Population Analysis & Breeding and Transfer Plan

Snowy Owl (*Bubo scandiacus*) AZA Species Survival Plan® Yellow Program

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PMC Population Management Center

LINCOLN PARK ZOO.

ASSOCIATION OF ZOOS & AQUARIUMS

Executive Summary
Species Survival Plan® for the Snowy Owl (*Bubo scandiacus*)

At the time of analyses, the Snowy Owl SSP population consists of 63 (32 males, 31 females) birds at 23 AZA (25.24.0) and eight non-AZA (7.7.0) institutions. Additionally, two new AZA and one non-AZA institution will be added to the SSP because of these recommendations. A target population size of 150 animals was set by the Raptor Taxon Advisory Group (TAG) in their Regional Collection Plan (2015); however, following recent discussions with the Raptor TAG Chair and the SSP Coordinator a target size of 100 has been set for the species at this time. Under AZA's current sustainability designations, this population qualifies as a Yellow SSP Program.

Based on the North American regional analytical studbook, the current gene diversity in the snowy owl population is 95.72% and is equivalent to that of about 12 unrelated animals (FGE = 11.67). Long-term projections based on a projected growth rate of 0% (lambda = 1.00), indicate that gene diversity will decline to approximately 55% over the next 100 years. When gene diversity falls below 90% of that in the founding population, it is expected that reproduction will be increasingly compromised by, among other factors, smaller clutch sizes, lower hatch weights, and greater hatchling mortality. Several management strategies could improve gene diversity; improving the population growth rate, increasing the effective population size (number of animals breeding), equalizing founder representation by using mean kinship to select breeding animals, and recruiting or acquiring additional founders.

Demography

Current size of SSP population (N) – Total (Males.Females.Unknown Sex)	63 (32.31.0)
Number of individuals excluded from genetic analyses	10 (4.6.0)
Population size following exclusions	53 (28.25.0)
Target population size (Kt) (updated 2017)	100
Mean generation time (T, years)	9.7
Population Growth Rates (λ; lambda)* Historical / 5-year / Projected	0.994 / 1.027 / 0.963<>0.994<>1.020

*Historical from life tables (N.AMERICA, 1975 – present); 5 – year from PopLink census (SnowyOwl_Oct2017.FED, 2013-2017); Projected from PMx stochastic 20 year projections bounded by 95% confidence intervals

Genetics**

	Current	Potential
Founders	37	13 additional
Founder genome equivalents (FGE)	11.67	30.68
Gene diversity (GD %)	95.72	98.37
Population mean kinship (MK)	0.0428	--
Mean inbreeding (F)	0.0082	--
Effective population size/potentially breeding population (Ne / N)	0.1805	--
Percentage of pedigree known before assumptions & exclusions	57	--
Percentage of pedigree known after assumptions & exclusions	100	--
Percentage of pedigree certain after assumptions & exclusions	96.2	--
Projections		
Years to 90% gene diversity	11	12
Years to 10% loss of gene diversity	19	25
Gene diversity at 100 years from present (%)	55.1	68.9
	Assuming λ = 1.00	Assuming λ = 1.02, Target size = 100

**Based on an analytical studbook (SnowyOw_08Oct2017 + PMC 2014) with pedigree assumptions intended to estimate relatedness and inbreeding, which may over- or under-estimate gene diversity.

Demographic analyses indicate that approximately eight hatches are needed to maintain the current population size (λ = 1.00). To reach the target population size of 100 in 25 years, approximately 9 to 14 hatches are required per year (λ = 1.019). With an average of 3.8 hatches annual observed over the past five years, increased focus on reproduction and/or imports will be necessary in order to meet these goals. The number of pairs recommended to breed is intended to begin to grow toward this goal as well as to replace individuals lost to natural attrition. As with most SSPs, recommended pairings have been determined with consideration of demographic goals, mean kinship, population change in gene diversity, maximum avoidance of inbreeding, and the needs of individual institutions in an attempt to increase and maintain gene diversity for as long as possible.

Summary Actions: The SSP recommends 17 females to breed and 13 transfers to facilitate new breeding pairs or meet institutional requests.

Table of Contents

Acknowledgements

The Snowy Owl SSP planning meeting was held 12 October 2017 at Lincoln Park Zoo in Chicago, Illinois and was attended by the following:

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Description of Population Status

Species Survival Plan® for the Snowy Owl (*Bubo scandiacus*)

Introduction: At the time of analyses, the Snowy Owl SSP population consists of 63 (32 males and 31 females) birds at 23 AZA (25.24.0) and eight non-AZA (7.7.0) institutions within North America. Additionally, two new AZA and one non-AZA institution will be added to the SSP as a result of these recommendations. The Raptor Taxon Advisory Group (TAG) set the target size for this population at 150 animals (2015 Regional Collection Plan); however, following recent discussions with the Raptor TAG Chair and the SSP Coordinator a target size of 100 has been set for the species at this time. At present, the population currently qualifies as a Yellow SSP under AZA's sustainability designations.

Comprehensive genetic and demographic analyses of the snowy owl population were performed in October 2017 and January 2018, resulting in this current Breeding and Transfer Plan, which is the second formal plan produced for this species. Analyses of an analytical version of the North American Regional Snowy Owl studbook (current to 28 June 2017) were performed using PopLink 2.4 and PMx v1.4.20160804. Recommendations contained in this plan supersede those made by earlier plans.

Status & Conservation: In 2017, the IUCN uplisted *Bubo scandiacus* (formerly *Nyctea scandiacus*) from Least Concern to Vulnerable on their Red List due to rapid population declines, especially in North America. According to the IUCN, there remains some uncertainty about the overall rate of decline, and if it proves to be even higher, the species may be eligible for further uplisting to Endangered. The species is listed on CITES Appendix II and is not listed with U.S. Fish and Wildlife Service.

Analytical Studbook: This population currently has a 57% known ancestral pedigree. An analytical overlay was developed to address the unknown parentage in the pedigree, based on information provided by the SSP Coordinator and the originating institutions (Appendix A). Additional assumptions may be developed for the remaining unknown pedigree individuals in the future as more information becomes available. Following these pedigree assumptions and the exclusion of 10 (4.6.0) individuals from the genetic analyses for reasons outlined in Appendix C, the potentially breeding population consists of 53 (28.25.0) individuals with a 100% known pedigree.

Demography: Snowy owls were first recorded in North American institutions in 1897. Small numbers of snowy owls were kept from this time, and although breeding was likely occurring early into the population's history, consistent recording of zoo and aquarium hatches did not begin until the mid-1970s. Since this time, population growth can largely be attributed to zoo hatches with consistent supplementation of rehabilitation animals as well as European imports (Fig. 1). The population reached a peak size of 107 in the early 1990s, but an outbreak of West Nile virus at the turn of the 21st century caused a severe decline in population size to a low of 49 birds in 2008. However, within the past five years, the snowy owl population has begun to recover (average five year $\lambda = 1.027$), in part due to an annual importation of approximately three birds per year into the North American Region from Europe and rehabilitation situations. Annual number of hatches over the last five years have begun to increase (mean = 3.8 per year); however, deaths (mean = 5.8 per year) still outnumber hatches (Fig. 2). Breeding efforts need to be increased in order to grow the population size and minimize reliance on imports.

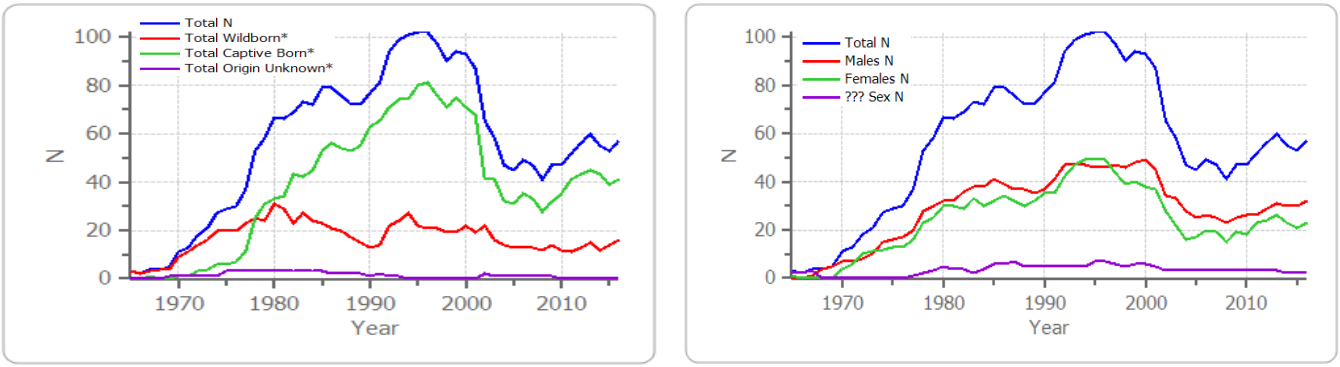

Figure 1. Population census of the North American population of snowy owls by origin (left) and sex (right) from 1965-2017.

The age structure of the potentially breeding population deviates somewhat from stable due to a slight male skew and several empty age classes because of inconsistent growth from year to year. These gaps reflect deaths throughout the age classes due to West Nile virus and inconsistencies in breeding success and survivorship, especially in recent years (Fig. 3). Hatches have been sporadic over the last five years ranging from zero to nine per year. Imports and a recent increase in hatches has created a solid base of younger birds to help offset deaths and support future reproduction in the population. In order to improve this age structure, the SSP should continue to focus on increasing breeding success to produce a steady number of offspring from year to year, which will contribute to demographic stability and offset the need for additional imports to meet institutional requests.

