PRIM	DO NOT BREED		juvenile

OMAHA

Omaha's Henry Doorly Zoo
Omaha, NE

Facility Note: Space for placing new offspring is currently very limited. Breed the recommended pair at your discretion, **only** if you have space to house mature offspring.

ID	Local ID	Sex	Age	Name	Disposition	Location	Breeding	With	Notes
148	20263	M	23	Warlock	HOLD	OMAHA	BREED WITH	210	
210	25714	F	10	Elphaba	HOLD	OMAHA	BREED WITH	148	

PHILADELP

The Philadelphia Zoo
Philadelphia, PA

Facility Note: Space for placing new offspring is currently very limited. Please continue to hold F141 (Kali) and F233 (Damien) together. If the females break apart, please contact the SSP Coordinator and Vice-Coordinator regarding contracepting one or both females in attempts to keep them together for longer. If you choose to contracept one of the females, Damien would be the better female to contracept due to her lower genetic value.

ID	Local ID	Sex	Age	Name	Disposition	Location	Breeding	With	Notes
141	105195	F	24	Kali	HOLD	PHILADELP	DO NOT BREED		
157	104668	M	21	Tolkein	HOLD	PHILADELP	DO NOT BREED		
213	104918	M	9	Loki	HOLD	PHILADELP	DO NOT BREED		
233	105239	F	5	Damien	HOLD	PHILADELP	DO NOT BREED		

SANDIEGOZ

San Diego Zoo
San Diego, CA

Facility Note: Schedule moves within the next year pending death of M104. Facility to be demolished in 2025 for new construction.

ID	Local ID	Sex	Age	Name	Disposition	Location	Breeding	With	Notes
176	514134	M	17	Nirina	SEND TO	DUKE PRIM	BREED WITH	183	alternative pairing: 237 and/or 245
183	100032	F	16	Claudia	SEND TO	DUKE PRIM	BREED WITH	176	
244	100068	F	2	Aloka	SEND TO	DUKE PRIM	BREED WITH	201	

Appendices

A. Analytical Assumptions

No pedigree assumptions were necessary.

B. Summary of Data Exports

Studbook Name	Aye-aye
Studbook Currentness Date	04/27/22
Studbook Software and version #	ZIMS for Studbooks v 3.0
Overlay Name (if applicable)	N/A
PMx version #	1.6.2.20220314
.fed file	N/A
Descriptive Survival Statistics Report	report is archived with PMC/AZA and Median Life Expectancy can be viewed here: https://www.aza.org/species-survival-statistics

PMx Project: AyeAye_SSP_2022Apr28
Created: 2022-04-28

Studbook information:
Data compiled by: Dean Gibson
Scope of data: AZA Regional

Primary data file:
zims.zims
Filter conditions:
Dates: 1987-01-01 to 2022-04-28
Association: AZA

Moves data files:
genetic.csv
demographic.csv
Filter conditions:
Dates: 1987-01-01 to 2022-04-28
Association: AZA

Census data file:
Exchens.txt
Filter conditions:
Dates: annual census taken on 12/31
Association: AZA

There is one birth to parents with unknown ages that has been added in proportion to known aged parents. This is 2% of TOTAL births (N=47).

Sustainability Partners: none

C. Animals Excluded from Genetic Analyses

ID	Location	Sex	Age	Reason for Exclusion
134	CLEVELAND	F	27	medical exclusion
158	DUKE PRIM	F	20	medical exclusion

D. Life Tables

Px = survival; Qx = mortality; Lx = cumulative survivorship; Mx = fecundity; Ex = life expectancy; Vx = expected future reproduction, At Risk (Qx and Mx) = number of animals corresponding values are estimated from.

Ex not calculated because oldest male in demographic selection (SB# 104) is still living.
Qx for age class 35 changed to 1.0 for all analyses, with no notable impact.

