

Report to:
Chinese Association of Zoological Gardens (CAZG)
Giant Panda Office, Department of Wildlife Conservation, State Forestry Administration
Giant Panda Conservation Foundation (GPCF)

2016 Breeding and Management Recommendations
and
Summary of the Status of the Giant Panda
Ex Situ Population

11 - 13 November 2015
Dalian, China

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Executive Summary

This is a report on the meeting held 11 - 13 November 2015 in Dalian, China to update the analysis of the *ex situ* population of giant pandas and develop breeding recommendations for the 2016 breeding season. This is the 14th annual set of genetic management recommendations developed for giant pandas.

The current *ex situ* population of giant pandas consists of 423 animals (189 males, 232 females, 2 unsexed pandas) located in 78 institutions worldwide. In 2015 there were 43 births and 15 deaths. Transfers included 100 separate transfers of 73 animals between Chinese institutions and 3 transfers to Hong Kong and Macao. The genetic status of the population is currently healthy (gene diversity = 97.4%), with 52 founders represented and another 9 that could be genetically represented if they were to successfully breed. There are 5 inbred animals with estimated inbreeding coefficients > 4% and another 18 animals with a low level of inbreeding (< 4%).

There are 53 giant pandas in the studbook that are living or have living descendants and for which the sire is uncertain due to natural mating and/or artificial insemination with multiple males. Most of these (n=39) are young pandas that were born in 2013 or later; however, the remaining 15 pandas with uncertain paternity are responsible for over 50% of the uncertainty in the global pedigree. The result of these uncertain sires is that 11% of the gene pool of the *ex situ* population is derived from uncertain ancestry. **Four individuals account for much of this uncertainty: SB# 455 is a very important animal to resolve (accounts for about 25% of all uncertainty in the global pedigree), although this panda recently died; SB#s 439, 495 and 557 are living pandas that are also high priority for paternity verification.**

Molecular genetic analyses must continue to be used to confirm the parentage of these pandas as well as each year's new cubs before the next set of genetic management recommendations is made. This report contains the list of giant pandas that need to have their paternity verified (see Appendix B). Plans should continue to resolve as many of these uncertainties within the next year as possible.

Population growth in 2015 was 7%, which allows for some growth while implementing stronger genetic management. Growth focused on breeding genetically valuable animals as part of the genetic management strategy to preserve genetic diversity and minimize inbreeding, with some additional breeding targeting production of pandas for eventual potential release.

The current population goal for the giant panda *ex situ* population is **to maintain a target population of 400-600 giant pandas that retains at least 90% gene diversity of the wild population for 200 years.** A population of this size and genetic composition should be able to provide animals for reintroduction efforts if needed in the future.

The development of a Genome Resource Bank strategy for the systematic collection, storage and use of sperm and other biosamples is recommended to maximize long-term population viability. Development of an integrated conservation plan that includes conservation goals and actions for both the wild and captive giant panda populations is recommended to promote effective long-term conservation of this species.

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***Ex Situ* Giant Panda Management Program**

Introduction

This is a report on the meeting held 11 - 13 November 2015 in Dalian, China to update the analysis and breeding plan of the *ex situ* population of giant pandas. Workshop participants updated the studbook, identified priority pandas for breeding, and discussed a breeding strategy to meet the demographic and genetic needs of the long-term breeding program and reintroduction efforts. The meeting was organized by the Chinese Association of Zoological Gardens (CAZG), the Chengdu Research Base for Giant Panda Breeding, and the Dalian Zoo, and the technical workshop was facilitated by the IUCN SSC Conservation Breeding Specialist Group (CBSG).

The goals of the technical workshop were to:

- update the demographic and genetic analyses of the *ex situ* population; and
- formulate recommendations for breeding and management to promote program goals.

Population Goals

In 2009 the Technical Committee revised the program goal to maintain at least 90% gene diversity for 200 years with a target population size of approximately 500 (400-600) giant pandas. A longer timeline was adopted due to the uncertainty surrounding the possible significant threats of climate change and habitat destruction. The rate of growth toward this new target size can be slowed, and increased effort will be placed in genetic management and natural reproductive and parental behaviors. Genetic management is the most effective method of maintaining a genetically viable *ex situ* population capable of supporting a wild panda population. The current population of 423 giant pandas needs to increase by 77 to reach the goal of 500 pandas (Figure 1).

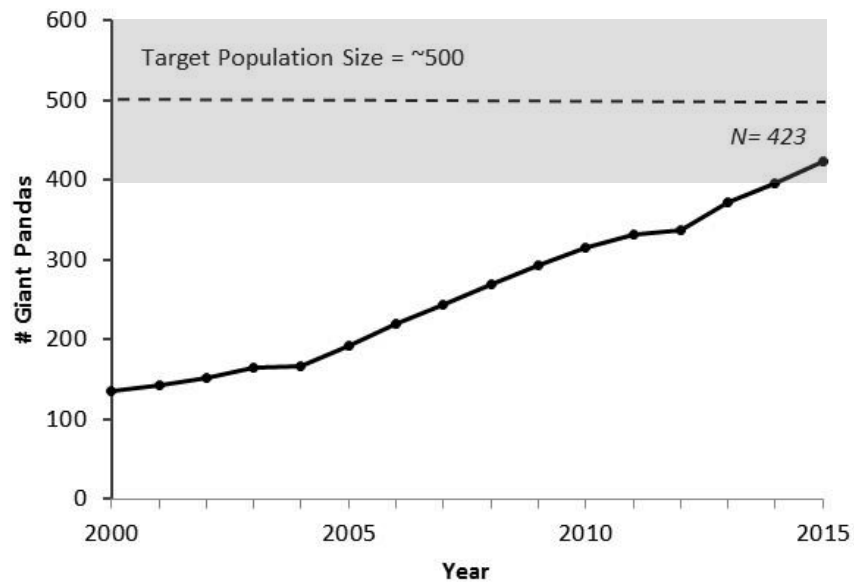


Figure 1. Growth of the *ex situ* giant panda population from 2000 to 2015.

Status of Captive Population

Data Analysis and Pedigree Assumptions

Data were taken from the 11 November 2015 version of the *International Giant Panda Studbook* compiled by Xie Zhong, CAZG, using the ISIS Single Population Analysis and Record Keeping System (SPARKS) v1.66 software program. PMx v1.2 software (Ballou, Lacy and Pollak) was used to conduct both demographic and genetic analyses. Data were current through the day of the workshop, as the studbook was updated during the workshop by institutional representatives.

Paternity is uncertain for many animals in the studbook. For many of these cases, females were first mated naturally and were then artificially inseminated. In others, lack of record-keeping in the early studbook years resulted in uncertainty about which males sired which cubs. Although molecular analyses have successfully identified the paternity of many pandas, there are still 53 pandas with uncertain paternity that affect the living gene pool. Most of these (n=39) are young pandas that were born in 2013 or later; however, the remaining 15 pandas with uncertain paternity are responsible for over 50% of the uncertainty in the global pedigree (listed in Appendix B). The result of these uncertain sires is that 11% of the gene pool of the *ex situ* population is derived from uncertain ancestry.

SPARKS v1.66 provides the option to list the studbook numbers of the potential sires along with the probability of each of them being the real sire. These uncertain sires can then be exported to PMx, where the pedigree analysis will take into consideration the uncertainties and calculate the kinships based on the estimated paternity across the uncertain sires (see Lacy *et al.* 2011 for the methods).

While the ability to include such uncertainty in the analyses are useful, and even necessary to proceed with developing breeding recommendations, the genetic analyses for this *ex situ* population will not be completely accurate until the paternities are known for certain through molecular genetic analyses. Accurate paternity verification will affect both population genetic measures (e.g., gene diversity, number of founders) as well as individual genetic measures (mean kinship, MSI scores).