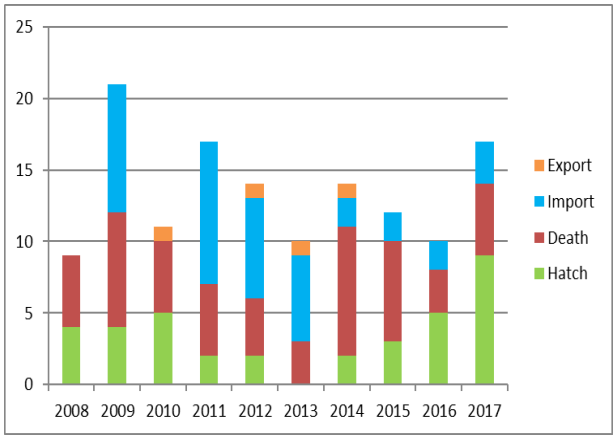

Figure 2. Annual number of hatches, deaths, imports and exports recorded for snowy owls in North American institutions from 2008-2017.

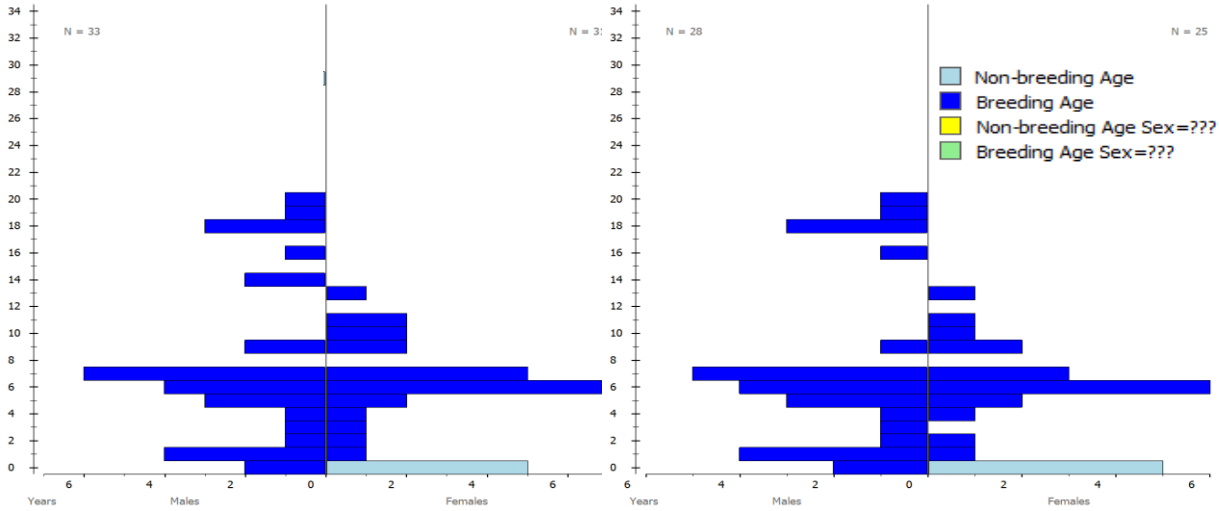

Figure 3. Age distribution of the total SSP Population of snowy owl before exclusions (left; N = 63 (32.31.0)) and the potentially breeding population after exclusions (right; N = 53 (28.25.0)).

Based on studbook data from 1975 to present, first-year mortality is approximately 33% for males and 36% for females (Appendix D). Males and females are reproductively mature at approximately two years of age and continue to reproduce until approximately 20 years old. The oldest male snowy owl on record lived to be 25 (zoo hatch) with the oldest currently living being 20 years old. The oldest zoo hatched female also lived to be 25 years old; however, currently the oldest living female is only 13. If an individual snowy owl survives its first year of life, median life expectancy is 10.2 years. That is, 50% of males and females can be expected to die before this age, and 50% after (See Appendix F for more details).

Demographic projections estimate that to keep this population stable (0% growth) approximately eight hatches are needed in the coming year. Snowy owls can produce up to 12 eggs in one clutch though typically only one to four chicks are allowed to hatch. Hatches are seasonal occurring between April and August with a peak in June and July. The incubation period of this species is approximately 31 days. Although zoo hatches have declined since the West Nile virus outbreak, at the peak of the snowy owl population size between 1985 and 1997, 13 hatches were recorded on average annually (7 – 24 chicks). Based on these averages and a target size of 100, a growth rate of ~2% (λ = 1.018) appears reasonable, requiring 10 to 14 hatches per year over the next 25 years. A focus on reproduction, increased annual hatches and survivorship will be necessary in order to meet these demographic goals.

Genetics: These genetic statistics are based on an analytical studbook with pedigree assumptions intended to estimate relatedness and inbreeding. After these assumptions, the potentially breeding snowy owl population is descended from 37 founders with 13 additional potential founders remaining. Gene diversity in the population is currently 95.72%, equivalent to that found in approximately 12 unrelated individuals (FGE = 11.67). Gene diversity at 100 years from present is estimated to be 68.9% according to projections based on an anticipated growth rate of 2% (λ=1.02) and a target population size of 100 individuals. When gene diversity falls below 90% of that in the founding population, it is expected that reproduction will be increasingly compromised by, among other factors, lower hatch weights and greater chick mortality.

There are several potential founders in the current population, as well as the possibility of additional potential founders being imported into the population from rehabilitation situations. All efforts should be made to recruit these potential founders into the current breeding population in order to retain and increase gene diversity for the long-term. To retain gene diversity for a longer period of time and possibly recruit additional potential gene diversity, individuals with low mean kinship values should be paired and prioritized for breeding in order to equalize the different founder lineages (Fig. 4). Due to the small size of this population and a large number of potential founders, some low mean kinship individuals are in "mismatched" pairings with genetically over-represented individuals in order to achieve demographic stability.

Of note is the small percentage of the potentially breeding population with offspring living in North American institutions (Ne/N = 0.1805, based on three breeding sires and four breeding dams). Long-term projections based on a low effective size ratio (Ne/N, proportion of breeders), predict a rapid loss of gene diversity over time as the genes of just a few founder lineages begin to dominate in frequency. Focusing on successful breeding and increasing the proportion of breeding individuals (Ne/N) will have a large impact on the amount of gene diversity retained and help to prevent demographic collapse.

Genetic Summary*

	2014	**Current**	**Potential**
Founders	*37*	37	13 additional
Founder genome equivalents (FGE)	*11.07*	11.67	30.68
Gene diversity (GD %)	*95.48*	95.72	98.37
Population mean kinship (MK)	*0.0452*	0.0428	-
Mean inbreeding (F)	*0.0229*	0.0082	-
Effective population size /potentially breeding population (Ne / N)	*0.0593 (includes founders)*	0.1805	-
% Pedigree known before assumptions and exclusions	*49.0*	57	-
% Pedigree known after assumptions and exclusions	*90.0*	100	-
% Pedigree certain after assumptions and exclusions	*-*	96.2	-
Projections			
Years to 90% Gene Diversity	*3*	11	12
Years to 10% Loss of Gene Diversity	*6*	19	25
Gene Diversity at 100 Years from Present (%)	*17.6*	55.1	68.9
	Assuming λ = 1.02, Target size = 100	Assuming λ = 1.00	Assuming λ = 1.02, Target size = 100

*Statistics are based on analytical studbook (SnowyOw_08Oct2017+PMC2014) with pedigree assumptions and may not be accurately compared across years due to changes in software, effective population size (Ne/N), generation time (T), and growth rates (λ).

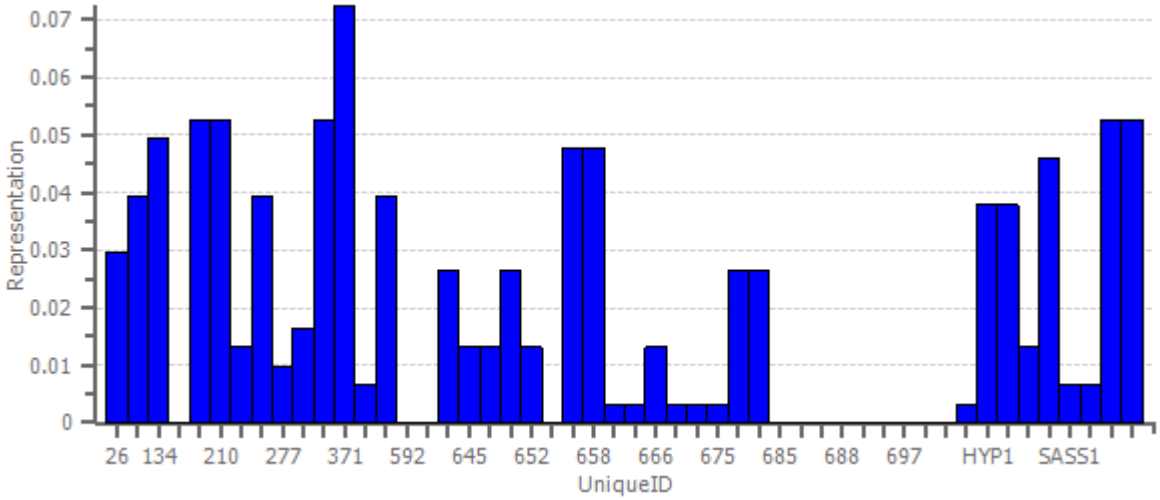

Figure 4. Founder representation graph illustrating the inequality of 37 true and hypothetical founder lineages represented in the current snowy owl population and the 13 potential founders still remaining in the population.