MALES											
Age	**Px**	**Mid Px**	**Qx**	**Risk Qx**	**Lx**	**Mid Lx**	**Mx**	**Risk Mx**	**Ex**	**Vx**	**Cx**
0	0.837	0.911	0.163	17.303	1.000	0.919	0.000	17.303	---	1.089	0.072
1	1.000	1.000	0.000	17.501	0.837	0.837	0.000	17.501	---	1.235	0.064
2	1.000	1.000	0.000	18.501	0.837	0.837	0.000	18.501	---	1.277	0.061
3	1.000	1.000	0.000	17.915	0.837	0.837	0.028	17.916	---	1.321	0.059
4	1.000	0.971	0.000	17.000	0.837	0.837	0.030	17.006	---	1.337	0.057
5	0.941	0.937	0.059	15.710	0.837	0.813	0.034	15.711	---	1.392	0.054
6	0.933	0.891	0.067	14.444	0.788	0.762	0.113	14.446	---	1.499	0.049
7	0.846	0.917	0.154	12.378	0.735	0.679	0.118	12.381	---	1.608	0.042
8	1.000	1.000	0.000	11.000	0.622	0.622	0.093	11.002	---	1.682	0.037
9	1.000	0.958	0.000	11.252	0.622	0.622	0.182	11.255	---	1.643	0.036
10	0.917	0.957	0.083	11.214	0.622	0.596	0.135	11.215	---	1.577	0.033
11	1.000	1.000	0.000	10.742	0.570	0.570	0.278	10.748	---	1.559	0.031
12	1.000	0.944	0.000	9.000	0.570	0.570	0.057	9.000	---	1.324	0.030
13	0.889	0.941	0.111	8.110	0.570	0.539	0.057	8.111	---	1.388	0.027
14	1.000	1.000	0.000	7.000	0.507	0.507	0.291	7.005	---	1.463	0.025
15	1.000	1.000	0.000	7.000	0.507	0.507	0.146	7.005	---	1.211	0.024
16	1.000	1.000	0.000	7.000	0.507	0.507	0.219	7.004	---	1.102	0.023
17	1.000	1.000	0.000	6.400	0.507	0.507	0.158	6.406	---	0.913	0.022
18	1.000	1.000	0.000	6.000	0.507	0.507	0.170	6.001	---	0.781	0.022
19	1.000	1.000	0.000	6.000	0.507	0.507	0.000	6.000	---	0.632	0.021
20	1.000	1.000	0.000	6.000	0.507	0.507	0.170	6.005	---	0.654	0.020
21	1.000	0.900	0.000	5.321	0.507	0.507	0.085	5.322	---	0.501	0.020
22	0.800	0.889	0.200	4.408	0.507	0.456	0.102	4.409	---	0.477	0.017
23	1.000	1.000	0.000	3.885	0.406	0.406	0.000	3.885	---	0.437	0.015
24	1.000	1.000	0.000	3.000	0.406	0.406	0.170	3.001	---	0.452	0.014
25	1.000	1.000	0.000	3.000	0.406	0.406	0.000	3.002	---	0.292	0.014
26	1.000	1.000	0.000	3.000	0.406	0.406	0.000	3.000	---	0.302	0.013
27	1.000	1.000	0.000	3.000	0.406	0.406	0.000	3.000	---	0.312	0.013
28	1.000	1.000	0.000	3.000	0.406	0.406	0.000	3.000	---	0.323	0.012
29	1.000	1.000	0.000	3.000	0.406	0.406	0.170	3.009	---	0.334	0.012
30	1.000	1.000	0.000	3.000	0.406	0.406	0.170	3.011	---	0.170	0.012
31	1.000	0.833	0.000	3.000	0.406	0.406	0.000	3.011	---	0.000	0.011
32	0.667	0.600	0.333	2.644	0.406	0.338	0.000	2.651	---	0.000	0.009
33	0.500	0.667	0.500	1.104	0.270	0.203	0.000	1.104	---	0.000	0.005
34	1.000	1.000	0.000	1.000	0.135	0.135	0.000	1.000	---	0.000	0.003