Molecular analyses are needed to resolve the paternity of these 53 pandas as soon as possible since genetic management recommendations will not be accurate with these unknowns in the pedigree.

Demographic Status

The current *ex situ* population of giant pandas consists of 423 animals (189 males, 232 females, 2 unsexed pandas) located in 78 institutions worldwide. In 2015 there were 43 births and 15 deaths as of the time of the workshop.

Reproduction over the last several years has resulted in an annual population increase of 9-15% for 2005 to 2010. The growth rates were lower in 2011 (5%) and 2012 (3%) – presumably due to the increased focus on producing genetically valuable animals rather than large numbers. The growth rate now is being increased to accommodate the needs of a developing release and reintroduction program, and 7% growth was observed in 2014 and 2015. The age structure of the living population is healthy and indicative of a population that would be expected to continue to grow (Figure 2). A greater proportion of adult pandas have reproduced, especially females (59% in 2015), which contributes positively to growth as well as the effective population size (N_e).

Females are generally reproductive from 5-20 years of age, while male fertility can continue into the 20s. Generation time for the population is 11 years. Litters consist of 1-2 cubs with almost equal frequency (five litters of triplets have been observed), producing a mean litter size of 1.5 cubs. About 50% of males survive to age 15, 25% survive to age 23, and only about 10% survive to age 28; female survivorship is slightly better, with about 50% reaching age 21, 25% surviving to age 29, and 10% surviving to age 36. These values include wild-caught pandas whose ages are estimated.

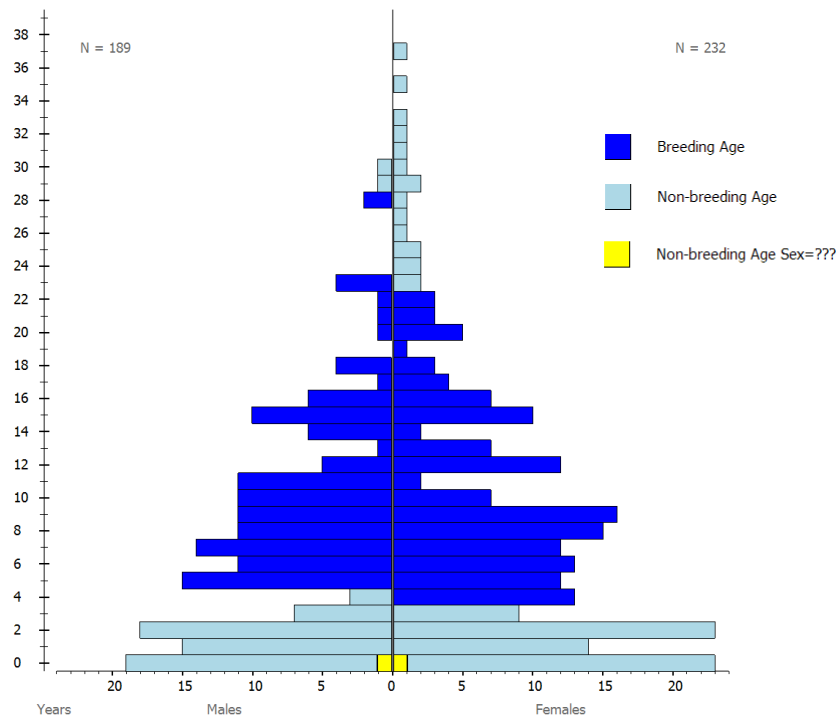


Figure 2. Age and sex structure of the 2015 population. Dark blue are breeding age individuals; light blue are immature (at bottom) or post-reproductive (at top) pandas; yellow is the unsexed individual.

Genetic Status

The *ex situ* giant panda population has descended from 52 wild-acquired founders (founders are defined as animals obtained from the wild that have successfully produced offspring or descendants in the current population). There are an additional 9 wild-acquired pandas that have yet to produce living offspring but have not been excluded due to age or poor health (these are potential founders). The population theoretically contains 97.4% of the genetic diversity of the wild population. This level of genetic diversity has a founder genome equivalent (*FGE*) of 19.5, which means that the population has the same level of genetic diversity as a population newly established with 19.5 unrelated founders. The genetic contribution of founders is highly skewed, with 26% of the gene pool derived from only 4 founders (Figure 3). The level of genetic diversity in the population could be increased to 99% if the population was ideally managed and the genes from the additional 9 founders fully incorporated into the population. The population would then have a founder genome equivalent of 51 (Table 1). Managing the population to minimize average kinship has been shown to be the optimal method for retaining genetic diversity. Managing by mean kinship will automatically identify descendants from the under-represented founders as priority breeders and inhibit the breeding of over-represented founders.

Table 1. Genetic summary of the 2015 *ex situ* population.

# Founders	52
# Potential (additional)	9
Gene Diversity Retained	0.9744
Potential Gene Diversity Retained	0.9903
Gene Value	0.9738
Founder Genome Equivalents (<i>FGE</i>)	19.50
Potential <i>FGE</i>	51.42
Mean Inbreeding	0.0022

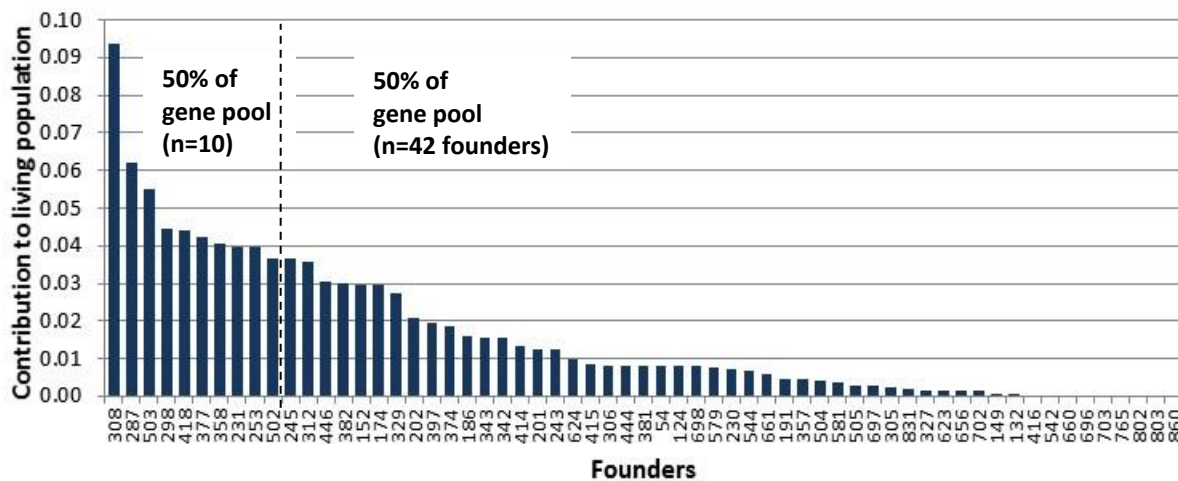


Figure 3. Genetic contribution of the 52 founders to the *ex situ* population gene pool. Each bar shows the contribution of a single founder. About 16% of the gene pool derives from only two founders (the left-most founders: 308 and 287). About 50% derives from only 10 founders.

