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Research Article

One Year Later: Evaluation of PMC-Recommended Births and Transfers

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To meet their exhibition, conservation, education, and scientific goals, members of the American Zoo and Aquarium Association (AZA) collaborate to manage their living collections as single species populations. These cooperative population management programs, Species Survival Plans® (SSP) and Population Management Plans (PMP), issue specimen-by-specimen recommendations aimed at perpetuating captive populations by maintaining genetic diversity and demographic stability. Species Survival Plans and PMPs differ in that SSP participants agree to complete recommendations, whereas PMP participants need only take recommendations under advisement. We evaluated the effect of program type and the number of participating institutions on the success of actions recommended by the Population Management Center (PMC): transfers of specimens between institutions, breeding, and target number of offspring. We analyzed AZA studbook databases for the occurrence of recommended or unrecommended transfers and births during the 1-year period after the distribution of standard AZA Breeding-and-Transfer Plans. We had three major findings: 1) on average, both SSPs and PMPs fell about 25% short of their target; however, as the number of participating institutions increased so too did the likelihood that programs met or exceeded their target; 2) SSPs exhibited significantly greater transfer success than PMPs, although transfer success for both program types was below 50%; and 3) SSPs exhibited significantly greater breeding success than PMPs, although breeding success for both program types was below 20%. Together, these results

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indicate that the science and sophistication behind genetic and demographic management of captive populations may be compromised by the challenges of implementation. Zoo Biol 0:1–11, 2006.

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INTRODUCTION

The successful captive propagation of animals is essential if zoos are to meet their exhibition, conservation, education, and scientific goals [Hutchins et al., 1996]. Given this imperative, as well as the inherent risks to small populations [Ballou and Foose, 1996], cooperative management across multiple institutions is often necessary to ensure survival of zoo populations [Wiese and Hutchins, 1994]. The American Zoo and Aquarium Association (AZA) implements cooperative management through its Species Survival Plans® (SSPs) and Population Management Plans (PMPs): these programs treat the collective specimens of each species as a single population. SSPs and PMPs aim to ensure the maintenance of genetic diversity and demographic stability through specimen-by-specimen recommendations that specify how many offspring are needed each year to meet program goals, which specimens breed and with whom, and which specimens are transferred between participating institutions. Until 2000 these recommendations were distributed every 12–14 months in a variable format Master Plan; from 2000 to the present recommendations have been distributed as standardized format Breeding-and-Transfer Plans. Despite more than 20 years of cooperative management there has never been an evaluation of success for specimen-by-specimen recommendations.

Each SSP or PMP is advised by either a population biologist of the AZA Population Management Center (PMC) or a non-PMC member of the AZA Small Population Management Advisory Group (SPMAG). Since its inception in June 2000, the PMC has assisted in the preparation and distribution of more than 175 standard format Breeding-and-Transfer Plans. This study uses reports prepared by the PMC to undertake the first quantitative evaluation of success for specific PMP and SSP recommendations.

Each Breeding-and-Transfer Plan sets an objective for the number of offspring to produce in a specified time period (usually 12 months) and makes recommendations for specific ‘‘pairings’’ of specimens for breeding, and transfers of specimens between institutions for breeding or other needs (e.g., display, space constraints, socialization).

The number of offspring that should result from each Breeding-and-Transfer Plan is determined using demographic projections that take into consideration estimates of the population’s past and potential growth rates (λ), mortality rates, mean litter or clutch size, and the amount of breeding and holding space available at participating institutions. Breeding recommendations use mean kinship [Ballou and Foose, 1996] and husbandry requirements (e.g., behavior, housing requirements) to specify which animals in the population should breed to meet each plan’s objective for number of offspring. To accommodate breeding recommendations or space constraints within participating institutions, animals are often recommended for transfer between institutions or between social groups at a single institution. When breeding or transfer recommendations do not occur as recommended, the ability of a program to meet its long-term goals (e.g., target population size, self-sustainability), its short-term objective for number of offspring, and the educational exhibit needs of its participating institutions, can be greatly diminished.

