PART I

SETTING THE STAGE: THE ROLE AND PROMISE OF CONSERVATION GENETICS

EXTINCTION CRISES AND LOSS OF GENETIC DIVERSITY

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WC: Thank you, George. I told Fiona Brady that I would be distinguished as a speaker by having no slides ... and no computer. I told her that I would prefer a toga, and perhaps a lei and she has provided that. (Laughter)

These are heady times for genomics. The significance of the sequencing of the human genome has been compared with man s first landing on the moon. New computational power has brought genetic insights to our perception of species survival. Embryo transfer, cloning, artificial insemination, and a host of other techniques offer new control of animal reproduction. Serendipitously, as George has indicated, all this is taking place at a time when wildlife populations are amidst a desperate extinction crisis.

Max Frisch has observed that technology is a way of organizing the world so that man does not have to experience it. How, then, are the new developments in genetics and reproductive science to be tied to real-world conservation? To scale ... to wild species? Under the title Noah s New Ark, *Time* recently reported the cloning of a threatened Southeast Asian species of wild cattle called *gaur*. The line that caught my eye about cloning was: If it lives up to its billing, it could produce potentially *unlimited* numbers of endangered species. We have those already. (Laughter)

If we divert attention from preserving nature to reproductive technologies with dubious genetic justifications, we neither enhance the public s understanding of the extinction crisis nor provide much help. It is tempting to consider the sickening decline of wild animals and plants as a kind of disease. Can it not be cured with science and technology? After all, we beat smallpox. No natural case of this disease has developed anywhere in the world since Ali Maalin developed the rash in Mercatown, Somalia, in October the 26, 1977. But we cannot even hope that a comparable cure for the disappearance of tigers and turtles, or cranes and crocodiles, will ever be found as one may be for cancer or AIDS.

Compared to saving nature, curing human disease is child s play. Even if we knew all that there is to know about the genetics of wildlife, we could not save a single species in nature unless we can influence the sovereignty of human social and political forces.

And, yet, so much of wildlife dear to us so necessary to us, so close to us is at stake. We share 98% of our DNA with chimpanzees. Matt Ridley observes: If you held hands with your mother, and she held hands with hers, and she with hers, the line would stretch only from New York to Washington before you were holding hands with your common ancestor with chimpanzees. This both emphasizes the fundamental nature of our biological bonds and confirms the fears of anyone who s been to Washington recently. (Laughter)

Although human biomass is already about 600 billion pounds, we are growing by 85 million persons each year. Yet, per capita grain production per capita has been diminishing since 1983. Over the past decade, per capita cropland has declined by 20%, and fish production by 7%. And each day we take more land, more forest, from wildlife.

Think of the scale. Most terrestrial animals and plants are found in forests, especially tropical forests and the plight of almost all tropical forests is desperate. Only about 7 1/2 million square kilometers of tropical evergreen forest remains. If their deforestation continues at the same rate as it did between 1979 and 1989, John Terborg calculates that the last tropical-forest tree in the world will fall in 2045. But the rate is increasing.

The Brazilian Amazon contains 40% of the world s remaining tropical rain forest, and plays a vital role in maintaining biodiversity, regional hydrology, climate and terrestrial carbon storage. It also has the world s highest rate of absolute forest destruction, currently averaging nearly 2 million hectares a year.

The good news is, the world s wealthiest nations have recently decided to channel $340 million to Amazon rain forest conservation. The bad news is that Brazil has announced planned rain-forest developments of more than $40 *billion* and the tropical-forest animals are far more endangered than even these figures suggest.

The Wildlife Conservation Society s John Robinson and his colleagues estimate the bushmeat kill in the Brazilian Amazon is 67,000 to 164,000 metric tons each year monkeys, peccaries, tapirs, toucans. It is a figure dwarfed by that in the tropical forests of Africa, now, annually more than 1 million metric tons boiled gorillas, roasted chimpanzees, salted elephants. In Cameroon, for example, over 800 gorillas were killed and cooked in 1998. Their bodies sold for about $40 each. These are intelligent, gentle creatures. Their DNA differs less than 3% from ours. We are eating members of our own family.

Superstitious, cruel and needless commercial practices, cloaked in the garments of traditional culture and inexcusable fashions, are equally depressing. Tigers killed for their parts for elderly Chinese gentlemen; Tibetan antelopes slaughtered to make $2,000 shahtoosh scarves for rich New Yorkers. Almost an eighth of the world s remaining wild species of birds, nearly a fifth of the mammals, 5% of the fish, 8% of terrestrial plants, are now seriously threatened with extinction.

Almost all big animals are in trouble: the big cats, and storks and cranes, and parrots and pythons, and antelopes; the great apes, elephants and rhinos. Less than 5,000 tigers remain; less than 400 Sumatran rhinos; perhaps 600 mountain gorillas; less than 100 Philippine eagles; a handful of Hawaiian monk seals.

