John Perrone/Minnesota Zoo

THE MATING GAME

Zoos are shifting the focus of their breeding plans

First in a two-part series

By JULIE ANN MILLER

Matchmaking at the zoo is rapidly shifting from an art to a science. Four years ago, when curators at the National Zoo in Washington, D.C., sat down to plan the next round of breeding for their captive population of golden lion tamarins, they had no protocols to guide them. So they decided to list all possible combinations of males and females and select the plan giving the least inbreeding — the fewest matings of closely related animals such as siblings, half siblings and cousins. But the planners were immediately dismayed to discover that their breeding population of 13 males and 13 females could be paired up in 6 billion different ways.

"Things have changed a lot since then," says Jonathan Ballou, one of those matchmaking curators. Breeding decisions have become more objective and more scientific, he says. At a recent meeting at the National Zoo's breeding facility in Front Royal, Va., an international group of geneticists and zoo-animal breeders discussed new techniques for analyzing the genetics of captive animal populations and described new breeding guidelines.

"These are sophisticated recommendations," says Ballou, an organizer of that meeting. "We are entering a new age of captive breeding."

The need for more sophisticated criteria in animal breeding grows out of the changing focus of many zoos. "Historically, zoo curators were concerned mainly with the welfare of individual animals," explains Katherine Ralls of the National Zoo. "They are now increasingly concerned with the welfare of entire captive populations, which has necessitated a change from the individual to the population way of thinking."

Concern with captive populations has arisen from the desire to develop self-sustaining groups. For many species, zoo curators can no longer count on periodically augmenting their collections with animals newly captured from the wild. And a small number of species, but a number expected to increase as habitat destruction continues around the world, exist only as zoo populations.

The new age of captive breeding requires a major educational effort to train zoo cura-

Animals Designated for Species Survival Plan

- Chinese Alligator
- Radiated Tortoise
- Aruba Island Rattlesnake
- Indian Python
- Madagascan Ground Boa
- Puerto Rican Crested Toad
- Bali Mynah
- White-Naped Crane
- Andean Condor
- Humboldt's Penguin
- Ruffed Lemur
- Black Lemur
- Golden Lion Tamarin
- Lion-Tailed Macaque
- Gorilla
- Orangutan
- Asian Small-Clawed Otter
- Red Wolf
- Siberian Tiger
- Asian Lion
- Snow Leopard
- Cheetah
- Indian Rhino
- Black Rhino
- Sumatran Rhino
- White Rhino
- Przewalski's Horse
- Grevy's Zebra
- Chacoan Peccary
- Barasingha
- Okapi
- Gaur
- Arabian Oryx
- Scimitar-Horned Oryx

tors in the application of population genetics to breeding programs, and it demands extensive coordination among breeders at the world's many zoos. Currently only a few species — including the Siberian tiger, golden lion tamarin, Przewalski's horse and Speke's gazelle—are being intensively managed in this way. But about 30 species have been targeted for such programs.

The simplest method of breeding, and the one used most frequently in the past, is making matches among the small number of animals of a species residing at each zoo. And if a pair of animals reproduced successfully, it would be bred over and over again.

But this convenient procedure is unsuited to the zoos' new role. First, small populations, such as the animals of a given species at one zoo, tend to go extinct because of chance events. A series of births of animals of the same sex, for example, may end the population line, or a disease may wipe out the entire population at that zoo.

A second drawback of small mating populations is that they develop problems associated with inbreeding (SN: 12/1/79, p. 374). These problems include low birth weights and high rates of infant death. Ralls and Ballou have examined breeding records of 44 species of mammals and found that in 93 percent of the species, mortality of inbred young is higher than of noninbred young animals.

Finally, small breeding populations do not best preserve genetic diversity, one of the goals of modern breeding programs. Genetic diversity is expected to increase the likelihood of a species' future survival, both in captivity and in the wild, and to serve as a future resource for such human endeavors as medical research.