Recommendation Outcomes: The website PMCTrack calculates the outcomes for SSP breeding and transfer recommendations by comparing recommendations to hatches and deaths recorded in the studbook (Fig. 5). Note that there are many reasons that recommendations might not be fulfilled, including interim recommendations issued by the SSP Coordinator, delays in transfers, deaths, etc.; these reasons can be captured using PMCTrack Outcomes Surveys. Future use of these measures will aid the SSP in producing the best recommendations possible. Therefore, SSP participants are always encouraged to communicate successes and shortfalls to the SSP Coordinator.

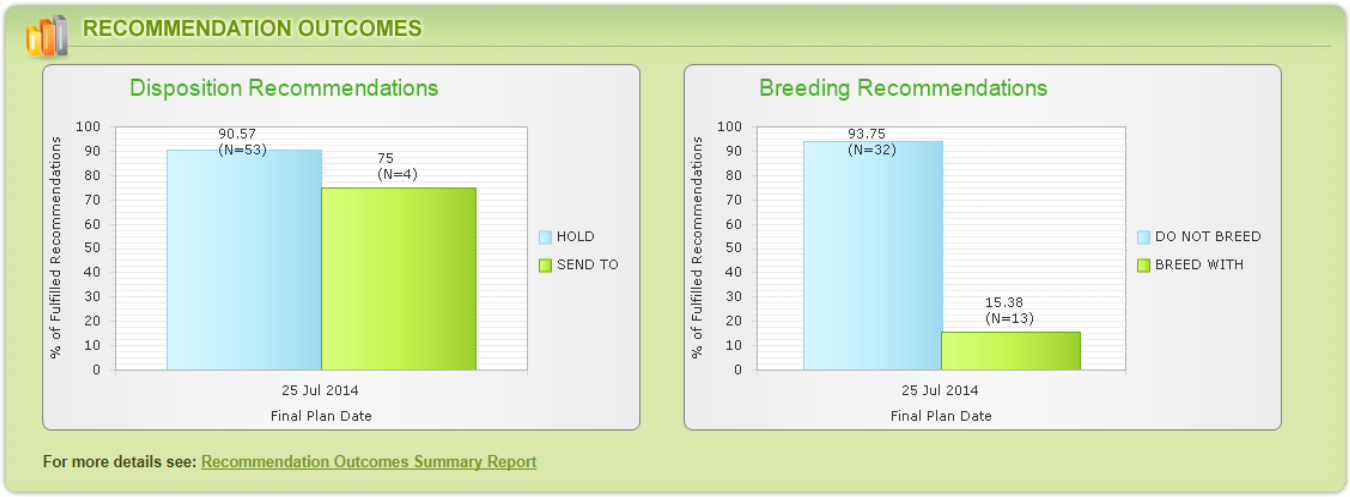

Figure 5. Recommendation outcome graphs by disposition (left) and breeding (right) for the past Snowy Owl SSP Breeding and Transfer Plans. *N* represents the number of recommendations scored for each recommendation type, per plan, and the number represents the percentage recommendations fulfilled. Please visit PMCTrack.org or contact pmctrack@lpzoo.org for more information or with any questions.

Management Strategy: The current snowy owl population consists of 63 (32.31.0) individuals at 23 AZA (25.24.0) and eight non-AZA (7.7.0) institutions. To maintain the current population size (lambda = 1.00), approximately eight hatches are needed in the coming year, and approximately 9 to 14 hatches (or imports) per year are need to grow to the recommended target population size of 100 individuals in 25 years (lambda =1.019).

High demand currently exists for this species, and the SSP recommends interested institutions look to North American facilities to obtain snowy owls. In recent years, institutions have relied on imports from Europe and the wild to meet exhibit needs; however, historical data indicate that a higher number of hatches may be achieved if institutions focus on breeding rather than imports. With efforts put toward reproduction, not only will individual institution's needs be met, but it will also help the population to increase gene diversity and achieve demographic stability for the long-term.

Pairings have been recommended with consideration of mean kinship, maximum avoidance of inbreeding differences in sire and dam mean kinships, and the needs of individual institutions in an attempt to maintain gene diversity for as long as possible. Some "demographic pairs" of genetically valuable individuals with over-represented individuals have been recommended to maintain demographic stability and meet institutional interest.

1. Recommends 17 females for breeding.
    - Institutions recommended to breed are expected to hold offspring for at least one year and encouraged to hold for two years. Please contact the SSP Coordinator with assistance in placing offspring.

2. Recommends 13 transfers to address institutional requests or to make new breeding pairs.

3. The SSP encourages institutions to allow pairs to parent-rear offspring, as it is believed that hand-reared chicks experience delays in breeding and may behave abnormally due to imprinting. If hand-rearing is necessary, please contact the SSP Coordinator for hand-rearing protocols.

4. Institutions contacted by rehabilitation facilities are asked to contact the SSP Coordinator to facilitate the best placement for these individuals.

5. Photoperiod manipulation to match seasonal day length patterns in nature has been shown to illicit earlier seasonal breeding in snowy owls and may help with infant mortality. Please contact the SSP Coordinator with any questions.

6. Institutions are encouraged to investigate the origins of their unknown pedigree animals in order to help determine relatedness and genetic importance of animals within the living population.
    - Animals coming from unknown sources, private breeders, or dealers often cannot be assumed to be unrelated to the zoo population. Institutions considering obtaining individuals from these sources should make every effort to determine pedigree information for the genetic health of the population.

7. Institutions interested in obtaining or placing snowy owls should contact the SSP Coordinator to coordinate transfers that will facilitate genetic and demographic stability.
    - Interested institutions in warmer climates are encouraged to contact the SSP Coordinator concerning exhibit recommendations and requirements.

8. Institutions interested in obtaining snowy owls for education programs are asked to contact the SSP Coordinator to discuss their use as education animals.

Summary of Breeding and Transfer Recommendations
by Studbook ID

SB ID	Location	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
154	WINNIPEG	G00153	F	11	HOLD	WINNIPEG	BREED WITH	~~704~~ 682	Changed during comment period
157	WINNIPEG	H00754	F	---	HOLD	WINNIPEG	BREED WITH	680	
~~217~~	~~SEATTLE~~	~~960340~~	~~M~~	~~29~~	~~HOLD~~	~~SEATTLE~~	~~DO NOT BREED~~	-	~~Excluded – Education Animal~~ (Updated during comment period)
236	CHICAGOLP	22899	F	6	HOLD	CHICAGOLP	BREED WITH	375	
337	TULSA	16373	F	6	HOLD	TULSA	BREED WITH	339	
339	TULSA	15786	M	18	HOLD	TULSA	BREED WITH	337	
343	NY BRONX	B00159	M	18	HOLD	NY BRONX	BREED WITH	624	
375	CHICAGOLP	20436	M	16	HOLD	CHICAGOLP	BREED WITH	236	
390	WATERTOWN	10191	M	18	HOLD	WATERTOWN	DO NOT BREED		
392	HERSHEY	A9.12	F	10	HOLD	HERSHEY	BREED WITH	623	
453	WATERTOWN	21191	F	7	HOLD	WATERTOWN	DO NOT BREED		Excluded – Education Animal
454	NATAVPGH	7920	M	7	HOLD	NATAVPGH	DO NOT BREED		Excluded – Education Animal
455	NASHV ZOO	4727	M	7	HOLD	NASHV ZOO	BREED WITH	554	
464	UTICA	297012	M	20	HOLD	UTICA	DO NOT BREED		
473	AKRON	101198	M	6	HOLD	AKRON	BREED WITH	688	
474	BINGHAMTO	13008	M	6	HOLD	BINGHAMTO	BREED WITH	475	
475	BINGHAMTO	13009	F	6	HOLD	BINGHAMTO	BREED WITH	474	
477	LVZOO	LV0323	M	7	SEND TO	TOLEDO	BREED WITH	648	
478	LOUISVILL	202543	F	7	HOLD	LOUISVILL	BREED WITH	653	
479	MINNESOTA	12333	M	9	HOLD	MINNESOTA	DO NOT BREED		Excluded – Education Animal
~~521~~	~~CRAWFRD W~~	~~UNK~~	~~U~~	~~21~~	~~HOLD~~	~~CRAWFRD W~~	~~DO NOT BREED~~		~~Excluded – Education Animal~~ (Made LTF during comment period)
~~522~~	~~CRAWFRD W~~	~~UNK~~	~~U~~	~~21~~	~~HOLD~~	~~CRAWFRD W~~	~~DO NOT BREED~~		~~Excluded – Education Animal~~ (Made LTF during comment period)
554	NASHV ZOO	3639	F	7	HOLD	NASHV ZOO	BREED WITH	455	
556	BRIDGEPRT	102156	F	7	HOLD	BRIDGEPRT	BREED WITH	656	
557	TOLEDO	10638	M	7	SEND TO	PARAMUS	DO NOT BREED		
558	NY BRONX	B14191	F	13	SEND TO	UTICA	DO NOT BREED		
592	ROCHESTER	105857	F	6	~~SEND TO~~ HOLD	~~JOHN BALL~~ ROCHESTER	~~BREED WITH~~ DO NOT BREED	~~686~~	Changed during comment period
593	SEATTLE	204989	F	5	HOLD	SEATTLE	BREED WITH	700	
595	NORRISTOW	120205	F	6	HOLD	NORRISTOW	DO NOT BREED		Excluded – Education Animal

