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HUMAN POPULATION, FOOD DEMANDS AND WILDLIFE NEEDS

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The scope of the title assigned to me cannot be covered, except superficially, in a short period of 30 minutes. None the less, I will do what I can to touch on some of the salient issues that must be dealt with in these complex inter-related problems, which threaten the survival of man and many other species.

GROWTH IN HUMAN NUMBERS

Man—and near man—is a late comer to the planet Earth. He is estimated to have arrived at somewhere between 5 and 15 minutes before midnight—5 to 15 million years ago—as measured on the 5-billion-year dial of the geologic clock of the Earth. He was preceeded by many millions of years by other mammalian species, and for even fantastically longer periods before by many other species.

Man's spectacular—perhaps temporary—success as a biologic entity coupled with his fecundity, currently threatens the survival of many other species, and even endangers the survival of his own civilization and his own species.

But competition among species on the planet Earth is not a new phenomenon. It undoubtedly began soon after the origin of life. Life is now documented with bacteria and blue-green algae fossil evidence to date back at least 3.2 billion years (Barghoorn, 1971). The competition and struggle for survival between species of plants, fishes, amphibians and reptiles had been going on for hundreds of millions of years before the appearance of mammalians and birds. Species either prospered or perished, depending upon their genetic ability or inability to respond to the natural imperative, *"evolve and adapt, or perish,"* imposed and executed by the relentless selection pressure of ever changing environments. More perished than prospered. Many millions of species flunked the biologic imperative before the appearance of man, and many others have disappeared since his arrival. Many that perished have left only their imprints in the book of fossil rocks and/or, indirectly, in a less conspicuous but much more vital and lasting way as imprints in the DNA and gene pools of surviving relatives.

Then came man, *Homo sapiens*. In the beginning there were only two. In this part of the world we know them as Adam and Eve; in other parts they are known by other names. In any event, their appearance probably provoked no fear and certainly gave no hint to the other species that then inhabited the Earth of the threat and impact they were to subsequently have on the planet Earth. In the first many thousands—or even hundreds of thousands—of years, their descendants made little or no impact on either the physical or biological environment of the Earth. Even though they were undoubtedly heeding the imperative given to Eve and her female descendants—"Be fruitful and multiply" they barely escaped extinction. More than once the survival of *Homo sapiens* must have hung in the balance, for he was poorly equipped to deal with survival in the hostile environment. He was a midget among giants. He had no control over his food supply, was poorly equipped to protect himself from both the elements and his stronger, better-equipped, biological predators. He had no protection against diseases and pests.

The increasing antiquity of Adam and Eve continues to unfold as anthropological and archeological studies continue. The development of techniques to measure the breakdown of radioactive elements, *i.e.* uranium-lead, potassium-argon, etc. during the past three decades has provided us with ever more accurate tools for measuring the antiquity of man.

Without getting involved in the semantics of trying to differentiate between modern *Homo sapiens*—Desmond Morris' naked ape—and certain closely related earlier species, it suffices to state that a growing body of evidence indicates that man is much older than we thought possible three decades ago.

Many anthropologists now agree that Adam and Eve and their descendants, for hundreds of thousands and perhaps for several millions of years, were vegetarians. There is considerable archeological evidence that indicates that about 5 million years ago a vegetarian, near-relative of the Naked Ape, emerged from the bush, somewhere in southeast Africa, stood up on his back legs and, with a rock in one hand and a club in the other, began to stalk small animals as an individual hunter, and thus became a carnivore (Ardrey, 1970; Pfeiffer, 1971). For a long time thereafter he struggled for survival as a hunter, while he continued to supplement his meat diet with wild fruits, nuts, grains and roots. By about 1.5 million years ago he had learned the benefits of group hunting, which permitted him to kill large animals. But human survival remained precarious and growth in human numbers remained slow until the discovery of agriculture and the domestication of animals, which took place only 9,000 to 10,000 years ago. At that time, it is estimated (Miles, 1971) the world population was approximately 10 million. These discoveries soon brought new hope to the Naked Ape. It ensured his food supply. It also brought in its wake the specialization of labor, the development of pottery making, weaving, metal working and other crafts and arts, and these products were exchanged for food. These events soon gave rise to trade, commerce and small industries. And so, in the process, villages, cities and city states and eventually our modern civilization evolved. Soon, however, it also resulted in the first "population explosion."