FEMALES											
Age	**Px**	**Mid Px**	**Qx**	**Risk Qx**	**Lx**	**Mid Lx**	**Mx**	**Risk Mx**	**Ex**	**Vx**	**Cx**
0	0.863	0.886	0.137	22.889	1.000	0.931	0.000	22.889	23.725	1.074	0.059
1	0.913	0.955	0.087	21.488	0.863	0.825	0.000	21.488	25.647	1.242	0.051
2	1.000	1.000	0.000	20.526	0.788	0.788	0.000	20.526	25.821	1.333	0.048
3	1.000	1.000	0.000	19.173	0.788	0.788	0.000	19.173	24.821	1.365	0.047
4	1.000	0.972	0.000	18.896	0.788	0.788	0.079	18.896	23.821	1.399	0.045
5	0.944	0.971	0.056	16.205	0.788	0.766	0.122	16.205	23.473	1.391	0.043
6	1.000	1.000	0.000	15.088	0.744	0.744	0.100	15.088	23.134	1.339	0.041
7	1.000	1.000	0.000	15.000	0.744	0.744	0.133	15.000	22.134	1.269	0.040
8	1.000	0.969	0.000	15.441	0.744	0.744	0.158	15.441	21.134	1.164	0.039
9	0.938	0.968	0.063	15.564	0.744	0.721	0.194	15.564	20.783	1.063	0.037
10	1.000	0.964	0.000	15.118	0.697	0.697	0.103	15.118	20.443	0.920	0.035
11	0.929	0.963	0.071	13.151	0.697	0.673	0.000	13.151	20.163	0.869	0.033
12	1.000	1.000	0.000	13.000	0.648	0.648	0.115	13.000	19.900	0.924	0.031
13	1.000	1.000	0.000	12.038	0.648	0.648	0.042	12.038	18.900	0.829	0.030
14	1.000	1.000	0.000	11.699	0.648	0.648	0.083	11.699	17.900	0.807	0.029
15	1.000	1.000	0.000	11.000	0.648	0.648	0.091	11.000	16.900	0.741	0.029
16	1.000	0.950	0.000	10.340	0.648	0.648	0.141	10.340	15.900	0.666	0.028
17	0.900	0.947	0.100	9.129	0.648	0.615	0.000	9.129	15.684	0.566	0.026
18	1.000	1.000	0.000	7.553	0.583	0.583	0.196	7.553	15.500	0.613	0.024
19	1.000	1.000	0.000	7.000	0.583	0.583	0.000	7.000	14.500	0.426	0.023
20	1.000	1.000	0.000	6.762	0.583	0.583	0.083	6.762	13.500	0.437	0.023
21	1.000	1.000	0.000	6.000	0.583	0.583	0.000	6.000	12.500	0.362	0.022
22	1.000	1.000	0.000	6.000	0.583	0.583	0.083	6.000	11.500	0.371	0.022
23	1.000	1.000	0.000	6.000	0.583	0.583	0.083	6.000	10.500	0.295	0.021
24	1.000	1.000	0.000	5.326	0.583	0.583	0.000	5.326	9.500	0.217	0.021
25	1.000	1.000	0.000	5.000	0.583	0.583	0.100	5.000	8.500	0.222	0.020
26	1.000	1.000	0.000	4.055	0.583	0.583	0.125	4.055	7.500	0.125	0.020
27	1.000	0.833	0.000	3.696	0.583	0.583	0.000	3.696	6.500	0.000	0.019
28	0.667	0.800	0.333	2.342	0.583	0.486	0.000	2.342	6.600	0.000	0.016
29	1.000	1.000	0.000	2.000	0.389	0.389	0.000	2.000	7.000	0.000	0.012
30	1.000	1.000	0.000	2.000	0.389	0.389	0.000	2.000	6.000	0.000	0.012
31	1.000	1.000	0.000	2.000	0.389	0.389	0.000	2.000	5.000	0.000	0.012
32	1.000	0.750	0.000	2.000	0.389	0.389	0.000	2.000	4.000	0.000	0.011
33	0.500	0.667	0.500	1.863	0.389	0.291	0.000	1.863	4.000	0.000	0.008
34	1.000	1.000	0.000	1.000	0.194	0.194	0.000	1.000	4.500	0.000	0.005

E. Ordered Mean Kinship List

These lists are current to May 2022 and values are subject to change with any birth/hatch, death, import, export, inclusion, exclusion, or changes in pedigree or pedigree assumptions.