SB ID	Location	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
623	HERSHEY	200911	M	9	HOLD	HERSHEY	BREED WITH	392	
624	NW TREK	201144	F	6	SEND TO	NY BRONX	BREED WITH	343	
634	GRANBY	B07010	F	10	HOLD	GRANBY	DO NOT BREED		Excluded – Education Animal
642	BALTIMORE	6873	M	5	HOLD	BALTIMORE	BREED WITH	644	
644	BALTIMORE	6874	F	5	HOLD	BALTIMORE	BREED WITH	642	
648	PARAMUS	3044	F	9	SEND TO	TOLEDO	BREED WITH	477	
653	LOUISVILL	202488	M	7	HOLD	LOUISVILL	BREED WITH	478	
655	CALGARY	109039	M	6	HOLD	CALGARY	DO NOT BREED		See Notes
656	BRIDGEPRT	102283	M	5	HOLD	BRIDGEPRT	BREED WITH	556	
680	WINNIPEG	P00042	M	5	HOLD	WINNIPEG	BREED WITH	157	
682	WINNIPEG	N00011	M	6	HOLD	WINNIPEG	~~DO NOT BREED~~ BREED WITH	154	Changed during comment period
685	CALGARY	109309	M	2	HOLD	CALGARY	DO NOT BREED		See Notes
686	NATAVPGH	8523	M	7	~~SEND TO~~ HOLD	~~JOHN BALL~~ NATAVPGH	~~BREED WITH~~ DO NOT BREED	~~592~~	Changed during comment period
687	NATAVPGH	8524	M	4	HOLD	NATAVPGH	DO NOT BREED		
688	BATTLE CR	B15005	F	4	SEND TO	AKRON	BREED WITH	473	
689	BIG BEAR	20896	M	14	HOLD	BIG BEAR	DO NOT BREED		Excluded – Unknown Pedigree
694	KAMLOOPS	4002	M	14	HOLD	KAMLOOPS	DO NOT BREED		Excluded – Medical
695	OCHSNER	2016-1	F	2	HOLD	OCHSNER	BREED WITH	696	Genetically valuable
696	OCHSNER	2016-0	M	2	HOLD	OCHSNER	BREED WITH	695	Genetically valuable
697	SASKATOON	1982	F	9	HOLD	SASKATOON	BREED WITH	699	
698	SASKATOON	2148	F	6	HOLD	SASKATOON	BREED WITH	699	
699	SASKATOON	1516	M	19	HOLD	SASKATOON	BREED WITH	697 or 698	
700	SEATTLE	206144	M	1	HOLD	SEATTLE	BREED WITH	593	
701	TORONTO	49527	F	3	HOLD	TORONTO	DO NOT BREED		Excluded – Unknown Pedigree
702	WINNIPEG	22178	F	1	HOLD	WINNIPEG	DO NOT BREED		
703	WINNIPEG	22184	M	1	HOLD	WINNIPEG	DO NOT BREED		
704	WINNIPEG	22185	M	1	~~HOLD~~ SEND TO	~~WINNIPEG~~ ECOMUSEUM	~~BREED WITH~~ DO NOT BREED	~~154~~	Changed during comment period
705	WINNIPEG	22186	M	1	HOLD	WINNIPEG	DO NOT BREED		
707	TULSA	17958	F	0	HOLD	TULSA	DO NOT BREED		
708	TULSA	17959	M	0	SEND TO	NW TREK	DO NOT BREED		
709	TULSA	17949	F	0	SEND TO	TREVOR	DO NOT BREED		
710	TULSA	17950	F	0	SEND TO	TREVOR	DO NOT BREED		
711	CHICAGOLP	23841	F	0	SEND TO	PARAMUS	DO NOT BREED		
712	CHICAGOLP	23842	F	0	SEND TO	STATEN IS	DO NOT BREED		
713	CHICAGOLP	23845	M	0	SEND TO	LVZOO	DO NOT BREED		

SB ID	Location	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
716	CRAWFRD W	2015-0003	F	11	HOLD	CRAWFRD W	DO NOT BREED		Excluded-Education (Added during comment period)
717	CRAWFRD W	2012-0001	F	7	HOLD	CRAWFRD W	DO NOT BREED		Excluded-Education (Added during comment period)

Breeding and Transfer Recommendations by Institution

AKRON
Akron Zoological Park
Akron, OH

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
473	101198	M	6	HOLD	AKRON	BREED WITH	688	
688	B15005	F	4	RECEIVE FROM	BATTLE CR	BREED WITH	473	

BALTIMORE
Maryland Zoo in Baltimore
Baltimore, MD

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
642	6873	M	5	HOLD	BALTIMORE	BREED WITH	644	
644	6874	F	5	HOLD	BALTIMORE	BREED WITH	642	

BATTLE CR
Binder Park Zoo
Battle Creek, MI

Institutional Note: Institution is temporarily phasing out until new exhibit is built and can accept birds. Please contact SSP Coordinator when ready to receive birds.

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
688	B15005	F	4	SEND TO	AKRON	BREED WITH	473	

BIG BEAR *(non-AZA)*
Moonridge Animal Park
Big Bear Lake, CA

Institutional Note: Please provide SSP with pedigree information for bird.

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
689	20896	M	14	HOLD	BIG BEAR	DO NOT BREED		Excluded – Unknown Pedigree

BINGHAMTO *(non-AZA)*
Binghamton Zoo at Ross Park
Binghamton, NY

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
474	13008	M	6	HOLD	BINGHAMTO	BREED WITH	475	
475	13009	F	6	HOLD	BINGHAMTO	BREED WITH	474	

BRIDGEPRT
Connecticut's Beardsley Zoo
Bridgeport, CT

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
556	102156	F	7	HOLD	BRIDGEPRT	BREED WITH	656	
656	102283	M	5	HOLD	BRIDGEPRT	BREED WITH	556	

CALGARY
Calgary Zoo, Garden & Prehistoric Park
Calgary, Alberta, Canada

Institutional Note: Both males are potential founders (genetically valuable) and could breed with any incoming rehabilitated wild caught females.

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
655	109039	M	6	HOLD	CALGARY	DO NOT BREED		See Notes
685	109309	M	2	HOLD	CALGARY	DO NOT BREED		See Notes

CHICAGOLP
Lincoln Park Zoological Gardens
Chicago, IL

Institutional Note: Contact SSP Coordinator to determine number of eggs to hatch.

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
236	22899	F	6	HOLD	CHICAGOLP	BREED WITH	375	
375	20436	M	16	HOLD	CHICAGOLP	BREED WITH	236	
711	23841	F	0	SEND TO	PARAMUS	DO NOT BREED		
712	23842	F	0	SEND TO	STATEN IS	DO NOT BREED		
713	23845	M	0	SEND TO	LVZOO	DO NOT BREED		

CRAWFRD W *(non-AZA)*
World Bird Sanctuary (Walter Crawford)
Valley Park, MO

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
~~521~~	~~UNK~~	~~U~~	~~21~~	~~HOLD~~	~~CRAWFRD W~~	~~DO NOT BREED~~		~~Excluded – Education Animal~~ Made LTF during comment period.
~~522~~	~~UNK~~	~~U~~	~~21~~	~~HOLD~~	~~CRAWFRD W~~	~~DO NOT BREED~~		~~Excluded – Education Animal~~ Made LTF during comment period.
716	2015-0003	F	11	HOLD	CRAWFRD W	DO NOT BREED		Added during comment period. Excluded – Education/Unknown Pedigree
717	2012-0001	F	7	HOLD	CRAWFRD W	DO NOT BREED		Added during comment period. Excluded – Education

DULUTH
Lake Superior Zoological Sociey
Duluth, MN

Institutional Note: Institution will be prioritized for birds when they become available.

ECOMUSEUM *(new non-AZA institution)*
Ecomuseum
Ste-Anne-de-Bellevue, Quebec, Canada

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
704	22185	M	1	RECEIVE FROM	WINNIPEG	DO NOT BREED		Added during comment period.

GRANBY
Granby Zoo / Zoo de Granby
Granby, Quebec, Canada

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
634	B07010	F	10	HOLD	GRANBY	DO NOT BREED		Excluded – Education Animal

HERSHEY
ZooAmerica (No. American Wildlife Pk.)
Hershey, PA

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
392	A9.12	F	10	HOLD	HERSHEY	BREED WITH	623	
623	200911	M	9	HOLD	HERSHEY	BREED WITH	392	

JOHN BALL
John Ball Zoological Garden
Grand Rapids, MI

Institutional Note: Institution will be prioritized to receive when birds become available.

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
~~592~~	~~105857~~	~~F~~	~~6~~	~~RECEIVE FROM~~	~~ROCHESTER~~	~~BREED WITH~~	~~686~~	Changed during comment period.
~~686~~	~~8523~~	~~M~~	~~7~~	~~RECEIVE FROM~~	~~NATAVPGH~~	~~BREED WITH~~	~~592~~	Changed during comment period.