Since that time, world population has been growing at an ever-increasing rate. The time required for world population to double has been shortening progressively, especially since man learned to protect himself from diseases, thereby drastically reducing death rates without concurrently reducing his birth rate. This predicament becomes evident by examining the average annual increase in world population growth:

1650-1750—0.3 percent
1750-1950—0.4 percent
1950-1960—1.5 percent
1960-1965—2.0 percent

Within the next 37 years today's world population will double, thereby adding another 3.7 billion to the human "family"; a number equal to all that has accumulated since the time of Adam and Eve. It is frightening! (Table 1).

The explosive increase in human numbers in the last 20 centuries has brought about the world population crisis which today threatens world civilization on many fronts. The explosive increase in human numbers is a multi-headed monster that threatens man, not only on the food production and preservation of wildlife fronts, but on the housing, clothing, medical care, employment opportunity, education, transportation, communication, energy, "non-renewable" resources, recreation, environment, social disorder and political fronts. These problems are common to all systems of government.

Not only is there a pending world population crisis, but the crisis has already arrived in many countries. Moreover, we must recognize that the population pressure and population growth are not uniform worldwide. This is clearly evident from a glance at Table 2. Nor is population uniformly distributed within a country. The plight of the enormous megalopolises such as New York, Calcutta, Dacca, Mexico City, Tokyo, etc. indicate that they are all fast reaching a point where they are becoming ungovernable by any government.

It is both discouraging and tragic to see many developing countries, which are now making excellent progress in increasing their food

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TABLE 1. THE GROWTH IN HUMAN (OR NEAR HUMAN) NUMBERS AND THE PENDING WORLD POPULATION CRISIS

Prehistorical or Historical Period	Time of:	Estimated World Population	Years Required for Population to Double
1) Adam and Eve	Kenyapithecus (the Homonid) 14,500,000 Years Ago	2	
			?
2) The Early Hunter	Individual hunter "The Naked Ape" 5 Million Years Ago	?	
			?
3) Early Group Hunting	Clan hunting 1,500,000 Years Ago	?	
			?
4) "Corporate Hunting"	Tribal hunting. Following migrating herds. 40,000-50,000 Years Ago	?	
			—
5) Discovery of Agriculture & Domest. of Animals	Stone Age Man 9,000-10,000 Years Ago	10 million	
			?
6) Time of Christ	1 AD	250 million	
			1,650
7) Late European Renaissance	1650 AD	500 million	
			200
8) Beginning of Bacteriology & Medicine	1850 AD	1,000 million	
			80
9) Advent of Miracle Drugs	1930 AD	2,000 million	
			—
10) Present World Population	1971 AD	3,700 million	
			37
11) A Frightening Look Ahead	2008	7,400 million (Estimated at present rate of increase of 2% per year)	

production and in increasing their industrialization, have these benefits vastly diluted or even nullified because of exploding population growth. A number of the densely populated countries in Africa, Asia and Latin America have been increasing their total GNP by 5 to 7 percent per annum. Nevertheless, because of population growths of from 2.6 to 3.4 percent, only very modest improvement in standard of living on a per capita GNP basis accrues to the millions of hungry and impoverished. There is, moreover, growing unemployment and illiteracy in some of these countries. Were the population growth rates of these countries similar to those of a number of European countries, *i.e.* 0.5 percent, there would now be rapid improvement in standard of living. Even worse, the populations in many of these

TABLE 2. THE GRAVITY OF POPULATION PRESSURES AND DIFFERENTIAL POPULATION GROWTH ON LAND AND OTHER NATURAL RESOURCES IN A REPRESENTATIVE GROUP OF NATIONS[1]