Current inbreeding levels in the population are low, with only 5 inbred animals with estimated inbreeding coefficients over 4% and another 18 animals with a low level of inbreeding (< 4%). While the current population is genetically healthy, pandas within institutions are closely related and it is becoming increasingly more difficult to identify non-related pairings within institutions. Of the 23 living inbred animals, 17 were born in the last three years (2013-2015). Inbreeding will increase as captive breeding increases and the influx of new founders from the wild remains proportionally low. This will be especially true for pairings within institutions or partner institutions, making the transfer of individuals among institutions for breeding more important in the future as a way to minimize inbreeding and the loss of gene diversity. In the near future, giant pandas, or their sperm, will need to be transferred among institutions to increase the number of genetically favorable breeding options in the primary breeding centers. This process is beginning, with many transfers of giant pandas between Chinese institutions in 2014 and 2015.

2016 Program Review and Recommendations

The last review of the giant panda *ex situ* program was conducted during the 2010 Technical Meeting. Much progress has been made since that time, with increased emphasis on genetic management (cub production based on ‘quality vs quantity’) as well as initiation of preliminary release efforts. The 2015 Giant Panda Technical Meeting in Dalian focused on a review of the program and revision of program goals and strategies to meet changing needs. Participants reviewed the status and goals of the *ex situ* population, considered software tools and guidelines valuable in conservation planning for both *ex situ* and *in situ* panda populations, and discussed a revised breeding strategy to meet demographic and genetic needs for a long-term *ex situ* program as well as for reintroduction efforts.

Program Goals

The conservation goal of the giant panda *ex situ* population is “the maintenance of a sustainable *ex situ* giant panda population that is genetically and demographically viable and can provide animals for release to support the wild population”.

The conservation roles of the *ex situ* population and related contributions of the *ex situ* community to giant panda conservation are:

- Source of giant pandas for reintroduction needs
- Insurance population against population decline or loss in the wild
- Research opportunities (e.g., disease prevention)
- Resource for developing techniques that can support wild panda conservation in China (e.g., censusing, health status)
- Economic and political benefits to support wild population conservation
- Resource for public education and public awareness

To serve these roles and maintain a healthy, viable *ex situ* population, a quantitative goal has been set to maintain a target population of about 500 (400-600) giant pandas that retains at least 90% gene diversity (GD) of the wild population for 200 years. The intensity of genetic management determines the amount of gene diversity that is retained. A population of 600 giant pandas will maintain 90% GD for 200 years under current conditions ($N_e/N = 0.20$). Genetic management will need to be more strictly applied ($N_e/N = 0.24$) to achieve the same result with a smaller population size of 500. Relaxation of genetic management will lead to more rapid loss of gene diversity.

Population Growth

Managed *ex situ* populations go through several developmental stages (Figure 4). The giant panda *ex situ* population is now moving from its ‘growth phase’ and approaching a ‘maintenance phase’ at the desired target population size. At the current growth rate, the *ex situ* population will reach about 500 giant pandas in 2-3 years. Once the population reaches its target size, significantly fewer litters will be needed to maintain that size. For example, only 11-12 litters will be needed to maintain 500 pandas (Figure 5).

These calculations are for the long-term *ex situ* population only. Additional offspring may be desirable for release. The number of pandas required for release should be determined separately and will require additional breeding pairs to meet the release program goals.

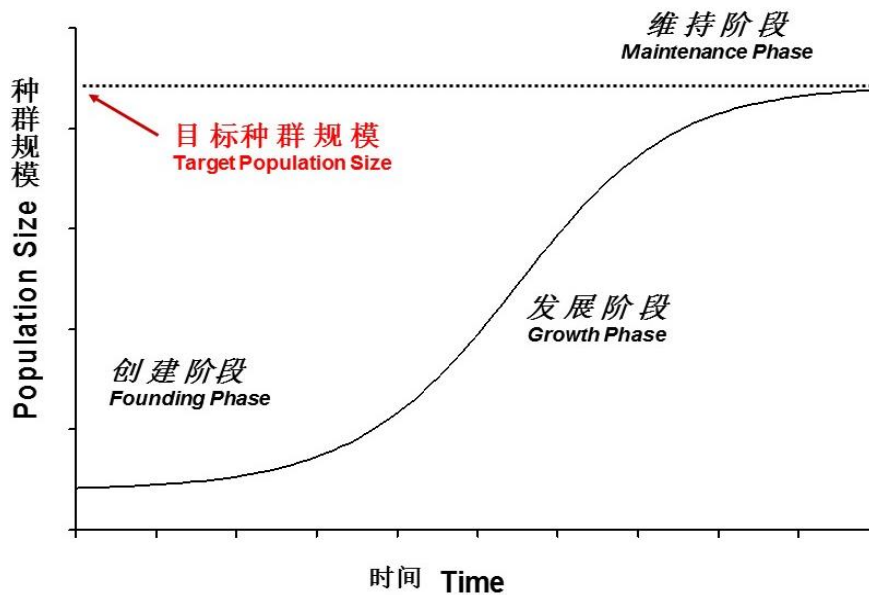


Figure 4. Phases in the development of a managed *ex situ* population.

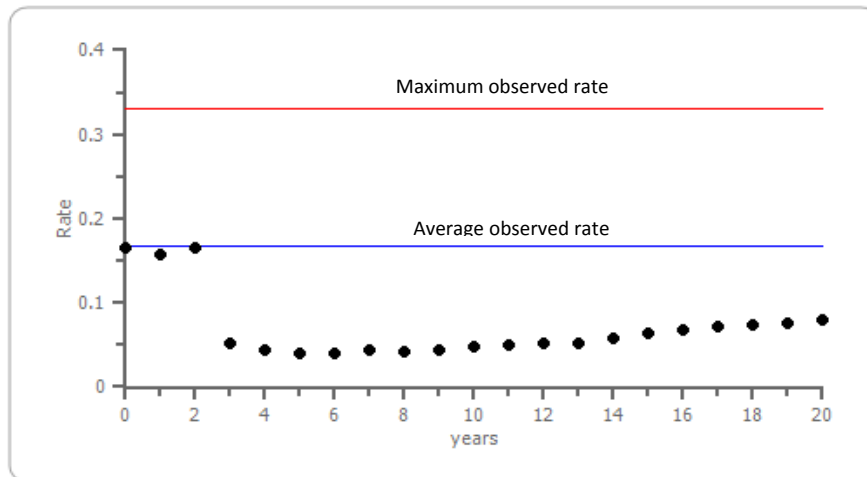


Figure 5. Reproductive rate (female M_x) needed each year to grow the giant panda population to 500 in three years (7% annual growth) and then maintain that size.

Breeding Strategy

Giant pandas are bred and offspring produced for two different purposes: 1) to maintain a genetically diverse, long-term breeding population; and 2) to produce animals for release. It is desirable to consider these goals separately when breeding pandas, as the number of cubs needed and characteristics of the selected breeders and breeding pairs are different between them.

A two-step process is suggested for developing breeding recommendations:

Step 1. Breeding plan for the insurance (captive breeding) population in China:

- a. Calculate the desired growth rate and the approximate number of breeding females needed for the next year.
- b. Identify priority breeders from the mean kinship list (males and females), including potential founders (see Appendix C).
- c. Use the MSI table (Appendix D) to select genetically valuable pairs, giving priority to pairs with $MSI < 4$, and avoiding any pairings with $MSI > 4$. Focus breeding attempts on genetic valuable pandas above the (population MK) line on the MK list and particularly on the priority animals at the top of the list highlighted in blue.
- d. Limit the number of total breedings to match the desired growth rate.
- e. Avoid using the same male (or his sperm) for too many breedings unless he is of high genetic value.