Distinctions between SSPs and PMPs could impact recommendation success. SSP recommendations are the result of a collaborative process between a species coordinator, management group, studbook keeper, and institutional representatives (IR) from participating institutions. PMP recommendations typically involve only a population manager or studbook keeper; there is no management group. For each program, draft plans undergo a mandatory 30-day review period during which comments are solicited from participating or holding institutions and then incorporated into the final plan. The most significant distinction between PMP and SSP recommendations is that SSP participants agree to abide by final recommendations (termed "full participation") whereas final recommendations for PMPs are advisory and decisions regarding animal management are ultimately made by each holding institution [American Zoo and Aquarium Association, 2000].

In addition to this fundamental distinction between SSP and PMP policy, it is likely that the different program types elicit different perceptions among participating institutions. Species managed at the SSP level tend to be endangered, charismatic, high-profile vertebrates that are popular with zoo visitors and consequently in high demand for display. PMP species are more likely to be smaller-bodied and less charismatic. Therefore it is likely the perceived value of PMP species and urgency of recommendations is lower than SSP species across institutions [Earnhardt et al., 2001] despite the greater difficulty and higher cost associated with transporting and exhibiting large-bodied SSP specimens.

We evaluate the success of recommendations in plans produced by the PMC 1 year after recommendations were issued. Specifically we ask the following questions: 1) Without regard to program types or number of participating institutions, how successful are a) breeding recommendations and b) recommended transfers? 2) Does program type or the number of participating institutions affect the average levels of success for a) breeding recommendations, b) recommended transfers, or c) a program's likelihood of achieving the recommended number of births?

MATERIALS AND METHODS

Paper or electronic copies of PMC-assisted final Breeding and Transfer Plans distributed between 2000 and 2003 were obtained from either the PMC files or the AZA web site. Studbook keepers were asked to provide current electronic studbook databases maintained in Single Population Analysis and Record Keeping Software, SPARKS [International Species Information System, 1997]. If a studbook keeper did not submit a studbook updated to at least 365 days after plan distribution, that plan was excluded from the study unless an updated version of the studbook was available from the ISIS Studbook Library CD [International Species Information System, 2003]. Studbooks are intended to be a true record of a taxon's pedigree and demographic history in captivity [Thompson and Earnhardt, 1996] and, if updated in a timely manner, should contain a record of all transfers and reproduction resulting from a Breeding-and-Transfer Plan.

Given that most plans make recommendations that are applicable only for the next year (ca. 12 months), measures of recommendation success were based on an evaluation of the studbook events (transfers and births) in the 365-day period immediately after distribution of a final plan; plans with recommendations intended to span >1 year, and plans that were distributed within 364 days of the beginning of this study, were not included in the analyses.

The following data were collected from each Breeding and Transfer Plan and corresponding studbook:

- *Program type*: PMP or SSP as designated in the Breeding and Transfer Plan;
- *Number of participating institutions*: the number of institutions assigned recommendations in the Breeding and Transfer Plan;
- *Number of breed recommendations*: the number of individuals recommended to breed in the Breeding and Transfer Plan;
- *Number of successful breed recommendations*: the number of individuals recommended to breed in the Breeding and Transfer Plan that produced offspring with the recommended mate within 1 year as recorded in the studbook;
- *Number of DNB recommendations*: the number of individuals assigned "Do Not Breed" recommendations in the Breeding and Transfer Plan;
- *Number of successful DNB recommendations*: the number of individuals assigned "Do Not Breed" recommendations in the Breeding and Transfer Plan that did not produce offspring within 1 year as recorded in the studbook;
- *Number of transfer recommendations*: the number of individuals recommended to transfer institutions in the Breeding and Transfer Plan;
- *Number of successful transfer recommendations*: the number of individuals recommended to transfer institutions that transferred to the assigned institution within 1 year as recorded in the studbook;
- *Number of hold recommendations*: the number of individuals assigned "Hold" recommendations in the Breeding and Transfer Plan (indicating that the individual should not transfer institutions);
- *Number of successful hold recommendations*: the number of individuals assigned "Hold" recommendations that did not transfer institutions within 1 year as recorded in the studbook;
- *Target*: the goal number of offspring to be produced in 1 year as specified in the Breeding and Transfer Plan;
- *Number of offspring produced*: the number of offspring produced by individuals at participating institutions within 1 year as recorded in the studbook, regardless of whether the offspring were the result of a pair recommended to breed.