Region or Country	1971 Population (Millions)	Annual Population Growth	Years for Population to Double
WORLD	3,706	2.0	37
A. AFRICA	354	2.7	26
1. Algeria	14.5	3.3	21
2. U.A.R.	34.9	2.8	25
3. Kenya	11.2	3.1	23
4. Uganda	8.8	2.6	27
5. Tanzania	13.6	2.6	27
B. ASIA	2,104.	2.3	31
1. China Mainland	772.9	1.8	39
2. India	569.5	2.6	27
3. Japan	104.7	1.1	63
C. NORTH AMERICA	229.0	1.2	58
1. U.S.A.	207.1	1.1	63
D. LATIN AMERICA	291	2.9	24
1. Brazil	95.7	2.8	25
2. Argentina	24.7	1.5	47
3. Peru	14.0	3.1	23
4. Mexico	50.9	3.4	21
5. Colombia	22.1	3.4	21
E. EUROPE	466.0	0.8	88
1. Finland	4.7	0.4	175
2. Sweden	8.1	0.5	140
3. France	51.5	0.7	100
4. Italy	54.1	0.8	88
5. Germany (East)	16.2	0.1	700
6. Germany (West)	58.9	0.4	175
F. USSR	245.0	1.0	70
G. AUSTRALIA	12.8	1.9	37

[1] Data from Population Reference Bureau Report, Revised Edition August 1971.

countries will double within the next 21 to 27 years, including Uganda, Kenya and Tanzania.

Unless the population growth monster can be slowed and tamed, there will be increasing trouble ahead on many fronts. We have no choice but to work imaginatively and aggressively on all of the fronts that threaten civilization, man and other species.

MAN'S NEVER-ENDING STRUGGLE FOR FOOD

Civilization, as it is known today, could not have evolved, nor can it survive, without an adequate, stable food supply. Man's struggle to ensure his daily food goes back to his first days on the planet Earth. Yet, food is something that is taken for granted by most world leaders, despite the fact that half of the population of the world is hungry. Man seems to insist on ignoring the lessons available from history and continues to relegate agriculture to the lowest rung on the social-economic scale. It is perhaps understandable that the vast percentages of the population living in megalopolises in the industrialized nations have lost their feel for agriculture since the production of their sustenance—food—is out of sight, far removed from their daily lives.

Man's survival, from the time of Adam and Eve, until the invention of agriculture and animal husbandry, must have been precarious because of his inability to ensure his food supply. During the long, obscure, dimly defined prehistoric period when man lived, first as a vegetarian and then as a hunter supplementing his meat diet with food gathering, frequent food shortages must have occurred. Man lived as a nomad and the development of village civilizations was impossible. The struggle for food was a full-time job for all.

In the misty, hazy past, as the Mesolithic Age gave way to the Neolithic, there suddenly appeared, in widely separated areas of the world, the most highly successful group of inventors and revolutionaries that the world has ever known. This group of Neolithic women and men, and almost certainly largely the former, domesticated all the major cereals, legumes and root crops, as well as all of the most important animals that to this day remain man's principal source of food. Scientific man has not to this day been able to match this achievement.

Apparently, nine thousand years ago, in the foothills of the Zagros Mountains—in what is today Iraq and Iran—man had already become both farmer and animal husbandryman. These discoveries soon permitted the specialization of labor and led to the development of village life. Similar discoveries and developments elsewhere soon laid the groundwork for all modern agriculture and animal industry and, in fact, the base on which all of the world's subsequent civilizations have evolved, within a short period of a few thousands of years.

The invention of agriculture and animal industry was a big step forward in expanding food production, but it did not permanently emancipate man from the fear of food shortages, hunger, and famine. Even in prehistoric times, after the discovery of agriculture, population growth must have threatened or exceeded man's ability to produce enough food. Then, when droughts, or outbreaks of diseases or insects ravaged crops, famine resulted. That such catastrophes occurred periodically in ancient times is amply clear from numerous biblical passages. That the reoccurring problem of food shortage persisted is further evident by Malthus's hypothesis on food and population, which was first published in 1793.