Step 2. Breeding plan for release:

- a. Calculate the desired number of breeding females to produce offspring for release
- b. Identify candidate females based on appropriate criteria (e.g., behavior, health, location).
- c. Identify acceptable males for the candidate females. Mates should be unrelated to the female and not heavily need for genetically valuable breedings for the *ex situ* population in Step 1.
- d. In the initial phase of the release program, the genetic value of cubs for release is not a high priority. However, if release training success rate is low and many of these cubs may be retained in captivity, then attention to genetic value is of more importance.

When choosing breeders and their mates, consider the following:

- There is no need to maximize growth and attempt to breed all females. Breeding efforts should concentrate on genetically valuable females to produce cubs for the *ex situ* population. Additional females that are good candidates for producing offspring for release also can be bred to support reintroduction efforts.
- Pairs with $MSI = 1$ to 3.5 should be given breeding priority, especially for institutions with pairing choices, as this will improve genetic diversity and reduce inbreeding.
- Efforts should be made to breed males and females with low mean kinship (MK) values. The average MK in the population is 0.0256. Animals with MK less than 0.0256 should be preferred breeders to maintain genetic diversity. The MK values are shown for each male and female on the MSI tables and on the mean kinship list (Appendix C).
- Priority efforts should be made to breed any wild-acquired pandas that have not produced surviving offspring, even if the MSI score = 3.5.
- Potential founders or other genetically valuable pandas should be bred with other high ranking pandas when possible ($MSI \leq 3$). However, it is acceptable to breed potential founders with lower ranking pandas if this is the best or only option for successful

reproduction for this highly valuable animal. To identify these special cases, MSI scores greater than 3 for pairs involving potential founders were changed to 3.5.

- AI should be restricted for use only for genetically valuable pairings that must be bred.

Genome Resource Bank Strategy

The successful use of artificial insemination (AI) has played an important role in the development of a healthy, growing giant panda *ex situ* population. As more emphasis is placed on fostering natural mating, it will become increasingly important to develop a strategic plan for the collection, long-term storage, and use of sperm (and perhaps other biosamples). The selection of males for sperm collection and storage, and the use of those samples, will depend upon the purpose of the genome resource bank (GRB) and its role in supporting the living population. Tools are available to assist this process. Development of a GRB strategy is recommended for the giant panda *ex situ* program.

Comprehensive Conservation Plan

To promote the most effective conservation of the giant panda, a One Plan approach is recommended to develop one integrated conservation plan for the species. Such a plan would integrate management of the wild population, captive population, and biosample collection (GRB), and the interactions of these populations with each other, into a comprehensive meta-population strategy. Clear conservation goals and objectives for each population and their management will promote effective long-term conservation of the giant panda. Tools are available to assist this process.

APPENDIX A: Assumptions about breeding population for analysis.

Data were taken from the 11 November 2015 version of the *International Giant Panda Studbook* compiled by Xie Zhong, CAZG, using the ISIS Single Population Analysis and Record Keeping System (SPARKS) v1.66 software. SPARKS v1.66 and PMx v1.2 software (Ballou, Lacy and Pollak) were used to conduct demographic and genetic analyses. Demographic characteristics of the population were analyzed for the period from 1 January 1990 to 11 November 2015. Genetic analysis was performed on the global living captive population. It is important to document the methods used in conducting the genetic analyses so that they can be repeated in future years.

This year 20 living pandas were excluded from the genetic analysis due to old age or chronic poor health, or because they are scheduled to be released into the wild; these pandas are listed in the table below. These pandas were excluded because they are not considered to be able to breed in captivity in the future and therefore can no longer contribute to the genetic diversity of the captive population. This left 403 pandas in the genetic population analysis.

SB #	Location	Sex	Age	Reason excluded
230	ABERDE HK	Female	~37	Too old
253	CHONGQING	Female	~33	Too old
264	FUCHOW	Female	~35	Too old
278	CHENGDU	Female	31	Too old
308	DJYGP BC	Male	~30	Too old
312	CHENPANDA	Female	~32	Too old
314	CHENPANDA	Female	29	Too old
320	BEIJING	Female	29	Too old
332	MEXICOCTY	Female	28	Too old
360	MEXICOCTY	Female	25	Too old
362	CHENGDU	Female	25	Too old
374	FUCHOW	Female	~26	Too old
404	GUILIN	Female	21	Too old
444	LOUGUANTA	Female	~27	Too old
500	LOUGUANTA	Female	~30	Too old
524	DJYGP BC	Male	15	Poor health
695	FUCHOW	Male	~28	Too old
701	DJYGP BC	Female	~20	Too old
866	WOLONG	Female	2	Scheduled for release
888	WOLONG	Female	2	Scheduled for release

APPENDIX B: Giant pandas with uncertain paternity.

Assumptions about Paternity

Often in captivity female pandas are both naturally mated and artificially inseminated with two or more males to maximize the probability of conception. For animals with uncertain sires, all of the potential sires and the probability of each male being the true sire have been entered into the studbook. Except for a few historical exceptions, the probability that a potential sire was the true sire was based on the following rules:

1. When a female was mated with multiple males using only one mating method – either only by natural matings (NM) or only by artificial inseminations (AI), equal probabilities were assigned to all potential sires.
2. When a female was mated using both NM and AI: In past cases, molecular genetic analyses showed that the male that was used for NM in almost all cases was the confirmed sire. Each sire mated by AI was given a 2% chance of being the true sire.
3. In cases of both NM and AI breeding methods, all males within the same method were given the same probability of being the true sire.
4. The sum of all probabilities for all potential sires for an animal = 100%.
5. In some cases, different probabilities had been entered previously into the 2013 International Studbook prior to analysis based on additional information; these probabilities were kept for analysis.
6. For 8 animals that were born before 2002 when the first population analysis was conducted, there is no information available on mating method (NM or AI), but a male was selected as the sire. For these animals, this sire was kept for analysis.

Examples:

- A:** ♂ 201 (AI) and ♂ 202 (AI)
201 = 50%; 202 = 50%
- B:** ♂ 174 (NM) and ♂ 201 (AI)
174 = 98%; 201 = 2%
- C:** ♂ 201 (AI), ♂ 202 (AI) and ♂ 174 (NM)
201 = 2%; 202 = 2%; 174 = 96%
- D:** ♂ 174 (NM), ♂ 424 (NM) and ♂ 201 (AI)
174 = 49%; 424 = 49%; 201 = 2%

The following tables list those pandas with uncertain paternity and that contribute to the living population gene pool (because either they are still living and/or they have produced descendants that are alive. Animals with uncertain paternity but that died with no living descendants have been excluded).

It will be important to resolve these and any future uncertain paternities to accurately evaluate the genetic value of individuals, the relationship between mates, and the status of the population as a whole.

Table B1. Giant pandas with multiple sires listed in the 2015 International Studbook.

There are 53 pandas listed in the 2015 studbook with uncertain paternity and that contribute to the living gene pool. Most of these (n=39) are young pandas that were born in 2013 or later, and hopefully routine paternity testing is scheduled for these pandas. However, there are also 15 pandas born between 1996 and 2010 with uncertain paternity that are responsible for over 50% of the uncertainty in the global pedigree. The result of these uncertain sires is that 11% of the gene pool of the *ex situ* population is derived from uncertain ancestry. **Four individuals account for much of this uncertainty: SB# 455 is a very important animal to resolve (accounts for about 25% of all uncertainty in the global pedigree), although this panda recently died; SB#s 439, 495 and 557 are living pandas that are also high priority for paternity verification.** % Contrib to UNK = % of total pedigree uncertainty contributed by each panda.