Based on these data, the following measures were calculated for each Breeding and Transfer Plan:

- *Breeding success*: the number of successful breed recommendations divided by the number of breed recommendations;
- *DNB success*: the number of successful DNB recommendations divided by the number of DNB recommendations;
- *Percent of target reached*: the number of offspring produced divided by the target;
- *Transfer success*: the number of successful transfer recommendations divided by the number of transfer recommendations;

- *Hold success*: the number of successful hold recommendations divided by the number of hold recommendations.

To determine what effect the program type or number of participating institutions may have on recommendation success, we carried out an analysis of variance assuming institution number as a continuous variable and program type as a fixed-effect. We used Type III sums of squares because sample sizes differed between program types. To meet assumptions of normality and constant variance we used an arc sin square-root transformation for transfer and breeding success rates and a square-root transformation on the ability to meet the PMC-targeted number of births. We used S-Plus 2000 for all analyses [MathSoft, 1999].

RESULTS

The studbooks and Breeding and Transfer Plans were obtained for 35 species (21 SSPs, 14 PMP; Table 1). The plans included 703 breed recommendations, 2,104 DNB recommendations, 399 transfer recommendations, and 3,463 hold recommendations. Of these plans, one plan (White stork PMP, 2002) was excluded from the analyses because we could not determine the number of participating institutions. When analyses involved transfer recommendations, one plan (Puma PMP, 2001) was excluded because it lacked specimen-by-specimen transfer recommendations; when analyses involved breeding recommendations, one plan (Okapi SSP, 2002) was excluded because the gestation period of the species exceeded 365 days; when analyses involved target number of offspring, one plan (Cotton-top tamarin SSP, 2002) was excluded because the recommended objective number of offspring (0) would yield an undefined level of success (29 offspring were produced).

Reproduction

The average breeding success across all individuals, regardless of species, was 18.8%; the average DNB success was 96.1% (Fig. 1). Across all species, the average percent of target reached was 75.4%. When analyzed by program type (with each species contributing equally, regardless of the number of individuals of each species), the average breeding success was significantly greater for SSP species than PMP species (19.7 ± SE 3.2% and 9.2 ± SE 3.6%, respectively) (Table 2, Fig. 1). There was no significant difference between SSP and PMP species for DNB success (96.9 ± SE 1.0% and 94.9 ± SE 2.4%, respectively) (Table 2, Fig. 1). The average percent of target reached was similar across program types; SSP species reached 75.9% (± SE 16.9%) of the target and PMP species reached 75.1% (± SE 18.3%).

Transfers

The average transfer success across all individuals, regardless of species, was 50.0%; the average hold success was 94.0% (Fig. 1). When analyzed by program type, the average transfer success was significantly greater for SSP species than PMP species (49.8 ± SE 5.3% and 33.3 ± SE 9.0%, respectively) (Table 2, Fig. 1). There was no significant difference between SSP and PMP species for hold success (94.4 ± SE 1.6% and 92.7 ± SE 2.1%, respectively) (Table 2, Fig. 1).