The first essential component of social justice is adequate food for all mankind. Food is the moral right for all who are born into this world. Without food man at most can live only a few weeks; without it all other components of social justice are meaningless. I am convinced world order or peace cannot be built on empty bellies. Yet today, 50 percent of the world population is undernourished and even a larger portion is malnourished. If we insist upon ignoring the world need for more food and fail to utilize our science and technology imaginatively and aggressively to expand production—and by so doing help to buy time while others fight on the population front to slow population growth—world order will collapse. The future of many species of wildlife is intricately entangled with the food production problems, not only indirectly so, as in the developed affluent nations, but even more directly so in the densely populated developing nations, which are frightfully hungry for animal protein. Agricultural scientists, animal scientists, wildlife biologists, game managers, foresters, demographers and recreation officials must all work together if we are to avoid disaster and solve the complex problems which threaten mankind.

It is a sad fact that on our planet Earth, at this late date, there are two different worlds, as far as food production and availability are concerned, namely the "privileged world" and the "forgotten world" (Borlaug, 1970). The privileged world consists of the affluent developed nations comprising about 33 percent of the world population. In these nations agriculture is efficient—and industrialization is well advanced—with only 5 to 20 percent of the population engaged in agriculture, but capable of producing sufficient food for their own nation's needs as well as surpluses for export. The consumer in these nations has an abundant and diverse food supply available at a low price; his entire food budget represents only 17 to 30 percent of his income after taxes. Most of the people in these nations live in a luxury never before experienced by man. The vast proportion of the population (70-80%) in these countries is urban. They take the abundant and cheap food for granted. Many of them think it comes from the supermarkets and fail to understand the investments, toil, struggle, risks and frustrations on the ranches and farms that are required to produce the abundance they take for granted.

The "forgotten world" is made up of the developing nations, where most of the people, comprising 50 percent of the world's population, live in poverty with hunger a frequent companion and fear of famine a constant menace. In these nations a vast segment of the total population—ranging from 60 to 80 percent—is tied to a small plot of land in an inefficient subsistence agriculture. In these nations food, and especially animal protein, is always in short supply and expensive. The urban consumer in such countries expends 60 to 80 percent of his income on food in normal times, and when droughts, floods, diseases or pests reduce the harvests, all of his earnings go for food, and even then he is unable to buy what he needs. Many of the subsistence farmers themselves are often short of food and even a larger proportion are suffering from protein malnutrition.

Why does this great discrepancy exist between the privileged and the forgotten nations in food production? Although many factors are involved, the four major causes are: the difference in per capita endowment of natural resources, *i.e.* good arable land, the availability or non-availability of proper modern technology developed by research for increasing yields, the presence or absence of strong economic and extension infrastructures and adequate or inadequate visionary policy supported by government. Of these, the two greatest problems of the developing countries are the small amount of arable land available on a per capita basis coupled with low and stagnant per hectare yields.

Table 3 illustrates the comparative food production capabilities of land exploited under hunting and various types of agriculture. It is apparent that modern American agriculture employing advanced technology is capable of producing much more food per unit of land than other methods of exploitation.

I have, with a team of scientific colleagues from many countries, spent the past 27 years trying to help many developing nations increase the efficiency of food production of their agriculture and, I hope, in the process, to also have at least in some small way alleviated temporarily human population pressure on some wildlife habitats.

TRANSFORMING A TRADITIONAL AGRICULTURE

In most of the hungry, densely populated nations of the world, agriculture is inefficient. Crop yields are low and stagnant and have been so for centuries. The soil is tired and "worn out," depleted of

TABLE 3. COMPARATIVE FOOD PRODUCTION CAPABILITIES OF LAND EXPLOITED UNDER HUNTING AND VARIOUS TYPES OF AGRICULTURE
(Storck and Teague, 1952)
(Productivity expressed in number of people that can be supported per unit of area)

System of Exploitation	Area Required	Number of People Fed
Hunting[1]	2500 hectares	1
Foraging[2]	250 hectares	1
Hoe agriculture[3]	250 hectares	3
Plow agriculture[4]	250 hectares	750
Modern agriculture[5]	250 hectares	2,000*

[1] Indians of the North American plains (before European influence).
[2] Californian Indians (before European influence).
[3] Eastern wood-land Indians of N. America (before European influence).
[4] Ancient Egyptian agriculture.
[5] Highly developed modern agriculture of the USA (based on 1950 yields).
* If 1970 yields were used this figure would increase by between 35 to 40 per cent.

one or more of the essential plant nutrients, after hundreds of years of continuous cropping. The cereal crop plant has a difficult time surviving and so do the weeds, the disease organisms and insects that feed on the cereal plant. Then imagine the plight of the peasant farmer trying to eke out a living under such conditions. But the entire system is in "balance with nature"—but what a balance.