SB#	Year born	% Contrib to UNK	Possible sires	Confirmed by genetic analysis?	Relevant notes and information from 2014 studbook	Sires used in analysis
437	1996 (dead)	0.13	308 (NM); 298 (AI)	Sire unresolved by 2001 analysis	308 listed in 2013 SB; changed to MULT in 2014 SB	308 (98%); 298 (2%)
439	1996	0.53	308, 329 (NM); 298 (AI)	No	329 listed in 2013 SB; changed to MULT in 2014 SB	308 (49%); 329 (49%); 298 (2%)
455	1997 (dead)	2.38	308, 329 (NM)	Sire unresolved by 2001 analysis	329 listed in 2013 SB; changed to MULT in 2014 SB	308 (50%); 329 (50%)
495	1999	0.59	308, 329 (NM)	Confirmed 2001 but disputed?	2001 analysis indicated sire as 329 but sire of its twin 496 as 308; 329 listed in 2013 SB; changed to MULT in 2014 SB	308 (50%); 329 (50%)
532	2001	0.26	377, 394, 399 (?)	No	No comments. 394 listed as sire; changed to MULT in 2014 SB (basis of probabilities unknown)	394 (60%); 399 (38%); 377 (2%)
538	2001	0.13	308 (NM), 357 (AI)	No	Sire 308 in 2001 SB with 357 as AI; 308 listed in 2013 SB; changed to MULT in 2014 SB	308 (98%); 357 (2%)
539	2001	0.26	308 (NM), 357 (AI)	No	Sire 308 in 2001 SB with 357 as AI; 308 listed in 2013 SB; changed to MULT in 2014 SB	308 (98%); 357 (2%)
547	2002	0.26	308, 394 (NM); 357 (AI)	No	394 listed in 2013 SB; changed to MULT in 2014 SB (basis of probabilities?)	394 (60%); 308 (38%); 357 (2%)
548	2002	0.13	308, 394 (NM); 357 (AI)	No	394 listed in 2013 SB; changed to MULT in 2014 SB (basis of probabilities?)	394 (60%); 308 (38%); 357 (2%)
557	2002	0.46	399 (NM); 327 (AI)	No	399 listed in 2013 SB; changed to MULT in 2014 SB	399 (98%); 327 (2%)
566	2003	0.33	399 (NM), 424 (NM)	No	424 listed in 2013 SB; changed to MULT in 2014 SB; NM with 424 4x, NM with 399 once	424 (80%); 399 (20%)
652	2006	0.33	424, 503 (NM); 467 (AI)	No		424 (49%); 503 (49%); 467 (2%)
766	2010	0.13	496 (NM); 394, 454 (AI)	No		496 (96%); 394 (2%); 454 (2%)

784	2010	0.13	502 (NM, AI); 399 (AI)	No		502 (98%); 399 (2%)
877	2013	0.13	502, 503 (NM)	No		502 (50%); 503 (50%)
883	2013	0.13	623 (NM), 503 (AI)	No		623 (98%); 503 (2%)
905	2013	0.13	579, 623, 661 (NM)	No		579 (33%); 623 (33%); 661 (33%)
910	2014	0.13	502, 503 (?)	No		502 (50%); 503 (50%)
916	2014	0.13	579, 623 (?)	No		579 (50%); 623 (50%)
917	2014	0.13	624, 831 (AI)	No		624 (50%); 831 (50%)
918	2014	0.13	540, 649 (NM)	No		540 (50%); 649 (50%)
919	2014	0.13	540, 649 (NM)	No		540 (50%); 649 (50%)
920	2014	0.13	540, 649 (NM)	No		540 (50%); 649 (50%)
924	2014	0.13	649 (NM); 532 (AI)	No		649 (98%); 532 (2%)
925	2014	0.13	649 (NM); 532 (AI)	No		649 (98%); 532 (2%)
926	2014	0.13	488 (NM); 503 (AI)	No		488 (98%); 503 (2%)
935	2014	0.13	502, 503 (NM)	No		502 (50%); 503 (50%)
936	2014	0.13	579, 623 (NM)	No		579 (50%); 623 (50%)
937	2014	0.13	579, 623 (NM)	No		579 (50%); 623 (50%)
938	2014	0.13	661 (NM); 579 (AI)	No		661 (98%); 579 (2%)
940	2014	0.13	540, 584 (?)	No		540 (50%); 584 (50%)
946	2015	0.13	503, 623 (NM)	No		503 (50%); 623 (50%)
951	2015	0.13	502, 674 (?)	No		502 (50%); 674 (50%)
952	2015	0.13	502, 674 (?)	No		502 (50%); 674 (50%)
953	2015	0.13	502, 503 (?)	No		502 (50%); 503 (50%)
954	2015	0.13	649 (NM); 532 (AI)	No		649 (98%); 532 (2%)
959	2015	0.13	502, 623, 719 (?)	No		502 (33%); 623 (33%); 719 (33%)
960	2015	0.13	502, 623, 719 (?)	No		502 (33%); 623 (33%); 719 (33%)
961	2015	0.13	649 (NM); 532 (AI)	No		649 (98%); 532 (2%)
962	2015	0.13	649 (NM); 532 (AI)	No		649 (98%); 532 (2%)
963	2015	0.13	624, 831 (AI)	No		624 (50%); 831 (50%)
964	2015	0.13	624, 831 (AI)	No		624 (50%); 831 (50%)
970	2015	0.13	502, 743 (?)	No		502 (50%); 743 (50%)
971	2015	0.13	502, 743 (?)	No		502 (50%); 743 (50%)
972	2015	0.13	623, 661 (?)	No		623 (50%); 661 (50%)
973	2015	0.13	623, 661 (?)	No		623 (50%); 661 (50%)
975	2015	0.13	579, 719 (?)	No		579 (50%); 719 (50%)
976	2015	0.13	579, 719 (?)	No		579 (50%); 719 (50%)
978	2015	0.13	458, 609 (?)	No		458 (50%); 609 (50%)
985	2015	0.13	540, 584 (NM)	No		540 (50%); 584 (50%)
986	2015	0.13	540, 584 (NM)	No		540 (50%); 584 (50%)
987	2015	0.13	540, 574 (AI)	No		540 (50%); 574 (50%)
988	2015	0.13	540, 574 (AI)	No		540 (50%); 574 (50%)

Table B2. Giant pandas with undocumented basis for sire identification.

These additional 10 giant pandas originally had uncertainty in their paternity in the studbook. At some point a sire was designated in the studbook; however, it is unclear whether the designated sire was determined based on molecular genetic analysis or if these were assumptions based on breeding methods or other factors. These 10 pandas represent approximate 6.6% of the genetic pool of the 2015 living population. **These uncertainties regarding sire designation should be resolved and designated appropriately in the International Studbook.**

SB#	Year born	Possible sires	Confirmed by molecular genetic analysis?	Relevant notes and information from 2014 studbook	Sires used in analysis
237	1981 (dead)	150, 186 (?)	No	No note of NM or AI; studbook entered 186 as the sire	186 ¹
278	1984	174, 201 (?)	2001 analysis excluded 202 as possible sire	1991 note says may be 174, 201 or 202; 174 was entered as the sire. No note on which NM or AI.	174 ¹
297	1985 (dead)	174 (NM); 201, 202 (AI?)	??	2001 note used 174 as sire due to NM; 174 listed in 2014 studbook	174 ²
314	1986	174, 201, 202 (AI?)	No	1991 note used 201 but says may be any of these. Note says this was the first successful use of frozen semen.	201 ¹
320	1986	135, 149 (?)	No	1991 note says sire may be 135 or 109, but likely typo indicating 149; 149 listed as sire.	149 ¹
323	1986	150, 186 (?)	No	Note says sire may be 150 or 186. 186 listed as the sire.	186 ¹
507	2000	345, 369 (?)	No	1999 studbook had 369	369 ¹
549	2002	308, 394 (NM); 357, 415 (AI)	??	394 listed in 2014 studbook	394 ²
743	2009	377, 621 (AI)	??	Both AI	377 ²
772	2010	623 (NM); 502 (NM, AI)	??	Need to verify methods	502 ²

¹ Male was listed as the sire in earlier versions of the studbook; however, there is no note on how the male was confirmed as the sire.