Currently there are a large number of potential breeding plans. The choice is dictated in part by the number, and family relationships, of the animals available. Participants in the conference stressed that the choice of breeding plan also should depend on the goals of the breeding program. Such objectives might be the adaptation of a newly collected species to captivity, long-term conservation of an endangered species, propagation of animals for release into the wild, or supply of domestic, laboratory and game animals.

Of course, these plans are limited to animals that breed successfully in captivity. About one-sixth of all types of mammals and one-twelfth of all the world's species of birds have been bred in zoos in the last few years, according to the Species Survival Plan (SSP) guide produced by the American Association of Zoological Parks and Aquariums (AAZPA) in Wheeling, W. Va. Recent successes with such new reproductive technologies as embryo transplants across species lines (SN: 6/9/84, p. 358) and frozen embryos are expected to extend successful captive breeding plans to ever more species.

The participants at the meeting proposed two sample protocols for specific situations. "These are the extremes of a continuum," says Russell Lande, a theoretical biologist at the University of Chicago. In both cases the starting population should ideally be the offspring of at least 10 to 20 "founder" animals and the group should have as much genetic diversity as possible. The total population in each case should eventually be divided into subunits, perhaps housed at different institutions or living on different continents.

Take the case of animals being raised with the objective of eventually restocking a natural habitat—for example, the golden lion tamarins. The group recommends that these animals be bred to rapidly reach the "carrying capacity," the maximum population that can be contained in the zoo space available. Ideally this population should include at least 250 animals. Once the carrying capacity is reached, the breeders should try to maximize generation time, thus slowing the rate of subsequent genetic change.

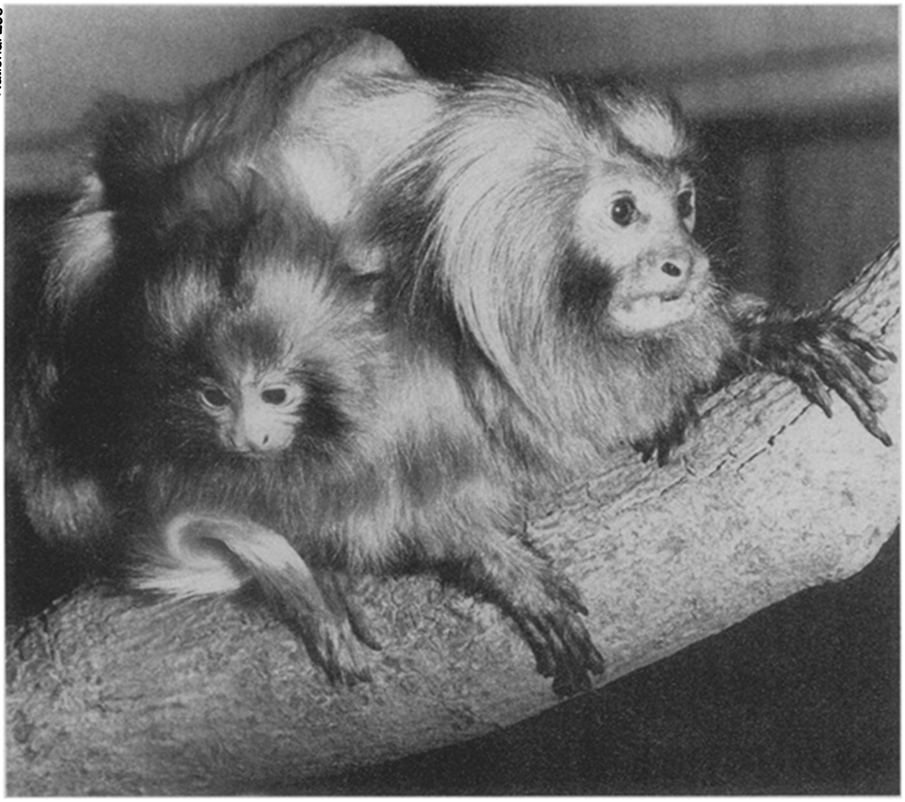
The population should then be subdivided into groups of no more than 100 members. Between groups, a migration rate of one animal per generation should be maintained. Within each subgroup, breeding decisions should attempt both to equalize family sizes and to correct previous disparities in the number of descendants of each founder. The scientists should, through their breeding decisions, attempt to eliminate deleterious genetic changes, such as hernias in the golden lion tamarins. Whenever possible there should be continued introduction of wild animals into the breeding population.