KAMLOOPS *(non-AZA)*
British Columbia Wildlife Park
Kamloops, BC, Canada

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
694	4002	M	14	HOLD	KAMLOOPS	DO NOT BREED		Excluded – Medical

LOUISVILL
Louisville Zoological Garden
Louisville, KY

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
478	202543	F	7	HOLD	LOUISVILL	BREED WITH	653	
653	202488	M	7	HOLD	LOUISVILL	BREED WITH	478	

LVZOO
Lehigh Valley Zoo
Schnecksville, PA

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
477	LV0323	M	7	SEND TO	TOLEDO	BREED WITH	648	
713	23845	M	0	RECEIVE FROM	CHICAGOLP	DO NOT BREED		

MINNESOTA
Minnesota Zoological Garden
Apple Valley, MN

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
479	12333	M	9	HOLD	MINNESOTA	DO NOT BREED		Excluded – Education Animal

NASHV ZOO
Nashville Zoo at Grassmere
Nashville, TN

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
455	4727	M	7	HOLD	NASHV ZOO	BREED WITH	554	
554	3639	F	7	HOLD	NASHV ZOO	BREED WITH	455	

NATAVPGH
National Aviary in Pittsburgh
Pittsburgh, PA

Institutional Note: Both male 686 and 687 are potential founders (genetically valuable). Please contact SSP Coordinator prior to importing birds, so pedigree can be verified.

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
454	7920	M	7	HOLD	NATAVPGH	DO NOT BREED		Excluded – Education Animal
686	8523	M	7	~~SEND TO~~ HOLD	JOHN BALL	~~BREED WITH~~ DO NOT BREED	~~592~~	Changed during comment period.
687	8524	M	4	HOLD	NATAVPGH	DO NOT BREED		

NORRISTOW
Elmwood Park Zoo
Norristown, PA

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
595	120205	F	6	HOLD	NORRISTOW	DO NOT BREED		Excluded – Education Animal

NW TREK
Northwest Trek Wildlife Park
Eatonville, WA

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
624	201144	F	6	SEND TO	NY BRONX	BREED WITH	343	
708	17959	M	0	RECEIVE FROM	TULSA	DO NOT BREED		

NY BRONX
Bronx Zoo/Wildlife Conservation Society
Bronx, NY

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
343	B00159	M	18	HOLD	NY BRONX	BREED WITH	624	
558	B14191	F	13	SEND TO	UTICA	DO NOT BREED		
624	201144	F	6	RECEIVE FROM	NW TREK	BREED WITH	343	

OCHSNER *(non-AZA)*
Ochsner Park Zoo
Baraboo, WI

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
695	2016-1	F	2	HOLD	OCHSNER	BREED WITH	696	Genetically valuable
696	2016-0	M	2	HOLD	OCHSNER	BREED WITH	695	Genetically valuable

PARAMUS
Bergen County Zoological Park
Paramus, NJ

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
557	10638	M	7	RECEIVE FROM	TOLEDO	DO NOT BREED		
648	3044	F	9	SEND TO	TOLEDO	BREED WITH	477	
711	23841	F	0	RECEIVE FROM	CHICAGOLP	DO NOT BREED		

ROCHESTER
Seneca Park Zoo
Rochester, NY

Institutional Note: Institution will be prioritized to receive a non-flighted rehabilitated bird.

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
592	105857	F	6	~~SEND TO~~ HOLD	~~JOHN BALL~~ ROCHESTER	~~BREED WITH~~ DO NOT BREED	~~686~~	Changed during comment period.

SASKATOON *(non-AZA)*
Saskatoon Forestry Farm and Zoo
Saskatoon, Saskatchewan, Canada

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
697	1982	F	9	HOLD	SASKATOON	BREED WITH	699	
698	2148	F	6	HOLD	SASKATOON	BREED WITH	699	
699	1516	M	19	HOLD	SASKATOON	BREED WITH	697 or 698	

SEATTLE
Woodland Park Zoo
Seattle, WA

Institutional Note: Contact SSP Coordinator to determine number of eggs to hatch.

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
~~217~~	~~960340~~	~~M~~	~~29~~	~~HOLD~~	~~SEATTLE~~	~~DO NOT BREED~~		~~Excluded - Education Animal~~ (Updated during comment period.)
593	204989	F	5	HOLD	SEATTLE	BREED WITH	700	
700	206144	M	1	HOLD	SEATTLE	BREED WITH	593	

STATEN IS *(new AZA institution)*
Staten Island Zoo
Staten Island, NY

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
712	23841	F	0	RECEIVE FROM	CHICAGOLP	DO NOT BREED		

TOLEDO
Toledo Zoological Gardens
Toledo, OH

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
477	LV0323	M	7	RECEIVE FROM	LVZOO	BREED WITH	648	
557	10638	M	7	SEND TO	PARAMUS	DO NOT BREED		
648	3044	F	9	RECEIVE FROM	PARAMUS	BREED WITH	477	

TORONTO

Toronto Zoo
Scarborough, Ontario, Canada

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
701	49527	F	3	HOLD	TORONTO	DO NOT BREED		Excluded - Unknown Pedigree

TREVOR *(new AZA institution)*
Trevor Zoo at Millbrook School
Millbrook, NY

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
709	17949	F	0	RECEIVE FROM	TULSA	DO NOT BREED		
710	17950	F	0	RECEIVE FROM	TULSA	DO NOT BREED		

TULSA
Tulsa Zoo
Tulsa, OK

Institutional Note: Contact SSP Coordinator to determine number of eggs to hatch.

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
337	16373	F	6	HOLD	TULSA	BREED WITH	339	
339	15786	M	18	HOLD	TULSA	BREED WITH	337	
707	17958	F	0	HOLD	TULSA	DO NOT BREED		
708	17959	M	0	SEND TO	NW TREK	DO NOT BREED		
709	17949	F	0	SEND TO	TREVOR	DO NOT BREED		
710	17950	F	0	SEND TO	TREVOR	DO NOT BREED		

UTICA *(non-AZA)*
Utica Zoo
Utica, NY

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
464	297012	M	20	HOLD	UTICA	DO NOT BREED		
558	B14191	F	13	RECEIVE FROM	NY BRONX	DO NOT BREED		

WATERTOWN *(non-AZA)*

NY State Zoo at Thompson Park
Watertown, NY

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
390	10191	M	18	HOLD	WATERTOWN	DO NOT BREED		
453	21191	F	7	HOLD	WATERTOWN	DO NOT BREED		Excluded - Education Animal

WINNIPEG

Assiniboine Park Zoo
Winnipeg, Manitoba, Canada

SB ID	Local ID	Sex	Age	Disposition	Location	Breeding	With	Notes
154	G00153	F	11	HOLD	WINNIPEG	BREED WITH	~~704~~ 682	Changed during comment period.
157	H00754	F	---	HOLD	WINNIPEG	BREED WITH	680	
680	P00042	M	5	HOLD	WINNIPEG	BREED WITH	157	
682	N00011	M	6	HOLD	WINNIPEG	~~DO NOT BREED~~ BREED WITH	154	Changed during comment period.
702	22178	F	1	HOLD	WINNIPEG	**DO NOT BREED**		Offspring of 680 or 682.
703	22184	M	1	HOLD	WINNIPEG	**DO NOT BREED**		Offspring of 144.
704	22185	M	1	~~HOLD~~ SEND TO	~~WINNIPEG~~ ECOMUSEUM	~~BREED WITH~~ DO NOT BREED	~~154~~	Changed during comment period.
705	22186	M	1	HOLD	WINNIPEG	**DO NOT BREED**		Offspring of 144.

Appendix A
Analytical Assumptions

Hypothetical Individuals:

Studbook ID	Sire	Dam	First Location	Notes
HYP1	WILD	WILD	UNKNOWN	Master Analytical Notes: Hypothetical wild hatched parents to link breeding females at European institutions KREFELD, WASSENAAR, KRONBERG, SASSNITZ, & AMSTERDAM as full siblings.
HYP2	WILD	WILD	UNKNOWN	
AMSTER1	WILD	WILD	UNKNOWN	Master Analytical Notes: Hypothetical wild caught sire to represent hypothetical breeding pair at AMSTERDAM and link unknown parentage individuals #603, 641, 651, 659, & 667 as first cousins.
AMSTER2	HYP1	HYP2	UNKNOWN	Master Analytical Notes: Hypothetical dam created to represent hypothetical breeding pair at AMSTERDAM, and link unknown parentage individuals #603, 641, 659, & 667 as first cousins through HYP1/HYP2.
KREF1	WILD	WILD	UNKNOWN	Master Analytical Notes: Hypothetical wild caught sire to represent hypothetical breeding pair at KREFELD and link unknown parentage individuals #603, 641, 651, 659, & 667 as first cousins.
KREF2	HYP1	HYP2	UNKNOWN	Master Analytical Notes: Hypothetical dam created to represent hypothetical breeding pair at KREFELD, and link unknown parentage individuals #603, 641, 659, & 667 as first cousins through HYP1/HYP2.
KRON1	WILD	WILD	UNKNOWN	Master Analytical Notes: Hypothetical wild caught sire to represent hypothetical breeding pair at KRONBERG and link unknown parentage individuals #603, 641, 651, 659, & 667 as first cousins.
KRON2	HYP1	HYP2	UNKNOWN	Master Analytical Notes: Hypothetical dam created to represent hypothetical breeding pair at KRONBERG, and link unknown parentage individuals #603, 641, 659, & 667 as first cousins through HYP1/HYP2.
SASS1	WILD	WILD	UNKNOWN	Master Analytical Notes: Hypothetical wild caught sire to represent hypothetical breeding pair at SASSNITZ and link unknown parentage individuals #603, 641, 651, 659, & 667 as first cousins.
SASS2	HYP1	HYP2	UNKNOWN	Master Analytical Notes: Hypothetical dam created to represent hypothetical breeding pair at SASSNITZ, and link unknown parentage individuals #603, 641, 659, & 667 as first cousins through HYP1/HYP2.
WASSEN1	WILD	WILD	UNKNOWN	Master Analytical Notes: Hypothetical wild caught sire to represent hypothetical breeding pair at WASSENAAR and link unknown parentage individuals #603, 641, 651, 659, & 667 as first cousins.
WASSEN2	HYP1	HYP2	UNKNOWN	Master Analytical Notes: Hypothetical dam created to represent hypothetical breeding pair at WASSENAAR, and link unknown parentage individuals #603, 641, 659, & 667 as first cousins through HYP1/HYP2.