TABLE 1. Breeding-and-Transfer Plans included in analyses

Species	Program type	Date of plan
Allen's swamp monkey (*Allenopithecus nigroviridis*)	SSP	Jan 2003
Asian small-clawed otter (*Amblonyx cinereus*)	SSP	Jun 2001
Bali mynah (*Leucopsar rothschildi*)	SSP	Sep 2001
Blue-grey tanager (*Thraupis episcopus*)	PMP	Dec 2002
Bolivian grey titi monkey (*Callicebus* spp.)	PMP	Mar 2001
Callimico (Goeldi's monkey) (*Callimico goeldii*)	SSP	Sep 2000
Cotton-top tamarin (*Sagunius oedipus*)[a]	SSP	Feb 2002
Eastern diamondback rattlesnake (*Crotalus adamanteus*)	PMP	Feb 2001
Fennec fox (*Vulpes zerda*)	PMP	Aug 2002
François langur (*Trachypithecus francois*)	SSP	Aug 2000
Geoffroy's marmoset (*Callithrix geoffroyi*)	SSP	Jan 2001
Green-naped pheasant pigeon (*Otidiphaps nobilis*)	PMP	Nov 2002
Guam rail (*Rallus owstoni*)	SSP	Sep 2002
Guinea baboon (*Papio papio*)	SSP	May 2002
Hamadryas baboon (*Papio hamadryas*)	SSP	Jun 2002
Inca tern (*Larosterna inca*)	PMP	Mar 2001
Jamaican boa (*Epicrates subflavus*)	PMP	Oct 2002
Laughing kookaburra (*Dacelo novaeguineae*)	PMP	Jan 2002
Louisiana pine snake (*Pituophis ruthveni*)	SSP	Mar 2001
Micronesian kingfisher (*Halcyon cinnamomina cinnamomina*)	SSP	May 2001
Mongoose lemur (*Eulemur mongoz*)	SSP	Dec 2000
Okapi (*Okapia johnstoni*)[a]	SSP	May 2002
Parma wallaby (*Macropus parma*)	PMP	Dec 2002
Polar bear (*Ursus maritimus*)	SSP	Nov 2000
Puma (*Puma concolor*)[a]	PMP	Jan 2001
Pygmy hippo (*Choeropsis liberiensis*)	SSP	Oct 2002
Red wolf (*Canis rufus gregoryi*)	SSP	Dec 2001
Ring-tailed lemur (*Lemur catta*)	SSP	Oct 2001
Silver-beaked tanager (*Ramphocelus carbo*)	PMP	Dec 2002
Sloth bear (*Melursus ursinus*)	SSP	Nov 2000
Sunbittern (*Eurypuga helias*)	PMP	Sep 2001
Turquoise tanager (*Tangara mexicana*)	PMP	Dec 2002
Wattled crane (*Bugeranus carunculatus*)	SSP	Jun 2001
White stork (*Ciconia ciconia*)[a]	PMP	Jul 2002
White-naped crane (*Grus vipio*)	SSP	Mar 2002

[a]Data excluded from certain analyses.

Effect of the Number of Institutions

We found no significant effect of the number of participating institutions on breeding success (Table 2). However, results indicated that as the number of participating institutions increased, the percent of target obtained increased (Table 2, Fig. 2). Programs with fewer institutions were likely to fall short of their objectives for number of offspring, whereas programs with more institutions were likely to exceed their objectives for number of offspring. There was also a significant effect of the number of institutions on transfer success; the greater the number of participating institutions, the higher the transfer success (Table 2).