In contrast, a different breeding plan is needed for adapting animals to captivity.

San Diego Zoo

Przewalski's horses in an intensively managed program at the San Diego Zoo.

National Zoo



Golden lion tamarins bred at the National Zoo (left) were recently returned to their native forest home in Brazil.

This might be the goal of a program to create a zoo population of a nonendangered animal species, or it might be the first step in a long-term program to breed animals for eventual release.

In this case, the meeting participants recommend maintaining smaller subpopulations than in the previous example. The zoos should allow natural selection to occur, with no attempt to equalize the success of founders, to control family sizes or to extend generation times. No wild animals should be introduced into the ongoing project, and animals should only infrequently be transferred between subgroups.

These recommendations and their implementation rest on a new alliance between zoo curators and geneticists who have long studied natural and laboratory populations. "We sought out the population geneticists, they didn't come to us," says Ralls.

One important effect of the alliance has been an emphasis on zoos' keeping accurate long-term records of their breeding programs. "Without continuously and scrupulously maintained records of each individual animal's lineage, fertility, sex, longevity, care and medical history, populations cannot be managed to avoid inbreeding and other pathological patterns: Long-term preservation will not be possible," says the SSP.

"A few years ago only three or four places in North America kept such records," Ballou says. Today records from many zoos are maintained in the computerized International Species Inventory Systems (ISIS) at the Minnesota Zoo in Apple Valley.

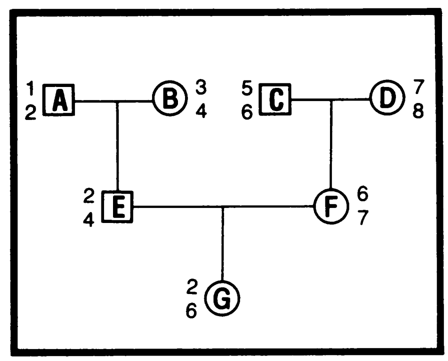
Besides developing general breeding plans, one use of population genetics in the zoo is the analysis of medical problems. For example, computers can be used to determine whether a deleterious condition that appears among the animals has a genetic basis, and thus might be eliminated by manipulating the breeding program. Deborah Meyers of Johns Hopkins University Medical Center in Baltimore is a human geneticist who has analyzed pedigrees of golden lion tamarins. With computer programs designed to examine human pedigrees, she concludes that the hernia that occasionally appears in the tamarins is a genetic problem, probably due to a single recessive gene.

Although the computer programmer working with Meyers did not realize the data came from the zoo and assumed it was just a rather extreme example of the human inbred populations they had previously studied, zoo-animal pedigrees do raise special challenges. The major structural differences between human and zoo-animal populations are the prevalence of multiple matings and extremely close inbreeding, what one might call incest. "But these don't influence the computational approaches," says Elizabeth Thompson of Cambridge University in England.

Thompson has worked out detailed analytical methods to compute kinship relationships and the probability of a gene's becoming extinct. She has based her work on such human groups as an island population of 268, of whom 85 percent are descendants of 11 original founders, and a west Greenland Eskimo family in which 13 individuals — including three sister-brother pairs — comprised 11 marriages, none incestuous.

Another genetic technique, recently developed by Jean MacCluer of the Southwest Foundation in San Antonio, Tex., is simply called "gene dropping." MacCluer says, "It is quick to use. It is a tool easier than the more analytical methods."

MacCluer makes a computer model of a pedigree based on the records of a breeding population and assigns each founder animal two hypothetical genes. Then she uses a random-number generator to determine which gene from each founder any member of subsequent generations receives. To analyze the genetics of a population, she repeats this operation 10,000 times. MacCluer's analysis, like others, does not take into account the forces of natural selection on individual genes.