² Male was listed as the sire in the 2014 studbook; need to confirm that this was based on molecular genetic analysis.

APPENDIX C: Ranked mean kinship (MK) list for giant panda captive population.

Individual giant pandas are listed in order of genetic value for breeding (males on the left; females on the right; unsexed pandas on both lists, in *italics*). Individuals at the top of the list have small mean kinship (MK) values because their genetic lines are under-represented and therefore are valuable breeders. Individuals with high MK values near the bottom of the list are over-represented in the population. The line in the middle of the list represents the average MK value for the population (0.0256); **individuals above this line are underrepresented and are priority breeders to increase gene diversity in the population.**

The top priority breeders for the 2016 breeding season (12 males, 12 females) are highlighted in blue. Focused efforts should be made to breed these pandas if possible, especially the older animals, and to mate them with a genetically valuable mate if possible. The attached MSI tables (Appendix D) can be used to identify their mates.

Caution should be used in using low ranking males (i.e., those near the bottom of the MK list) for multiple breedings.

MALES			
SB#	MK	Location	Age
542	0.0000	DJYGP BC	16
703	0.0000	LOUGUANTA	8
802	0.0000	LOUGUANTA	11
803	0.0000	LOUGUANTA	11
327	0.0007	ABERDE HK	29
831	0.0010	CHENPANDA	15
938	0.0024	DJYGP BC	1
661	0.0029	YAAN BC	9
579	0.0039	YAAN BC	14
415	0.0043	SANDIEGOZ	23
886	0.0046	YAAN BC	2
865	0.0049	YAAN BC	2
624	0.0050	CHENPANDA	11
937	0.0054	DJYGP BC	1
623	0.0066	YAAN BC	11
342	0.0078	CHENPANDA	28
912	0.0101	LOUGUANTA	1
905	0.0106	GENGDA BC	2
775	0.0118	GENGDA BC	5
674	0.0121	GENGDA BC	8
752	0.0127	GENGDA BC	6
787	0.0139	SHENZHEN	5
788	0.0139	CHENPANDA	5
748	0.0141	GENGDA BC	6
917	0.0144	CHENPANDA	1
963	0.0146	CHENPANDA	0

FEMALES			
SB#	MK	Location	Age
416	0.0000	DJYGP BC	22
660	0.0000	LOUGUANTA	18
696	0.0000	DJYGP BC	20
765	0.0000	CHENPANDA	9
860	0.0000	YAAN BC	6
702	0.0007	YAAN BC	8
505	0.0013	WOLONG	15
581	0.0019	WOLONG	13
544	0.0033	DJYGP BC	21
698	0.0040	DJYGP BC	12
837	0.0041	GENGDA BC	3
838	0.0041	GENGDA BC	3
916	0.0041	WOLONG	1
827	0.0046	YAAN BC	4
936	0.0054	DJYGP BC	1
862	0.0056	GENGDA BC	2
507	0.0083	MEMPHIS	15
911	0.0101	LOUGUANTA	1
757	0.0111	LOUGUANTA	6
908	0.0111	LOUGUANTA	2
965	0.0118	CHENPANDA	0
966	0.0118	CHENPANDA	0
791	0.0124	HUAYING	5
434	0.0128	KOBE PARK	20
691	0.0134	YAAN BC	8
562	0.0138	LOUGUANTA	12

MALES			
SB#	MK	Location	Age
964	0.0146	CHENPANDA	0
711	0.0158	CHENPANDA	7
609	0.0161	GENGDA BC	10
526	0.0161	VIENNA	15
724	0.0166	CHENPANDA	7
582	0.0166	WEIFANG J	11
972	0.0169	YAAN BC	0
951	0.0177	YAAN BC	0
952	0.0177	YAAN BC	0
719	0.0180	YAAN BC	7
606	0.0182	ABERDE HK	10
502	0.0183	YAAN BC	16
461	0.0183	ATLANTA	18
975	0.0189	YAAN BC	0
510	0.0192	CHIANGMAI	15
978	0.0197	NZP-WASH	0
830	0.0200	HUAYING	4
731	0.0203	CHENPANDA	7
466	0.0204	MEMPHIS	17
736	0.0205	BEAUVAL	7
386	0.0206	CHENPANDA	23
713	0.0209	LOUGUANTA	7
613	0.0211	PANYU	10
769	0.0215	SHENZHEN	5
563	0.0220	DJYGP BC	12
749	0.0220	SHIH CHIA	6
842	0.0220	SANDIEGOZ	3
620	0.0222	ADELAIDE	10
874	0.0224	WOLONG	2
649	0.0224	CHENPANDA	9
910	0.0224	YAAN BC	1
520	0.0224	CHENPANDA	15
607	0.0225	YICHANG	10
595	0.0229	DJYGP BC	10
689	0.0230	YAAN BC	8
690	0.0230	SINGAPORE	8
586	0.0231	GENGDA BC	11
488	0.0235	DJYGP BC	16
949	0.0235	YAAN BC	0
950	0.0235	WOLONG	0
926	0.0236	WOLONG	1
792	0.0237	CHENPANDA	5
793	0.0237	CHENPANDA	5
906	0.0237	MADRID Z	2

FEMALES			
SB#	MK	Location	Age
947	0.0142	CHENPANDA	0
948	0.0142	CHENPANDA	0
473	0.0148	NZP-WASH	17
382	0.0150	DJYGP BC	24
569	0.0165	EDINBURGH	12
955	0.0167	WOLONG	0
973	0.0169	YAAN BC	0
883	0.0172	BEIJING	2
725	0.0173	CHENPANDA	7
512	0.0178	YAAN BC	15
403	0.0186	BEIJING	22
561	0.0186	CHENPANDA	12
654	0.0187	YAAN BC	9
980	0.0187	YAAN BC	0
650	0.0187	YAAN BC	9
976	0.0189	YAAN BC	0
755	0.0190	YAAN BC	6
784	0.0193	BEIJING	5
509	0.0195	LOUGUANTA	15
387	0.0196	CHENPANDA	23
572	0.0196	YAAN BC	12
601	0.0199	DEQING	10
941	0.0200	YAAN BC	1
401	0.0201	CHENPANDA	22
643	0.0202	SANJIANG	9
439	0.0202	YAAN BC	19
801	0.0203	CHENPANDA	5
870	0.0203	ATLANTA	2
871	0.0203	ATLANTA	2
385	0.0204	BAOX ECTR	23
452	0.0209	ATLANTA	18
761	0.0209	GUANGZHOU	6
762	0.0209	GUANGZHOU	6
425	0.0211	CHENPANDA	20
407	0.0211	YAAN BC	21
959	0.0215	YAAN BC	0
960	0.0215	YAAN BC	0
680	0.0217	CHENPANDA	8
692	0.0219	WOLONG	8
576	0.0220	MADRID Z	12
756	0.0220	GENGDA BC	6
474	0.0222	WOLONG	17
678	0.0222	CHENPANDA	8
596	0.0223	WOLONG	10