Population MK = 0.1045

Males

ID	MK	Known	Age	Location
176	0.0536	100	17	SANDIEGOZ
148	0.0833	100	23	OMAHA
191	0.0982	100	13	CINCINNAT
201	0.0982	100	11	DUKE PRIM
252	0.1034	100	0	DUKE PRIM
104	0.1042	100	35	DUKE PRIM
157	0.1161	100	21	PHILADELP
213	0.1190	100	9	PHILADELP
202	0.1250	100	11	DENVER

Females

ID	MK	Known	Age	Location
244	0.0789	100	2	SANDIEGOZ
228	0.0848	100	6	DUKE PRIM
183	0.0863	100	16	SANDIEGOZ
169	0.0982	100	18	DUKE PRIM
210	0.1057	100	10	OMAHA
137	0.1071	100	26	DUKE PRIM
141	0.1071	100	24	PHILADELP
237	0.1131	100	4	DUKE PRIM
245	0.1146	100	2	DUKE PRIM
175	0.1176	100	17	CINCINNAT
188	0.1235	100	14	DENVER
233	0.1235	100	5	PHILADELP
242	0.1362	100	3	DENVER

F. Definitions

Management Terms (as of December 2021)

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 Sustainability Partner 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 facilities is voluntary. Yellow SSP Programs are subject to AZA's Sustainability Partner Policy.

Red Species Survival Plan® (Red SSP) Program – A Red SSP Program has a population size of twenty or more animals managed among three or more participating AZA facilities. If a population does not meet these minimum criteria, but has an IUCN designation of Critically Endangered, Endangered, or Extinct in the Wild, and the TAG has developed three goals to sustain this population, then the population will be considered a Red SSP Program. Red SSPs cannot retain 90% gene diversity for 100 years or 10 generations and participation by AZA facilities is voluntary. Red SSP Programs are subject to AZA's Sustainability Partner Policy.

Candidate Program – A Candidate Program either has a population size of fewer than twenty individuals and/or found at fewer than three AZA facilities or it does not yet have a completed studbook so the population size is unclear. A Candidate Program is overseen by the TAG, with no additional AZA accountability requirements.

Sustainability Partners – AZA Animal Population Management (APM) Committee approved wildlife facilities that regularly exchange animals with AZA-accredited facilities and certified related facilities, typically as part of the Species Survival Plan® (SSP) Program Breeding and Transfer Plan or other SSP Program management process.

Full Participation – AZA policy stating that all AZA accredited facilities 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 facility 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 facilities 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 https://www.aza.org/board-approved-policies-and-position-statements.

Currentness Date – The date when the entire studbook is updated. This equates to the first date you received an update after requesting updates from all the facilities included in your studbook.

Demographic Terms

Age Distribution – A visual representation of the numbers or percentages of individuals in various age and sex classes.

Ex, Life Expectancy – The 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. A lambda of 1.11 means an 11% per year increase; a lambda of 0.97 means a 3% decline in size per year. The three lambdas highlighted in this BTP are: 1) Life Table, from the PMx life tables, the change in the population based on the demographic regional and date window exported from the studbook, the life table lambda is the rate at which the population would be expected to grow (in the future) given the birth and death rates reported in the life tables and assuming a stable age distribution (does NOT factor in imports or exports); 2) 5-year, from the studbook census, the 5-year lambda is calculated from observed changes in population size over the last 5 years and includes births, deaths, imports and exports; and 3) Projected, from the PMx stochastic 20-year projections (includes confidence intervals), models how the population is predicted to grow or decline over the next 20 years given the birth and death rates from the life tables and the age structure of the current population.

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.

Median Life Expectancy (MLE) – The 'typical' age at which an average animal is expected to live; 50% will die before the median life expectancy and 50% die after. The MLE reported in Breeding and Transfer Plans (BTPs) and Survival Stats Reports, does excludes individuals that did not survive to their first birthday. The MLE obtained from population management software (PM2000, PMx, ZooRisk) or from life tables in BTPs (e.g., where Lx = 0.5) will be lower because they include those individuals that did not survive to their first birthday in order to project the correct number of births needed. A Survival Statistics Library is maintained for most AZA Animal Programs on the AZA website: https://www.aza.org/species-survival-statistics.