In gene-dropping analysis, a computer considers 10,000 potential genetic variations on a given pedigree. In this variation, grandfather A contributes gene 2 to his son E and to his granddaughter G, and grandfather C contributes gene 6 to his daughter and granddaughter. Genes 1, 3, 4, 5, 7 and 8 are lost from the pedigree.

This simple method gives guidance in devising breeding plans by computing the probability that a gene from one founder will be lost from the population or that a gene will become fixed as the sole variation. It can also tell whether animals with particular traits share genes from one founder.

One breeding program MacCluer has examined is that of the Przewalski's horse, also called the Mongolian or Asian wild horse, which is now extinct in the wild. All 409 living animals are descendants of 13 founders, of which one was a Mongolian domestic horse rather than a wild Przewalski's horse. MacCluer used the gene drop method to determine which of the 13 founders has had the largest percentage of gene loss and which are at the highest risk of further gene loss. Breeders can now take these data into consideration to equalize the contributions of the founders to subsequent generations.

While most major zoos have accepted the new management goals for endangered species, there are still conflicts. For example, when successful breeding programs outstrip the available zoo space for a species — as in the case of the Siberian tiger — what happens to the excess animals? Although careful population management, sometimes including contraceptives, can minimize the number of excess animals, must zoos sometimes destroy individual members of an endangered species?

"Population analyses may reveal that existing aged animals should be replaced with younger animals of breeding age before the former die of natural causes. (Many zoo animals live much longer than they would in the wild due to good nutrition, protection from predators and veterinary care)," states Ralls in the April 1984 issue of the British journal BIOLOGIST. "Although efforts can be made to place animals that are old or genetically redundant in zoo situations that are purely for exhibition purposes, this is often not possible, and euthanasia is at times the only practical method of making room for additions to the population."

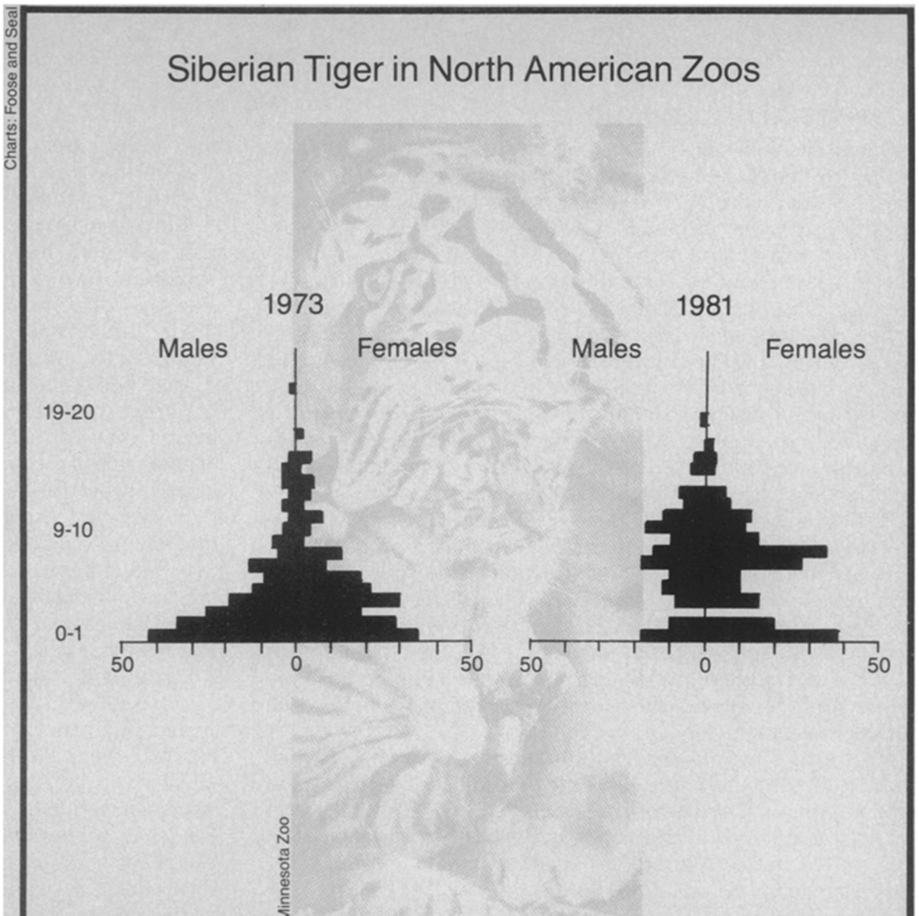
The world is getting smaller to those who manage captive breeding programs of endangered species. Because the new plans attempt to maximize the number of contributing animals, for many species the effective herd must include all animals of the species in zoos of the United States, or even of the world.