MALES			
SB#	MK	Location	Age
743	0.0238	YAAN BC	6
685	0.0241	LANGZHONG	8
789	0.0241	TSINAN	5
887	0.0241	DJYGP BC	2
954	0.0241	CHENPANDA	0
519	0.0241	MADRID Z	15
726	0.0241	MACAO CMA	7
772	0.0241	NANJING	5
390	0.0243	WAKAYAMA	23
592	0.0247	LANCHOW	11
532	0.0253	CHENPANDA	14
770	0.0253	CHANGSHA	5
857	0.0253	CHENPANDA	3
858	0.0253	CHENPANDA	3
714	0.0255	LIUGONGDA	7
747	0.0256	EMEI EP	6
778	0.0256	DJYGP BC	5
931	0.0256	WOLONG	1
879	0.0256	GENGDA BC	2
933	0.0259	DJYGP BC	1
413	0.0259	ANYANG	21
492	0.0261	DJYGP BC	16
715	0.0262	LOUGUANTA	7
518	0.0267	DAFENG	15
536	0.0267	ANJI BAMB	14
742	0.0270	DEQING	6
525	0.0270	FUCHOW	15
668	0.0270	XIUNING	8
669	0.0270	TIGER G	8
839	0.0271	CHENPANDA	3
564	0.0274	EDINBURGH	12
573	0.0275	CHENPANDA	12
614	0.0275	CHENPANDA	10
662	0.0275	LIUZHOU	8
503	0.0276	YAAN BC	16
745	0.0276	PAIRI DAI	6
746	0.0276	WEIFANG J	6
902	0.0276	TAIYUAN	2
758	0.0277	EMEI EP	6
852	0.0277	LINYI BG	3
961	0.0277	CHENPANDA	0
962	0.0277	CHENPANDA	0
890	0.0277	TAIYUAN	2
786	0.0278	NANJING	5

FEMALES			
SB#	MK	Location	Age
946	0.0223	YAAN BC	0
984	0.0224	YAAN BC	0
522	0.0224	CHENPANDA	15
694	0.0227	YAAN BC	8
897	0.0229	NZP-WASH	2
739	0.0230	TIGER G	7
794	0.0230	DJYGP BC	5
681	0.0234	CHENPANDA	8
637	0.0239	CHENPANDA	9
796	0.0239	CHANGSHA	5
943	0.0240	DJYGP BC	1
567	0.0240	YANGZHOU	12
706	0.0240	TIANMUHU	7
523	0.0241	CHENPANDA	15
771	0.0241	TSINAN	5
652	0.0244	CHENPANDA	9
598	0.0246	CHENPANDA	10
760	0.0246	WENLING S	6
811	0.0250	CHENPANDA	4
487	0.0251	WOLONG	16
759	0.0252	YAAN BC	6
823	0.0253	CHENPANDA	4
869	0.0254	DJYGP BC	2
631	0.0254	YAAN BC	9
810	0.0254	SHANGHAI	4
625	0.0255	WOLONG	9
800	0.0256	ANYANG	5
929	0.0256	WOLONG	1
932	0.0256	WOLONG	1
880	0.0256	DJYGP BC	2
967	0.0258	YAAN BC	0
968	0.0258	YAAN BC	0
566	0.0259	YAAN BC	12
983	0.0259	YAAN BC	0
587	0.0261	TAIPEI	11
924	0.0261	CHENPANDA	1
925	0.0261	CHENPANDA	1
763	0.0262	CHENPANDA	6
480	0.0263	CHENPANDA	16
568	0.0263	WOLONG	12
734	0.0264	SINGAPORE	7
877	0.0264	TIANJIN	2
495	0.0265	WOLONG	16
712	0.0265	YAAN BC	7

MALES			
SB#	MK	Location	Age
751	0.0279	PANYU	6
841	0.0280	LINYI BG	3
867	0.0280	DJYGP BC	2
899	0.0282	CHENPANDA	2
900	0.0282	CHENPANDA	2
515	0.0286	HEFEI W	15
575	0.0286	ANJI BAMB	12
454	0.0286	FUCHOW	18
875	0.0286	CHENPANDA	2
876	0.0286	CHENPANDA	2
744	0.0286	PANYU	6
956	0.0286	WOLONG	0
599	0.0287	XIXIAKOU	10
529	0.0291	SHIH CHIA	14
530	0.0291	WENZHOU	14
589	0.0291	NANCHANG	11
619	0.0291	WUHAN	10
904	0.0291	CHENPANDA	2
920	0.0291	CHENPANDA	1
574	0.0292	CHENPANDA	12
918	0.0292	CHENPANDA	1
738	0.0294	CHENPANDA	7
782	0.0294	WAKAYAMA	5
588	0.0294	TAIPEI	11
825	0.0294	HANGCHOW	4
935	0.0295	DJYGP BC	1
894	0.0296	BEIJING	2
895	0.0296	BEIJING	2
790	0.0296	HANGZHOUW	5
513	0.0297	CHONGQING	15
458	0.0297	NZP-WASH	18
639	0.0304	KUALA LUM	9
540	0.0305	CHENPANDA	13
768	0.0305	DALIAN	5
721	0.0305	TIANMUHU	7
633	0.0307	GENGDA BC	9
732	0.0311	TORONTO	7
538	0.0312	FUCHOW	14
985	0.0316	CHENPANDA	0
986	0.0316	CHENPANDA	0
636	0.0317	WENLING S	9
424	0.0317	CHONGQING	20
646	0.0317	FUCHOW	9
496	0.0320	BEIJING	16

FEMALES			
SB#	MK	Location	Age
641	0.0265	KUALA LUM	9
853	0.0267	CHENPANDA	3
735	0.0267	YAAN BC	7
740	0.0269	YAAN BC	6
884	0.0270	DJYGP BC	2
846	0.0270	NINGBO	3
909	0.0271	LOUGUANTA	2
664	0.0273	WOLONG	8
672	0.0274	YAAN BC	8
868	0.0274	CHENPANDA	2
565	0.0274	TAIHU EP	12
665	0.0275	CHENPANDA	8
663	0.0275	CHENPANDA	8
651	0.0276	DJYGP BC	9
704	0.0278	EMEI EP	7
750	0.0279	PANYU	6
953	0.0279	YAAN BC	0
855	0.0279	CHENPANDA	3
892	0.0279	CHENPANDA	2
549	0.0280	TAIHU EP	13
913	0.0281	WOLONG	1
511	0.0283	WOLONG	15
864	0.0284	TAIPEI	2
709	0.0285	CHENPANDA	7
834	0.0286	NINGBO	3
835	0.0286	LANGZHONG	3
557	0.0286	PANYU	13
600	0.0287	TOKYOUENO	10
970	0.0289	YAAN BC	0
971	0.0289	YAAN BC	0
554	0.0291	CHENGDU	13
741	0.0291	PAIRI DAI	6
903	0.0291	CHENPANDA	2
977	0.0291	KUALA LUM	0
919	0.0292	CHENPANDA	1
737	0.0294	CHENPANDA	7
783	0.0294	WAKAYAMA	5
832	0.0294	WAKAYAMA	3
944	0.0294	WAKAYAMA	0
945	0.0294	WAKAYAMA	0
618	0.0294	PANYU	10
824	0.0294	HANGCHOW	4
537	0.0295	CHENPANDA	14
766	0.0297	BEIJING	5