The African violet, so common in our parlors, is nearly gone in Africa. Ninety percent of the black rhinos has been killed in the past 18 years, while one-third of the world s 266 turtle species are now threatened with extinction, and 10 of the 17 species of penguins are declining.

Bushmeat hunters are not common in the U.S., but tower builders and cat-lovers are everywhere. Tall communication towers kill perhaps 40 million birds, of some 230 species, each year mostly at night. There are now 50,000 such towers. House cats are worse. Free-ranging domestic cats in Wisconsin are killing about 39 million birds each year. Nationwide, free-ranging cats are thought to have been responsible for the diminution of more bird species than any other cause except habitat destruction. In the U.S. they re contributing to the endangerment of such birds as least terns, piping plovers and loggerhead shrikes.

Beyond cats, humanity s vast herds of domestic animals have become a plague to wildlife   devastating habitat; spreading disease   anthrax, foot-and-mouth, rinderpest, distemper. Bovine tuberculosis has spread from domestic cattle to wild buffalo   thence to lions, cheetahs, kudus and baboons in South Africa   while it threatens wood bison in Canada.

Average populations of domestic cattle, as Jeremy Rifkin said last night, are about 1.3 billion. He didn t mention that there are 1.8 billion sheep and goats, 900 million pigs, and 17,200,000,000 chickens   which is why everything tastes, more or less, like chicken. (Laughter)

The only hope many island creatures have   whether they be Gal pagos giant tortoises, Jamaican iguanas or Hawaiian honeycreepers   is the extermination of introduced goats, rabbits, pigs, dogs, mongooses, rats and cats. Some native species, their numbers disproportionately enlarged by their ability to live on human garbage, have become equally destructive. Herring and black-back gulls have become predators of terns in the eastern U.S., while superabundant kelp gulls are killing cormorants and terns in Argentina.

Amazingly, we continue to distribute an unrelenting stream of destructive exotics. They range from zebra mussels in the Great Lakes to European boars in California, and Scottish deer in Argentina. To say nothing of what has happened to the famously disastrous situations in New Zealand, Hawaii and Australia.

In California s San Francisco Bay, an average of one new species has been established every 36 weeks since 1850, every 24 weeks since 1970, every 12 weeks in the last decade. It is estimated that over 40% of the earth s total terrestrial photosynthetic productivity is now being appropriated by humans.

We consume 25 to 35% of the primary productivity of the ecosystems of the continental shelves, and use 54% of all runoff in rivers, lakes and other accessible sources of freshwater. But we ve invested only 4 to 6% in the protection of land in parks and reserves, and a half of 1% in the marine realm. This, then, is the scale of the extinction crisis. I found it hard last night to believe that producing more food for humans will produce anything but more humans.

Stuart Pimm observes: When it comes to protecting ecosystems, larger is better than smaller; connected is better than fragmented, and natural is better than managed. However, in the foreseeable future the survival of more and more species will have to depend upon the care of habitat fragments   upon the enhancement of marginal habitat   and the restoration of some of that which has been lost.

Many species are destined to survive, if at all, in small disjunct populations in areas with limited carrying capacity, and no room to grow. Their survival will depend upon human care. This means that we will have to agree what species we want to care for, where, and in what numbers   and control the number of predators, or competitors, which threaten them, as well as their diseases.

Their survival will require the creation of genetic and demographic models, to which managers must work. The task is so immense that we will have to focus upon the well-being of particular kinds   especially landscape species, which WCS s John Robinson will speak to tomorrow. Ultimately, we must develop new ways of thinking about species/area relationships. Like it or not, much wildlife conservation will become an aggregation of many parks and megazoos.

Will genetic change affect captive animal populations or small reserves? (This is exciting.) (Laughter) Reducing the ability of some species to survive. The answer is yes. But the problem is not just the change, but the direction of change and its time scale. Animals bred in zoos, who sustain maximum heterozygosity, or preserved as frozen zygotes, may almost be said to be genetically fossilized or obsolescent adapted to environments which may no longer exist. Those in undersized reserves are no better off.

What does this mean for reintroductions? Initially, rare-animal reintroductions from captive collections were discouraging, as Josh [Ginsberg] said last evening. Much more so than translocations. After all, unless the factors that resulted in a species decline in the first place have been improved, there s no place for reintroduction. Of course, some genetic change will be less relevant if both the reintroduction habitat and its diseases and predators have changed. More importantly, we find that reintroduction efforts usually stimulate habitat restoration and protection.

The reintroduction of the American bison in the West, shortly after the turn of the century, by WCS s Bronx Zoo, was among the earliest. There are now more than 150,000 bison in parks, reserves ... and on menus. The recent reestablishment of the peregrine falcon has been particularly successful. In fact, since 1986, 21 of 28 reintroductions of raptors resulted in the establishment of viable breeding populations. Most use captive-bred young, and some are extraordinary.

For example in 1974 there were but four Mauritius kestrels left in nature. By 1984, captive breeding, predator control and the like, had made possible the release of nearly 400. There are now at least 600 birds in the wild.