Although during the past few years individual zoos have successfully cooperated in matching unmated animals for breeding, some more far-reaching coordination is required to meet the new goals of establishing self-maintaining populations of endangered species. The ambitious Species Survival Plan attempts to provide a sound basis for the allocation of zoo space among vanishing animals, to minimize the problems of inbreeding, inadvertent selection and genetic drift, and to coordinate scientific study of the problems facing long-term wild-animal husbandry.

The first specific program initiated by the SSP is for the propagation of the Siberian tiger, which is endangered in the wild. "Because of their requirements for vast reserves, and their direct competition and often conflict with man, the big cats will be the least preservable of species in the wild," say Thomas Foose, the AAZPA conservation officer, and Ulysses S. Seal of ISIS, both at the Minnesota Zoo.

Fifty North American zoos are participating in the Siberian tiger plan. These zoos have approximately 250 Siberian tigers, derived from fewer than 20 wild-born animals. The genetic legacy of the founders is quite disproportionate: Five of the founders have each contributed more than 10 percent of the genes in the current population and eight founders have each contributed less than 1.5 percent.

Charts: Foose and Seal



A stable population of captive tigers should have an age and sex distribution resembling a pyramid. Curbs on breeding, due to a saturation of available zoo space, led to a 1981 population that was much less stable than the 1973 population.

A special challenge to the SSP program for Siberian tigers is the stabilization of the unfavorable age distribution of the population. The reason for the instability goes back to the early 1970s, when the captive Siberian tiger population in North America expanded rapidly until it abruptly saturated the zoo space available. The response by zoos was a drastic curtailment of tiger reproduction. This soon resulted in more animals in older classes than in younger ones. Tiger births decreased in the 1970s, until there were only a few in 1978. They increased somewhat in 1980 and 1981, then declined again.

"If these trends continue for another 10 years, about 45 percent of females and 29 percent of the males would be past the reproductive prime for this species," say Foose and Seal. "The population would be well on the way to demographic senescence."

Foose and Seal have advised zoos to resume reproduction of the tigers and to remove (and, if necessary, destroy) certain animals from the different age classes. Once founder representation is rectified, they suggest that every animal be permitted to participate in production of two litters several years apart and that for each parent one offspring of each sex be recruited into the breeding population. They have also outlined procedures for incorporating new founder tigers, from the Russian and Chinese populations, into the North American population.

Survival plans for several other species, including the Przewalski's horse, guar, golden lion tamarin and snow leopard, are being worked out. But many practical difficulties remain.

"Changing from a management viewpoint based on the welfare of individual animals to one based on maintaining a healthy captive population over a long period of time is not easy," says Ralls. "It may be difficult to convince those in charge of zoo finances that it is necessary to purchase a new animal of a particular species when, apparently, several perfectly good ones are already on hand ... Furthermore, the best strategy from a population viewpoint often conflicts with maximizing the life spans of individual animals," she says.

"But failure to initiate sound genetic and demographic management of zoo populations," Ralls concludes, "will ultimately result in the extinction of many species in captivity." □

NEXT: A special breeding plan for desperate situations — controlled inbreeding of the Speke's gazelle.