MALES			
SB#	MK	Location	Age
982	0.0320	CHONGQING	0
987	0.0320	TORONTO	0
707	0.0321	DJYGP BC	7
915	0.0324	CHENPANDA	1
670	0.0332	WENZHOUE	8
851	0.0332	CHENPANDA	3
688	0.0333	DAFENG	8
584	0.0334	CHENPANDA	11
957	0.0335	CHENPANDA	0
958	0.0335	CHENPANDA	0
583	0.0337	SHANGHAI	11
612	0.0337	TOKYOUENO	10
928	0.0343	CHENPANDA	1
666	0.0343	LIUZHOU	8
717	0.0343	MACAO CMA	7
460	0.0344	LOUGUANTA	18
922	0.0355	PANYU	1
923	0.0355	PANYU	1
644	0.0363	ZIBO YSH	9
878	0.0366	PANYU	2
605	0.0372	XIXIAKOU	10
627	0.0378	CHENPANDA	9
628	0.0378	QINGDAO	9
629	0.0381	ZIBO YSH	9
630	0.0381	WUXI	9
780	0.0381	ANJI BAMB	5
815	0.0381	FUDE TJ	4
399	0.0381	BAOX ECTR	22
394	0.0431	BEIJING	23

FEMALES			
SB#	MK	Location	Age
494	0.0301	LOUGUANTA	16
555	0.0301	CHENPANDA	13
638	0.0301	ADELAIDE	9
610	0.0301	ABERDE HK	10
632	0.0301	GUILIN	9
548	0.0301	CHONGQING	13
453	0.0302	CHENPANDA	18
570	0.0304	CHENPANDA	12
813	0.0304	CHANGSHA	4
774	0.0305	DALIAN	5
634	0.0307	GENGDA BC	9
889	0.0307	CHENPANDA	2
514	0.0307	VIENNA	15
547	0.0309	PANYU	13
818	0.0310	SHANGHAI	4
819	0.0310	SHANGHAI	4
493	0.0311	CHONGQING	16
516	0.0312	GENGDA BC	15
476	0.0312	YAAN BC	17
593	0.0318	CHENPANDA	11
940	0.0318	LOUGUANTA	1
539	0.0319	CHIANGMAI	14
781	0.0320	DALIAN	5
907	0.0320	DJYGP BC	2
848	0.0320	CHENPANDA	3
648	0.0320	CHONGQING	9
829	0.0320	CHONGQING	4
896	0.0320	CHONGQING	2
988	0.0320	TORONTO	0
708	0.0321	DJYGP BC	7
432	0.0321	YAAN BC	20
635	0.0322	CHENPANDA	9
821	0.0324	GUIZHOU W	4
822	0.0324	GUIZHOU W	4
645	0.0324	CHENPANDA	9
914	0.0324	CHENPANDA	1
820	0.0324	FUDE TJ	4
676	0.0327	TORONTO	8
521	0.0331	WAKAYAMA	15
671	0.0332	CHENPANDA	8
491	0.0333	CHENPANDA	16
881	0.0336	CHENPANDA	2
882	0.0336	CHENPANDA	2
611	0.0337	HANGZHOUW	10

FEMALES			
SB#	MK	Location	Age
682	0.0337	LIUGONGDA	8
490	0.0338	CHENPANDA	16
872	0.0340	LOUGUANTA	2
667	0.0343	MACAO CMA	8
477	0.0344	YAAN BC	17
571	0.0350	YAAN BC	12
921	0.0355	PANYU	1
969	0.0359	PANYU	0
764	0.0363	CHENPANDA	6
722	0.0381	QINGDAO	7
723	0.0381	BEAUVAL	7
779	0.0381	ANJI BAMB	5
814	0.0381	CHANGSHA	4
371	0.0384	SANDIEGOZ	24

APPENDIX D: Giant panda MSI values for mate selection during the 2016 breeding season (distributed at the meeting in Dalian in November 2015).

This appendix provides the MSI tables for giant panda *ex situ* population for use in determining breeding pairs for the 2016 breeding season. Permanent non-breeders and dead pandas (including sperm samples) were excluded from the genetic analysis and therefore are not represented in this table. Mean kinship values and MSI scores change over time with births and deaths in the population, so a current MSI table should be calculated each year.

When choosing mates, consider the following:

- There is no need to maximize growth and attempt to breed all females. Breeding efforts should concentrate on genetically valuable females to produce cubs for the *ex situ* population. Additional females that are good candidates for producing offspring for release also can be bred to support reintroduction efforts.
- Pairs with MSI = 1 to 3.5 should be given breeding priority, especially for institutions with pairing choices, as this will improve genetic diversity and reduce inbreeding.
- Efforts should be made also to breed males and females with low mean kinship (MK) values. The average MK in the population is 0.0256. Animals with MK less than 0.0256 should be preferred breeders to maintain genetic diversity. The MK values are shown for each male and female on the MSI tables and on the mean kinship list (Appendix C).
- Priority efforts should be made to breed any wild-acquired pandas that have not produced surviving offspring, even if the MSI score = 3.5.
- Potential founders or other genetically valuable pandas should be bred with other high ranking pandas when possible ($MSI \leq 3$). However, it is acceptable to breed potential founders with lower ranking pandas if this is the best or only option for successful reproduction for this highly valuable animal. To identify these special cases, MSI scores greater than 3 for pairs involving potential founders were changed to 3.5.
- AI should be restricted for use only for genetically valuable pairings that must be bred.

The following MSI tables list one row for each male and one column for each female, in alphabetical order by institution. The intersecting cell for a male and female contains the MSI score for that pair. The MK value of each animal is given next to its studbook number. These MK values are color coded according to percentile, with dark green representing the most genetically valuable animals for breeding (low MK value), changing to light green and then yellow in the middle of the MK list, and finally to orange and then red for animals at the bottom of the MK list. Red indicates animals that are genetically overrepresented and should not be bred unless their cubs are needed for demographic reasons (e.g., for release). The studbook numbers for the potential founders are highlighted in yellow to identify them as high priority breeders.

MateRx listings

The PMx software includes the MateRx tool, which is designed and developed to be a genetic tool that will guide population management decisions. For every male/female pair in the population, MateRx calculates a single numeric index indicating the relative genetic benefit or detriment to the population of breeding that particular pair. This index, called the mate suitability index (or MSI), is calculated from considering each pair's mean kinship values, the difference in the male's and female's mean kinship, the inbreeding coefficient of the offspring produced, and the amount of unknown ancestry in the pair. MateRx is designed to simplify the decisions about which pairs should be bred by condensing all that we know about the genetics of a pair into a single number.

MSI values are labeled as beneficial (scores = 1, 2, or 3) or detrimental (scores = 4, 5, or 6) to the population. Beneficial MSIs denote no detrimental effects relative to the genetic values of that pair, and MSI values of 4, 5, or 6 indicate at least one detrimental effect.

MSI Score Definitions:

1 = very beneficial pair;
2 = moderately beneficial pair;
3 = slightly beneficial pair;

4 = slightly detrimental pair;
5 = detrimental pair, should only be used if demographically necessary;
6 = very detrimental pair, (should only be used if demographic considerations override preservation of genetic diversity, or if this is the only good option for breeding a very highly ranked individual).

“-“ = so detrimental that the pair should never be bred

Note: When one of the animals in the pair is a potential founder (wild-caught animal with no living offspring or descendants) and therefore of high priority for breeding, $MSI \geq 4$ were revised to prevent the situation where these animals are not bred because their only available mates were of relatively low genetic value (leading to a high MSI). In these cases, $MSI = 3.5$.

- Breeding by MSI values does not address demographics, behavior or logistics.
- MSI values are not intended for use with all captive managed species. Many species have unusual population histories and structures that require the expertise and attention of a trained population biologist. These populations may have characteristics such as few founders, many captive generations, extremely small numbers, or many unknown origins or parentage data that prohibit generic management.
- MSI values (and MK values) are time sensitive: the MSI rankings are only valid as long as there are no substantial changes in the population. These MSI tables should be considered invalid after one year following its date of creation.