DISCUSSION

Overall, our study clearly shows that the success of PMC-issued recommendations in the year after their distribution are much lower than planned for transfers

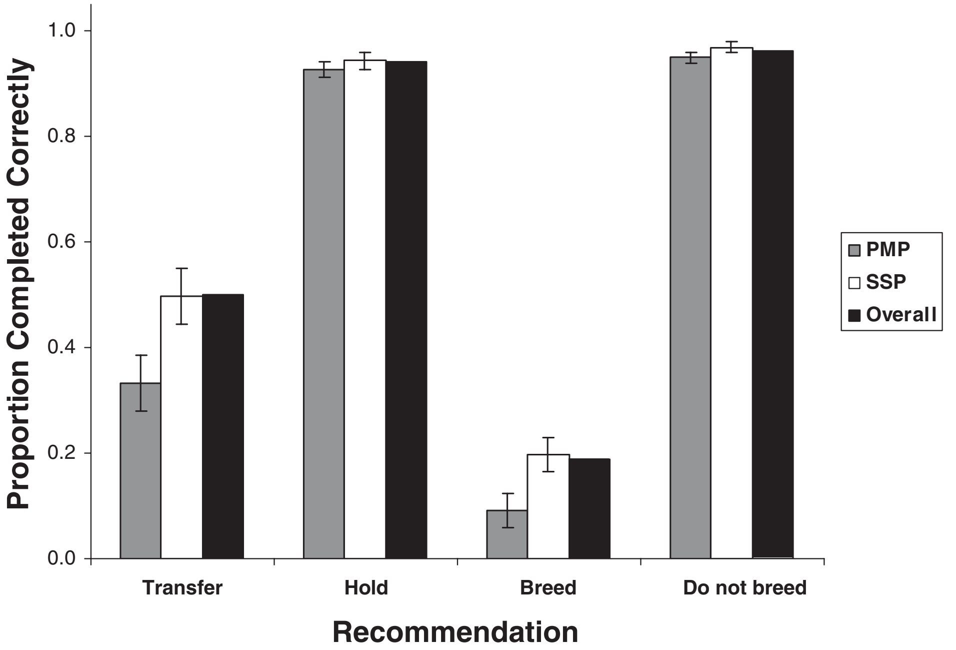

Fig. 1. The effect of program type on average plan success (with standard error) on ability to meet number of holds, transfers, and recommendations to breed or not to breed.

TABLE 2. F-ratios from ANOVAs of the effects of management and number of participating institutions on transfers, breeding, and reproduction

	df	Transfer	Hold	Breed	Do not breed	Offspring (*n*)
Program (PMP or SSP)	1	2.744*	0.237	3.670*	0.344	0.747
Institutions (*n*)	1	3.549*	0.045	0.268	0.000	16.000**
Residual *df*		30	29	25	25	29

*$P<0.1$.
**$P<0.001$.

and breeding (Fig. 1); few programs are able to reach their targeted goals. Fewer than 20% of the breeding recommendations led to offspring, and regardless of whether offspring were the result of a recommended breeding pair, programs on average fell about 25% short of their target number of offspring.

Species Survival Plans® exhibited greater breeding and transfer success than PMPs (Fig. 1). Although the sample size in this study is small relative to the number of SSP and PMP species (116 and 300, respectively), our results suggest that the operational distinctions between SSPs and PMPs, as well as the types of species managed under the two schemes, impact the potential success of recommendations. SSP recommendations are binding, whereas PMP recommendations remain voluntary. Although PMP program managers often solicit information regarding the needs of participating institutions before creating a plan,