Maximum Longevity – The maximum age at which we have observed a species to live. If the oldest observed animal is currently living, we do not yet know the maximum longevity.

Mx, Fecundity – The average number of same-sexed offspring born to animals in that age class. Because studbooks typically have relatively small sample sizes, studbook software calculates Mx as 1/2 the average number of offspring 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 an age class; is conditional on an individual being alive at the beginning of the age class. Alternatively, the proportion of individuals that survive from the beginning of one age class to the next.

Qx, Mortality – The probability that an individual of age *x* dies during an age class (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.

Target Population Size (TPS) – The desired number of SSP animals to be held across AZA and approved partner facilities over a specific, stated timeframe. This number is determined with consideration for program roles and goals (genetic, demographic, and others), logistical constraints, spatial competition with other TAG-managed species, and other population-specific concerns. Target Population Size is determined by the Taxon Advisory Group (TAG) and published in their Regional Collection Plan (RCP).

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

Genetic Terms

Allele – Alternate forms of DNA at a particular position in a genome (genetic locus). Alleles represent the most basic form of genetic diversity.

Gene Diversity (GD) – The probability that two alleles randomly sampled from the same genetic locus across a population are not identical by descent. Gene diversity is calculated relative to a population’s founders, which are assumed to be unrelated and not inbred, and is the proportional diversity retained by the current, descendant population.

Effective Population Size (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 allele 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 allele frequency drift is measured in the current generation). More specifically, PMx software uses the definition as the size of the current population that have produced offspring, assuming that there are current breeders, that these current breeders have a Poisson distribution of family sizes, that none of the current breeders are now post-reproductive, and none of the not-yet-breeding adults will breed.

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 of wild-caught individuals (founders) that represent 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 – The proportion of the alleles in the living, descendant population that are derived from that founder.

Inbreeding Coefficient (F) – The probability that the two alleles present at an individual’s genetic locus are identical by descent (i.e., both alleles originated from an ancestor common to both the individual’s parents).

Mean Kinship (MK) – The mean (or average) kinship coefficient between an animal and all animals (including itself) in the living, captive-born population. An individual’s mean kinship is a measure of how well its alleles are represented within a population. Animals with low mean kinships have few relatives, are from under-represented founder lineages, and have transmitted few of their alleles to the next generation; these individuals should be prioritized for breeding to slow a population’s gene diversity loss.

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

G. AZA Animal Population Management (APM) Committee Disclaimers

as of June 2019

This Animal Program is currently a Red SSP and recommendations proposed are non-binding – participation is voluntary. Transfers to non-AZA facilities must comply with each facility's acquisition/transfer policy, in accordance with the AZA Policy on Responsible Population Management. APM Committee-approved Sustainability Partners are expected to agree and abide by AZA's Code of Professional Ethics, SSP Full Participation Policy, Policy on Responsible Population Management, and Accreditation Standards related to animal care and welfare.

H. Directory of Institutional Representatives

Contact Name (IR or Advisor)	Mnemonic – Facility Name	Email Address	Phone
Matt Spence	CINCINNAT Cincinnati Zoo & Botanical Gardens	matt.spence@cincinnatizoo.org	(513) 559-8356
Tad Schoffner	CLEVELAND Cleveland Metroparks Zoo	tad@clevelandmetroparks.com	(216) 635 - 3335
Matt Lenyo	DENVER Denver Zoological Gardens	MLenyo@denverzoo.org	720-337-1500
Julie McKinney – Vice Coordinator Britt Keith	DUKE PRIM Duke Lemur Center	julie.mckinney@duke.edu britt.keith@duke.edu	(919) 401-7224
Christie Eddie	OMAHA Omaha's Henry Doorly Zoo	christiee@omahazoo.com	(402) 557 - 6932
Michael Stern	PHILADELP The Philadelphia Zoo	stern.michael@phillyzoo.org	(215) 243-5352
Dean Gibson - SSP Coordinator	SANDIEGOZ San Diego Zoo	dgibson@sdzwa.org	(619) 557 - 3985