Analytical Data for True Individuals:

Studbook ID	Field	True	Overlay	Notes
144	Dam	MULT21	26	Master Analytical Notes: #134 chosen as sire as he is the only potential sire with living descendants (15, 17, & 136 all LTF with no living descendants). #26 arbitrarily chosen as dam as all potential dams were dead or LTF with no living descendants.
	Sire	MULT20	134	
160	Dam	UNK	WILD	Master Analytical Notes: Assumed wild caught rehab animal.
	Sire	UNK	WILD	
165	Dam	UNK	WILD	Master Analytical Notes: Early zoo hatch, assume parents were wild caught.
	Sire	UNK	WILD	
182	Dam	UNK	WILD	Master Analytical Notes: Early zoo hatch, assume parents were wild caught.
	Sire	UNK	WILD	

Studbook ID	Field	True	Overlay	Notes
337	Dam	UNK	WILD2	Master Analytical Notes: Donated from private individual known to have wild caught breeding pair. Assumed sibling to #624.
	Sire	UNK	WILD1	
397	Dam	UNK	WILD	Master Analytical Notes: Early zoo hatch, assume parents were wild caught.
	Sire	UNK	WILD	
452	Dam	UNK	WILD	Master Analytical Notes: Assume wild caught rehab animal.
	Sire	UNK	WILD	
610	Dam	UNK	WILD	Master Analytical Notes: Assume wild caught rehab animal at extinct Canadian facility (HAVELOCKR).
	Sire	UNK	WILD	
624	Dam	UNK	WILD2	Master Analytical Notes: Donated from private individual known to have wild caught breeding pair. Assumed sibling to #337.
	Sire	UNK	WILD1	
640	Dam	UNK	WILD	Master Analytical Notes: Animal was hatched at AUGSBRUG, assumed unique lineage to North American or European population.
	Sire	UNK	WILD	
645	Dam	UNK	WILD	Master Analytical Notes: Assume unique Eastern European lineage (originated Estonia and Russia) unrelated to other European and North American animals.
	Sire	UNK	WILD	
646	Dam	UNK	WILD	
	Sire	UNK	WILD	
650	Dam	UNK	WILD	Master Analytical Notes: Assume wild caught individual unrelated to European or North American population.
	Sire	UNK	WILD	
652	Dam	UNK	WILD	Master Analytical Notes: Assume rehab animal donated to KRONBERG from private
	Sire	UNK	WILD	
657	Dam	UNK	WILD	Master Analytical Notes: Assume unique STUTTGART lineage unrelated to other European or North American animals.
	Sire	UNK	WILD	
658	Dam	UNK	WILD	
	Sire	UNK	WILD	
661	Dam	UNK	WILD	Master Analytical Notes: Assume unique RHEINE lineage unrelated to other European or North American animals.
	Sire	UNK	WILD	
666	Dam	UNK	WILD	Master Analytical Notes: Assume unrelated to other European or North American animals.
	Sire	UNK	WILD	
672	Dam	UNK	WILD	Master Analytical Notes: Assume unique KOLN lineage unrelated to other European or North American animals.
	Sire	UNK	WILD	
674	Dam	UNK	WILD	Master Analytical Notes: Assume unique UK lineage, assume unrelated to rest of European or North American population.
	Sire	UNK	WILD	
675	Dam	UNK	WILD	Master Analytical Notes: Assume unique UK lineage, assume unrelated to rest of European or North American population.
	Sire	UNK	WILD	
603	Dam	UNK	KRON1	Master Analytical Notes: Hypothetical parents to link individuals from Krefeld, Wassenaar, Sassnitz, Kronberg, and Amsterdam at the level of first cousins through the maternal line.
	Sire	UNK	KRON2	
641	Dam	UNK	KREF1	
	Sire	UNK	KREF2	
651	Dam	UNK	SASS2	
	Sire	UNK	SASS1	
659	Dam	UNK	AMSTER2	
	Sire	UNK	AMSTER1	
667	Dam	UNK	WASSEN2	
	Sire	UNK	WASSEN1	
702, 703, 704, 705	Sire	UNK	MULT22	Master Analytical Notes: MULT22 represents the only two potential sires present at WINNIPEG at the time of the hatches: #680 & 682. (Changed during comment period.)

PMX MULTS

ID: MULT22

*SIRES: 680; 682

Appendix B
Summary of Data Exports

PMx Project: SnowyOwl_11Apr2018
Created: 2018-04-11 by PMx version 1.5.20180324
File: C:\PMxProjects\SnowyOwl_11Apr2018.pmxproj
Description: Updated for final report

Primary data file
Data File Name: XXSnowyOw_08Oct2017.ped
Common Name: Snowy Owl
Scientific Name: Bubo Scandiacus
Data Source: PopLink
Studbook Name: SnowyOw_08Oct2017
Exported On: 2018-04-11
Software version: PopLink 2.4
Current through: 2017-06-28
Compiled by: J. Cody Hickman
Scope: Regional
Dates: 2018-04-11
Association: SnowyOwl_Oct2017.FED (AZA + BIG BEAR + BINGHAMTO + CRAWFRD W + ECOMUSEUM + KAMLOOPS + OCHSNER + SASKATOON + UTICA + WATERTOWN)
Other Filters: Status = Living
User: alawless

Locations data file
Data File Name: location.txt

Demographic input files
MPrn file: mXXSnowyOw_08Oct2017.prn
FPrn file: fXXSnowyOw_08Oct2017.prn
Census1 file: Exchcens.txt

Male/Female LifeTable filter:
*Common Name: Snowy Owl
*Scientific Name: Bubo Scandiacus
*Data Source: PopLink
*Studbook Name: SnowyOw_08Oct2017
*Exported On: 2018-04-11
*Software version: PopLink 2.4
*Current through: 2017-06-28
*Compiled by: J. Cody Hickman
*Scope: Regional
***Dates: 1975-01-01 to 2018-04-11**
***Locations: N.AMERICA**
*Association:
*Other Filters: Status = Living
*User: alawless

Data Changes During Comment Period: (All changes updated in demographic and genetic analyses)
- SB ID 217 (M) at SEATTLE recorded as released in 1996
- SB ID 475 at BINGHAMTO hatch date updated to 6/1/2011
- SB ID 702 at WINNIPEG sire updated to MULT22 and dam to 154
- SB ID 703 at WINNIPEG sire updated to MULT22 and dam to 144
- SB ID 704 at WINNIPEG sire updated to MULT22 and dam to 144
- SB ID 705 at WINNIPEG sire updated to MULT22 and dam to 144
- SB ID 521 at CRAWFRD W made LTF on 4/5/2018
- SB ID 522 at CRAWFRD W made LTF on 4/5/2018
- SB ID 716 (F) at CRAWFRD W added during comment period
- SB ID 717 (F) at CRAWFRD W added during comment period

Appendix C
Animals Excluded from the Genetic Analysis

SB ID	Location	Age	Sex	Reason for Exclusion
~~217~~	~~SEATTLE~~	~~29~~	~~M~~	~~Education~~(Updated during comment period)
453	WATERTOW	7	F	Education
454	NATAVPGH	7	M	Education
479	MINNESOTA	9	M	Education
~~521~~	~~CRAWFRD W~~	~~21~~	~~U~~	~~Education~~ (Sent LTF during comment period)
~~522~~	~~CRAWFRD W~~	~~21~~	~~U~~	~~Education~~ (Sent LTF during comment period)
595	NORRISTOW	6	F	Education
634	GRANBY	10	F	Education
689	BIG BEAR	14	M	Missing wing/Unknown pedigree
694	KAMLOOPS	14	M	Medical
701	TORONTO	3	F	Unknown pedigree
716	CRAWFRD W	11	F	Education/Unknown pedigree (Added during comment period.)
717	CRAWFRD W	7	F	Education (Added during comment period.)

Appendix 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.