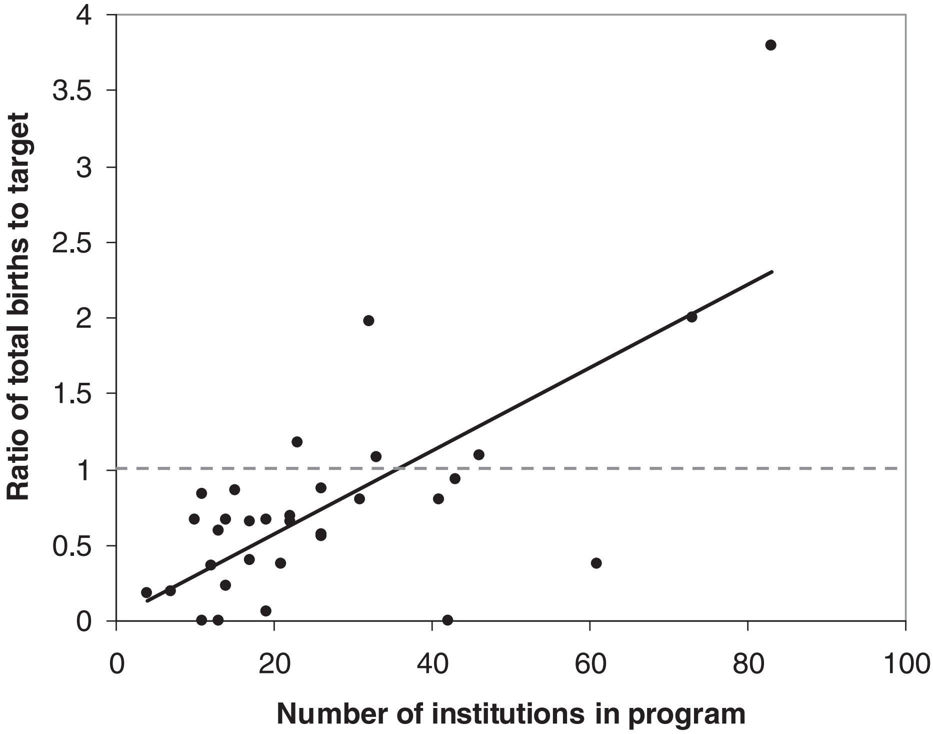

Fig. 2. The ability of a program to meet or exceed its targeted number of offspring increases with the number of participating institutions. The dashed line shows where a plan would perfectly meet its target. Because these are untransformed data and do account for the potential effect of program type, the correlation and slope of the line are not presented in the figure.

institutions are ultimately empowered to make their own decisions regarding animal transfers.

Our findings reinforce concerns expressed by Earnhardt et al. [2001], who identified significant differences in population sizes, life histories and genetic structures between PMP and SSP species. Whereas SSP species tend to be charismatic megavertebrates with long mean generation times, moderate to large population sizes and relatively high gene diversity; PMP species are typically small-bodied with shorter mean generation times, relatively small population sizes and precariously low gene diversity. Earnhardt et al. [2001] concluded that, to meet goals related to population persistence and long-term availability for zoo collections, PMP species should be more intensively managed (i.e., obligatory not voluntary participation) than SSP species.

Programs were able to achieve, on average, 75% of target number of births. However, only approximately 50% of births resulted from recommended pairings, indicating that many unplanned births occurred. Unplanned births can occur for a number of reasons, such as when animals are housed in inappropriate groupings or enclosures (e.g., incorrectly sexed animals thought to be housed in a same-sex group, animals not adequately separated to prevent breeding opportunities), when contraception techniques fail to prevent pregnancy, or as a result of individual institutions pursuing births not endorsed by the programs. Unfortunately, there is no systematic documentation of the reasons for unplanned births. Regardless of the cause, unplanned births hamper the ability of managed populations to achieve their demographic and genetic goals because offspring from unplanned pairings occupy limited holding space at the expense of animals that may be more genetically valuable to the long-term sustainability of the population.

It is probable that some or most of the ‘‘unplanned’’ births noted in this study represent the results of ‘‘on-the-fly’’ recommendations made by the species coordinator, with or without consultation with the management group, after the final plan was distributed. On-the-fly recommendations are necessary responses to changes in animal status (e.g., health, physical condition, etc.) or institutional needs, and logistics (e.g., shipping constraints). Unfortunately, there is no standard procedure for making on-the-fly recommendations and although some may be written (e.g., as letters or e-mails to the affected participants), many are communicated orally; it is likely that few, if any, are actually recorded for future review and analyses. Thus, it is unclear to what extent unplanned births reflect either a lack of success that undermines program objectives or whether they reflect additional success.