But there is also the case of the Arabian oryx. They were shot to extinction in nature by local hunters. Then, beginning in the 1960s, captive stocks were gradually increased. At last, with the support from the Sultan of Oman, they were reintroduced on the Arabian Peninsula in 1982. Soon, more than 400 of these magnificent antelope were running free. A few months ago a quarrel broke out between local tribes, and the oryx were slaughtered. Scarcely 100 were rescued, and returned to captivity.

Nevertheless, reintroduction attempts are becoming more common. In the 92-year period between 1900 and 1992, attempts were made to introduce only two species of invertebrates. But in 1998 alone, 19 were reintroduced. The comparable figures for fish introductions during 1900 to 1992 is nine but 11 in 1998 alone. For reptiles and amphibians, 22 for the 92-year period *42* in 1998. For birds, 54 and 69. And for mammals, 39 and then 77 in 1998 alone. Again, almost all of these efforts have resulted in new protection and new habitat restoration. It is a kind of biotechnology.

Most reintroduced animals will have to live in an altered environment, where predation and behavioral challenges are dealt with by management. But let s not underrate animal smarts. Studies of moose predation by reintroduced wolves in Wyoming, by WCS s Joel Berger, have shown that a single generation was enough time for na ve populations, which had had no contact with wolves for 75 years, to get wise to them and to act appropriately.

Na ve or not, almost all wildlife is threatened by the menace of global warming. Because future climatic changes will involve anthropogenic as well as natural forces, they may be rapid as well as large, and will affect huge human populations. While some societies may be able to cope, there will be unprecedented social disruptions. Most plants and wild animals will be unable to follow shifting climate zones, blocked by human developments.

What conservation strategies might be helped by genetic knowledge or reproductive technologies? Will cloning prove important? Dolly was cloned as the sole result of *277* nuclear transfer—derived embryos, produced from 400 oocytes recovered surgically from donor ewes. We know far too little of the reproductive biology of most endangered species, and there are far too few appropriate surrogates for such invasive clone or embryo-transfer procedures.

Consider the number and kinds of species which need help the scale of the problem. Nonetheless, there are situations where assisted reproduction beyond the low-tech artificial incubation and chick switches commonly used with birds can be useful. Artificial insemination has long been important in endangered crane and raptor propagation, and, for example, in breeding black-footed ferrets. Genome-resource banking, and so-called frozen zoo sperm banks, might provide alternatives to natural breeding when animal pairs are incompatible, allow posthumous reproduction of genetically valuable animals, and offer insurance against catastrophic loss. The ability to move sperm, rather than animals, between parks or zoos may become of increasing genetic importance.

But given the scale of the global extinction crisis, the conservation implications of high-tech assisted reproductive technology are extremely modest. In contrast, genetics are fundamental to the maintenance and reconstruction of small populations. Its insights are essential to the evaluation of founder stock for reintroduction; dispersal effectiveness; genetic drift; minimum viable populations; and translocation strategies. Thus, management methodologies.

It has become a forensic science, helping to determine what a species is or was, and where it came from. From as little as a restaurant scrap, geneticists can distinguish an endangered species of whale or monkey. From parrot feathers or gorilla dung they can reveal family relationships with surprising accuracy.

But when it comes to dung, it must also be noted that trained scenting dogs have proved 100% accurate in distinguishing kit-fox scats from those of coyotes, skunk and badger, while identifications based on mitochondrial DNA analysis by geneticists cost about 40 bucks a sample. Perhaps our analysts should be trained to follow their noses.

Today, almost every educated person understands that the preservation of biodiversity is fundamental to the maintenance of healthy ecosystems; to the stewardship of natural resources; to the realization of human potential and enjoyment; and to a sustainable society. Everyone also knows that few decision-makers take any of this seriously that not one nation on earth has made preservation of its biological environment a budgetary priority.

Over the long term, nature conservation and economic development are not in conflict. Over the short term, and at the local level of scale, there exist *huge* conflicts. No one has figured out how to get rich from mountain gorillas, whooping cranes, black-footed ferrets, snow leopards or furbish louseworts. For most people, wildlife conservation seems a luxury. Technological fixes and easy ways out dominate our attention.

Disconnects between scientific understanding and productive applications to global problems are common. But if the overall task of wildlife conservation is to save functioning ecosystems and wildlife populations, perhaps the particular focus of conservation genetics, and reproductive science, must be to help save *broken* ecosystems and marginalized species. Conservation genetics can help us to care for small populations which will otherwise be lost.

The news that a wildlife population is facing genetic drift or founder effect will rarely win protection for a species or its habitat. That takes inspiration, education and on-the-ground involvement. We must not allow the public to delude itself about the scale of the extinction crisis or the difficulty of its resolution. There are no quick technological fixes.

To achieve major wildlife conservation we must orchestrate a continuity of political commitment that is wholly foreign to human affairs. It will take the work of thousands of people, and the understanding of millions, to make a difference. If we want to save wildlife, we will have to save habitat.

Thank you.

(Applause)