MALES

Age	Px	Qx	Risk Qx	Lx	Mx	Risk Mx	Ex	Vx
0	0.67	0.33	125.80	1.00	0.01	183.10	---	1.20
1	0.93	0.07	132.80	0.67	0.02	140.20	---	1.53
2	0.94	0.06	131.80	0.62	0.07	136.90	---	1.61
3	0.96	0.04	128.50	0.59	0.08	131.70	---	1.61
4	0.93	0.07	120.80	0.56	0.09	127.50	---	1.61
5	0.95	0.05	115.80	0.52	0.12	118.50	---	1.62
6	0.89	0.11	101.70	0.50	0.12	109.00	---	1.62
7	0.91	0.09	88.80	0.44	0.10	92.30	---	1.66
8	0.98	0.02	79.60	0.40	0.19	80.50	---	1.65
9	0.91	0.09	74.00	0.39	0.13	78.90	---	1.54
10	0.89	0.11	65.30	0.36	0.08	70.60	---	1.55
11	0.95	0.05	63.00	0.32	0.31	63.50	---	1.60
12	0.93	0.07	57.60	0.30	0.16	60.50	---	1.37
13	0.92	0.08	53.80	0.28	0.07	56.30	---	1.30
14	0.90	0.10	46.70	0.26	0.17	48.90	---	1.34
15	0.86	0.14	38.40	0.23	0.35	42.00	---	1.33
16	0.87	0.13	33.60	0.20	0.46	36.00	---	1.13
17	0.90	0.10	29.30	0.18	0.40	30.50	---	0.75
18	0.93	0.07	26.00	0.16	0.30	26.80	---	0.38
19	0.86	0.14	19.50	0.15	0.04	21.10	---	0.09
20	0.86	0.14	13.50	0.13	0.06	14.40	---	0.06
21	0.73	0.27	9.00	0.11	0.00	11.30	---	0.00
22	0.73	0.27	5.90	0.08	0.00	7.50	---	0.00
23	0.73	0.27	5.20	0.06	0.00	5.50	---	0.00
24	0.75	0.25	3.40	0.04	0.00	4.00	---	0.00
25	0.67	0.33	2.10	0.03	0.00	3.00	---	0.00
26	1.00	0.00	2.00	0.02	0.00	2.00	---	0.00
27	1.00	0.00	2.00	0.02	0.00	2.00	---	0.00
28	1.00	0.00	2.00	0.02	0.00	2.00	---	0.00
29	1.00	0.00	1.90	0.02	0.00	1.90	---	0.00
30	1.00	0.00	1.00	0.02	0.00	1.00	---	0.00
31	1.00	0.00	1.00	0.02	0.00	1.00	---	0.00
32	1.00	0.00	0.70	0.02	0.00	0.70	---	0.00

MALES

Age	Px	Qx	Risk Qx	Lx	Mx	Risk Mx	Ex	Vx
33	1.00	0.00	0.00	0.02	0.00	0.00	---	0.00
34	1.00	0.00	0.00	0.02	0.00	0.00	---	0.00

r = -0.005, λ = 0.995, Ro = 0.953, T= 10.3, N20 = 25

FEMALES

Age	Px	Qx	Risk Qx	Lx	Mx	Risk Mx	Ex	Vx
0	0.65	0.35	130.60	1.00	0.00	193.50	8.058	1.21
1	0.90	0.10	127.40	0.65	0.01	138.50	9.43	1.61
2	0.90	0.10	124.80	0.59	0.09	132.60	9.366	1.76
3	0.93	0.07	116.20	0.53	0.02	121.00	9.152	1.81
4	0.95	0.05	110.60	0.49	0.09	113.80	8.675	1.89
5	0.95	0.05	105.50	0.47	0.14	109.90	8.079	1.88
6	0.92	0.08	96.00	0.44	0.22	101.70	7.568	1.85
7	0.91	0.09	82.30	0.41	0.17	87.90	7.177	1.76
8	0.94	0.06	76.10	0.37	0.29	78.40	6.683	1.71
9	0.92	0.08	68.50	0.35	0.23	72.20	6.108	1.51
10	0.91	0.09	60.90	0.32	0.28	65.60	5.582	1.39
11	0.84	0.16	51.90	0.29	0.33	56.30	5.226	1.26
12	0.85	0.15	42.30	0.25	0.31	46.20	5.004	1.09
13	0.83	0.17	33.10	0.21	0.28	37.30	4.762	0.92
14	0.97	0.03	29.00	0.17	0.23	30.00	4.211	0.71
15	0.66	0.34	24.10	0.17	0.27	29.00	3.928	0.58
16	0.82	0.18	17.10	0.11	0.35	19.00	4.046	0.43
17	0.66	0.34	12.70	0.09	0.10	14.60	4.073	0.10
18	0.89	0.11	9.30	0.06	0.00	9.50	4.09	0.00
19	0.65	0.35	7.40	0.05	0.00	8.50	3.977	0.00
20	1.00	0.00	5.50	0.04	0.00	5.50	3.778	0.00
21	1.00	0.00	4.30	0.04	0.00	4.30	2.778	0.00
22	0.71	0.29	2.60	0.04	0.00	3.50	2.08	0.00
23	0.40	0.60	1.40	0.03	0.00	2.50	1.857	0.00
24	1.00	0.00	1.00	0.01	0.00	1.00	1.5	0.00
25	0.00	1.00	1.00	0.01	0.00	1.00	1	0.00
26	0.00	1.00	0.00	0.00	0.00	0.00	0	0.00
27	0.00	1.00	0.00	0.00	0.00	0.00	0	0.00
28	0.00	1.00	0.00	0.00	0.00	0.00	0	0.00
29	0.00	1.00	0.00	0.00	0.00	0.00	0	0.00
30	0.00	1.00	0.00	0.00	0.00	0.00	0	0.00
31	0.00	1.00	0.00	0.00	0.00	0.00	0	0.00
32	0.00	1.00	0.00	0.00	0.00	0.00	0	0.00

FEMALES

Age	Px	Qx	Risk Qx	Lx	Mx	Risk Mx	Ex	Vx
33	0.00	1.00	0.00	0.00	0.00	0.00	0	0.00
34	0.00	1.00	0.00	0.00	0.00	0.00	0	0.00

r = -0.013, λ = 0.987, Ro = 0.891 T= 9.0, N20 = 25

Appendix E
Ordered Mean Kinship List

Note: These lists are current to April 2018 and values are subject to change with any hatch, death, import, export, inclusion, exclusion, or changes in pedigree or pedigree assumptions.

Population Mean Kinship = 0.0428

MALES

SB ID	MK	Known	Age	Location
699	0.0000	1.0000	19	SASKATOON
623	0.0000	1.0000	9	HERSHEY
686	0.0000	1.0000	7	PITTS CA
655	0.0000	1.0000	6	CALGARY
687	0.0000	1.0000	4	PITTS CA
685	0.0000	1.0000	3	CALGARY
696	0.0000	1.0000	2	OCHSNER
682	0.0132	1.0000	6	WINNIPEG
680	0.0132	1.0000	5	WINNIPEG
473	0.0175	1.0000	6	AKRON
653	0.0212	1.0000	7	LOUISVILL
474	0.0219	1.0000	6	BINGHAMTO
464	0.0222	1.0000	20	UTICA
642	0.0236	1.0000	5	BALTIMORE
656	0.0236	1.0000	5	BRIDGEPRT
703	0.0321	1.0000	1	WINNIPEG
704	0.0321	1.0000	1	ECOMUSEUM
705	0.0321	1.0000	1	WINNIPEG
343	0.0383	1.0000	18	NY BRONX
455	0.0448	1.0000	7	NASHV ZOO
477	0.0448	1.0000	7	LVZOO
339	0.0515	1.0000	18	TULSA
557	0.0553	1.0000	7	TOLEDO
708	0.0554	1.0000	0	TULSA
700	0.0563	1.0000	1	SEATTLE
713	0.0563	1.0000	0	CHICAGOLP
390	0.0567	1.0000	18	WATERTOWN
375	0.0600	1.0000	16	CHICAGOLP

FEMALES

SB ID	MK	Known	Age	Location
157	0.0000	1.0000	---	WINNIPEG
697	0.0000	1.0000	9	SASKATOON
698	0.0000	1.0000	6	SASKATOON
592	0.0000	1.0000	6	ROCHESTER
688	0.0000	1.0000	4	BATTLE CR
695	0.0000	1.0000	2	OCHSNER
392	0.0132	1.0000	10	HERSHEY
648	0.0219	1.0000	9	PARAMUS
624	0.0329	1.0000	6	NW TREK
702	0.0337	1.0000	1	WINNIPEG
154	0.0395	1.0000	11	WINNIPEG
236	0.0395	1.0000	6	CHICAGOLP
478	0.0448	1.0000	7	LOUISVILL
337	0.0461	1.0000	6	TULSA
558	0.0553	1.0000	13	NY BRONX
554	0.0553	1.0000	7	NASHV ZOO
556	0.0553	1.0000	7	BRIDGEPRT
475	0.0553	1.0000	6	BINGHAMTO
644	0.0553	1.0000	5	BALTIMORE
593	0.0553	1.0000	5	SEATTLE
709	0.0554	1.0000	0	TULSA
710	0.0554	1.0000	0	TULSA
707	0.0554	1.0000	0	TULSA
711	0.0563	1.0000	0	CHICAGOLP
712	0.0563	1.0000	0	CHICAGOLP

Appendix F
Descriptive Survival Statistics Report

Snowy Owl Studbook
Bubo Scandiacus
Regional Studbook

Studbook data current as of 6/28/2017

Compiled by
J. Cody Hickman
cody.hickman@CZS.org

PopLink Studbook filename: SnowyOw_08Oct2017
PopLink User Who Exported Report: alawless
Date of Export: 1/3/2018
Data Filtered by: Locations = N.AMERICA AND StartDate = 1/1/1975 AND EndDate = 1/3/2018
PopLink Version: 2.4

REPORT OVERVIEW:

Based on this analysis, if a Snowy Owl survives to its first birthday, its median life expectancy is 10.2 years. Please see the body of the report for more details.