There are several possible explanations for programs falling short of their objectives for number of offspring and recommended pairings. First, the recommended pairings may have low intrinsic capacities for success and program leaders may be overly optimistic. To maximize gene diversity, programs recommended breeding those animals with the lowest mean kinship [Foose and Ballou, 1996]. However, many of these genetically underrepresented individuals may have been unsuccessful breeders due to age, past management or husbandry practices, behavioral abnormalities or health conditions; pairing these individuals may be overly optimistic but space limitations dictate that the overall goal for offspring must consider placement of any offspring that might result from these optimistic pairings. This recommendation scenario is particularly relevant for animals nearing reproductive senescence in a final effort to increase their genetic representation in the population. Regardless of the underlying bases for breeding recommendations, because a majority of programs fell short of their target for offspring, it would seem that annual reproductive goals are overly optimistic relative to the observed success of breeding recommendations.

Second, a host of logistical issues, often unanticipated, can disrupt the implementation of breeding pairings and transfers required to effect pairings. These factors include medical problems and health concerns (e.g., death, disease, quarantine delays), data accuracy issues (e.g., incorrectly identified sexes, unreported events such as births or deaths), behavioral incompatibility of selected pairings, and transportation/shipping complications (e.g., weather, cost, distance). Although it was not the intent of this project to determine why recommended transfers or births did not occur, it can be logically concluded that many failures could not have been anticipated during the planning process. As noted above, in some cases on-the-fly recommendations may be made to counteract these failures.

Third, inefficient communication among those involved in the planning process, as well as between and within participating institutions, can hinder a program’s ability to complete recommended actions. Interestingly, we found that the number of participating institutions predicts a program’s ability to achieve its annual goal number of offspring (Fig. 2). As the number of participating institutions increases so too does the likelihood that the programs meet or exceed their goal. Because the total number of individuals in a plan is tightly correlated with the number of institutions, this relationship could arise if each institution's individuals in the population had a fixed probability of producing unplanned offspring, and thus as the number of participating institutions, populations and managed individuals increase so does the expected number of unplanned offspring. As the size and complexity of programs increases, gathering feedback from institutional representatives becomes increasingly important and challenging. Although the current planning process allows draft amendments to accommodate the needs of participating institutions and the goals of the program, PMC staff report that the mandatory 30-day comment period for draft PMP and SSP plans generally yields few comments (personal communication, S. Long, C. Lynch, S. Thompson).

Together, these results indicate that the science and sophistication behind genetic and demographic management of captive populations may be compromised by the challenges of implementation. The goals of SSPs and PMPs are to apply the predictive tools of applied small population biology to ensure the maintenance of genetic diversity and demographic stability. Yet our results suggest that the scientific predictions are compromised by the logistics of cooperative management. Our results indicate that models, projections, and management decisions that assume perfect, or even relatively high (80–90%) success are likely to yield inaccurate estimates of demography and genetic diversity. Management recommendations are often based on the results of computer simulations that use optimization techniques, e.g., minimization of mean kinship [Ballou and Foose, 1996], but our results indicate sub-optimal outcomes occur frequently. We suggest that future development of theoretical tools take into account the challenges of cooperative management or perform sensitivity analyses of sub-optimal outcomes. Moreover, we believe exercises such as this one, which evaluate historic program performance, should be repeated because they are essential if the AZA cooperative population management programs are to improve over time.

CONCLUSIONS

The target number of offspring was often underachieved. On average, both SSPs and PMPs fell about 25% short of their target; however, as the number of participating institutions increased so too did the likelihood that programs met or exceeded their target. Species Survival Plans® exhibited significantly greater transfer success than PMPs, although transfer success for both program types was below 50%, and they exhibited significantly greater breeding success than PMPs, although breeding success for both program types was below 20% Because sub-optimal outcomes occur in management, future demographic and genetic projections for captive populations should include sensitivity to unplanned births and transfers.

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