BACKGROUND ON ANALYSES:

These analyses were conducted using animals that lived during the period 1 January 1975 to 3 January 2018 at all institutions in the studbook. The analyses mainly focus on survival statistics from 1 year (e.g. excluding any individuals that did not survive past their first birthday). These statistics most accurately reflect typical survival for animals which can be seen on exhibit in zoos and aquariums.

This report summarizes survival records of individuals housed at zoological facilities for a specific geographic range and time period; these records trace an individual's history from birth or entry into the population to death, exit out of the population, or the end of the time period. As such, this history only reflects standard practices - including management, husbandry, and acquisition/disposition practices - for the specified time period and geographic range. Thus, the report contents should be viewed with some caution as they may not fully reflect current and newly emerging zoo and aquarium management techniques or practices. For example, if the population has not been maintained in zoos and aquariums long enough to have many adults living into old age, median life expectancy will likely be an underestimate until more data accrue in older age classes. Thus, users of these reports should recognize that the results produced will likely vary over time or depending on the subset of data selected.

Although for many species, including humans, survival statistics often differ for males and females, for these analyses male and female statistics were not statistically different[1]; these results therefore include pooled data from males, females, and unknown sex individuals.

SUMMARY OF ANALYSES:

SURVIVAL STATISTICS

The dataset used for analysis includes partial or full lifespans of 340 individuals, 251 (73.8%) of which had died by 3 January 2018.

If a Snowy Owl survives to its first birthday, its **median life expectancy**[2] is **10.2 years of age**. Given the quality of the data - how many animals are in the database and how many have died - there is a 95% chance that the true median falls between 9.1 and 11.5 years of age (i.e., these are the 95% confidence limits). Only 25% of Snowy Owl can be expected to survive to be 15.7 years or older.

First-year (infant) survival[3] for Snowy Owl is 70%. The year after birth/hatching is a period of relatively low survival for many species and life histories.

The **maximum longevity**[4] observed for Snowy Owl is **32.7 years**; this longevity record is based on an individual which was CENSORED as of the analysis end date (studbook number 249, sex = Male, origin = Captive Hatch, birth date estimate = None).[5]

The correct interpretation of these statistics is that, if it survives the first year of life, the 'typical' Snowy Owl will live 10.2 years; that half of all Snowy Owl can be expected to die before they reach 10.2 and half will live longer than 10.2; that only 25% of all Snowy Owl can be expected to live 15.7 years; and that it is rare but possible for Snowy Owl to live 32.7 years.

The median life expectancy, confidence interval, first-year survival, and maximum longevity may change as more data are accumulated, the population's age structure changes, or management practices improve.

While both median life expectancy and maximum longevity are discussed in this report, it is more appropriate to rely on median life expectancy to place the age of any one individual in context. To put these statistics in perspective, median life expectancy from age one for people in the United States is 77.5 years and the maximum longevity (documented worldwide) is 122 years[6]. Therefore, if a person lived to be 85 years old, the appropriate context is that they lived well beyond the median life expectancy (77.5), not that they fell short of the maximum longevity (122).

DATA QUALITY

The PopLink Survival Tool uses five data quality measures to determine whether data are robust enough to make reliable estimates of key survival parameters. **This population passed all of the following data quality tests:**

1. Can the median life expectancy be calculated? **PASS**
2. Is the sample size (number of individuals at risk) greater than 20 individuals at the median? **PASS**
3. Is the 95% Confidence Interval (CI) bounded? **PASS**
4. Is the sample size in the first age class of analysis (e.g. the first day of analysis) greater than 30 individuals? **PASS**
5. Is the length of the 95% CI < 33% of the maximum longevity? **PASS**

PopLink data validation has never been run; if errors are present in this studbook, they may affect the data in this analysis.

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[1] Statistical significance was determined by comparing 84% confidence intervals around median life expectancy for males and females, with 20 unknown sex individuals proportionally incorporated into the analysis. For this population, overlapping confidence intervals indicated that data could be pooled. See the PopLink manual for more details.

[2] The statistics analyzed for this report (median life expectancy, 95% confidence limits, and age to which 25% of individuals survive) exclude any individuals who did not survive to their first birthday; these individuals are excluded because this Report is focused on providing median survival estimates for the typical individual that survives the vulnerable infant stage. In other words, this report answers the question, 'how long is this species expected to live once it has reached its first birthday?' For this studbook, 130 individuals died before their first birthday and were excluded from these analyses.

For all animals that survive to their first birthday, 50% will die before the median life expectancy in this report and 50% die after. Note that the median life expectancy obtained from population management software (PM2000, PMx, ZooRisk) or from life tables in Breeding and Transfer Plans (e.g. where Lx = 0.5) will be lower because it includes these individuals that did not survive to their first birthday in order to project the correct number of births needed. See the PopLink manual for more details.

[3]For reference, first-year survival is provided. For this studbook and the selected demographic window, 130 individuals did not survive to their first birthday and were excluded from the estimates provided above (median life expectancy, 95% confidence limits, and age to which 25% of individuals survive).

[4] Maximum longevity is the age of the oldest known individual for this species, living or dead. It is not necessarily the biological maximum age, but only reflects the individuals included in the dataset.

[5] Censored individuals are individuals whose deaths have not been observed as of the end of the analysis window, including individuals who 1) are still alive as of the end date, 2) exited the geographic window before the end date (through transfer or release), or 3) were lost-to-follow up before the end date.

[6] Median life expectancy for people is estimated from: Xu, Jiaquan, Kochanek KD, Murphy SL, and Tejada-Vera B. 2007. Deaths: Final Data for 2007. National vital statistics reports; vol 58 no 19. Hyattsville, MD: National Center for Health Statistics. Jeanne Calment of France was the oldest documented and fully validated human and died at 122 years and 164 days; from: http://www.grg.org/Adams/Tables.htm. Accessed August 9, 2007.

Appendix G
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 https://www.aza.org/board-approved-policies-and-position-statements.

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 H
Directory of Institutional Representatives

Contact Name (IR)	Institution	Email
Shane Good	AKRON – Akron Zoological Park, Akron, OH	SJGood@akronzoo.org
Jill Marvin	AQUAQC - Aquarium du Quebec, Sainte-Foy, QC, Canada	marvin.jill@sepaq.com
Jen Kottyan	BALTIMORE – Baltimore Zoo, Baltimore, MD	Jen.kottyan@marylandzoo.org
Kathryn Sippel	BATTLE CR – Binder Park, Zoo Battle Creek, MI	ksippel@binderparkzoo.org
Bob Cisneros	BIG BEAR – Big Bear Alpine Zoo, Big Bear Lake, CA	bcisneros@sdd.sbcounty.gov
Christina Sheehan	BINGHAMTO – Ross Park Zoo, Binghamton, NY	csheehan@rossparkzoo.com
Don Goff	BRIDGEPRT – Beardsley Zoological Gardens, Bridgeport, CT	dgoff@beardsleyzoo.org
Mike Teller	CALGARY – Calgary Zoo, Calgary, Alberta, Canada	miket@calgaryzoo.com
Sunny Nelson	CHICAGOLP – Lincoln Park Zoo, Chicago, IL	snelson@lpzoo.org
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Patricia Presseau	ECOMUSEUM – Zoo Ecomuseum, Sainte-Anne-de-Bellevue, Quebec, Canada	Presseau.patricia@ecomuseum.ca
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Tal Wenrich	HERSHEY – ZooAmerica, Hershey, PA	twenrich@hersheypa.com
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Samantha Wegman	LVZOO – Lehigh Valley Zoo Schnecksville, PA	swegman@lvzoo.org
Dave Cruz	MINNESOTA – Minnesota Zoological Garden, Apple Valley, MN	Dave.Cruz@state.mn.us
Joe Degraauw	NASHV ZOO - Nashville Zoo at Grassmere, Nashville, TN	jdegraauw@nashvillezoo.org
Kurt Hundgen	NATAVPGH – National Aviary, Pittsburgh, PA	Kurt.hundgen@aviary.org
Cierra Allen	NORRISTOW – Elmwood Park Zoo, Norristown, PA	vettech@elmwoodparkzoo.org

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Cindy Norton	PARAMUS – Bergen County Zoological Park, Paramus, NJ	Cnorton@co.bergen.nj.us
David Hamilton	ROCHESTER – Seneca Park Zoo – Rochester, NY	DHamilton@monroecounty.gov
Tim Sinclair-Smith	SASKATOON – Saskatoon Forestry Farm and Zoo, Saskatoon	Tim.sinclair-smith@saskatoon.ca
Tina Mullett	SEATTLE - Woodland Park Zoological Gardens, Seattle, WA	Tina.mullett@zoo.org
Sarrah Kaye	STATEN IS- Staten Island Zoo, Staten Island, NY	skaye@statenislandzoo.org
Josee Tremblay	ST FELICI – Zoo Sauvage de St. Felicien, St. Felicien, Quebec, Canada	josee.tremblay@zoosauvage.org
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Shawn Jacobs	WATERTOWN – NY State Zoo at Thompson Park, Watertown, NY	shawn@nyszoo.org
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