To change such a system one must develop information through research which will permit the development of a package of new technological practices wherein all factors affecting yield and production can be manipulated.

There is no magic seed. One must begin with the soil and determine, through experimentation on each of the major soil types, which plant nutrients are limiting crop yields. In most soils it will be nitrogen and phosphorous, but others may also need potassium. Some may need in addition certain minor elements. Once the nutrient deficiencies have been determined and corrected by the addition of the right kind and amounts of chemical fertilizer, it is necessary to develop a set of improved cultural practices which will properly utilize the available moisture. Since weed growth will also flourish with the applications of fertilizer, mechanical and/or chemical control must be devised. Weeds do not produce food. Then a new variety with high genetic yield potential must be used to exploit efficiently the full value of the fertilizer and improved cultural practices, since the variety formerly grown by the peasant farmer is poorly adapted to the new conditions. The new variety must be, in so far as possible, resistant to the major disease and insect pests, since these organisms will now find a much more favorable environment in the lush growth. It must be pointed out that, although it is relatively easy to breed in or incorporate disease or insect resistance into a new variety, there is no assurance how long this resistance will remain functional. The micro-organisms and insects mutate and develop capabilities of attacking the resistant variety sooner or later. Therefore dynamic breeding programs must be maintained. Moreover, chemical and biological control measures for insects must be developed which can be used when emergencies arise.

Even when a new improved technological package is completed, it will not change food production until applied on vast numbers of the nation's farms.

The value of the new technology must be demonstrated on hundreds of farmers' fields in direct comparison with the peasant farmers' methods. Large yield differences of 100 to 300 percent, which is frequently possible, must be demonstrated if the farmer is to be convinced. Yield differences of 10 to 15 percent will convince no one.

Before the farmer can apply the new technology—even though he is convinced—government economic policy must be brought into line. Political stability is essential. The inputs such as chemical fertilizer and seed must be made available. Government credit for their purchase must be made available, since the peasant farmer has no capital. And finally, the government must establish and maintain a stimulatory and stable price for his grain.

We have had the satisfaction of seeing Mexican wheat production increase 7-fold, and per acre yields increase 4½-fold; in the process Mexico became self-sufficient in this cereal in 1956. Using the Mexican varieties—which were unique in having high-yielding ability combined with wide breadth of adaptation, because of the manner in which they were bred—and drawing on the Mexican agronomic and pathologic experience, combined with excellent, extensive, adaptive research conducted in India and Pakistan, a revolution in wheat production has occurred in these two countries. The popular press has referred to this rapid change in cereal production in the past four years as The Green Revolution. Wheat production in India has risen from a pre-Green Revolution 1965 high of 12 million metric tons to 23.3 million tons during the last harvest. Pakistan's production has risen from 4.3 million tons to more than 8 million. More significant, however, than even the increase in wheat production itself is that more than 90 percent of the increase in production resulted from increase in yields per hectare, particularly significant in a land hungry country. The Green Revolution, which began on wheat, is spreading to rice and maize. Some farmers in West Pakistan and Northern India, who use the new technology and new seeds to double crop of wheat and rice in one calendar year, are harvesting a total of 13 tons of grain per hectare instead of their former production of 2 tons. Although the progress is still modest compared to total need, it is a step in the right direction. Hope has at least temporarily displaced despair, but there is no time for complacency because the population monster grows relentlessly.

COMPETITION BETWEEN MAN AND WILDLIFE

Up until the last two decades, the population pressure of man on wildlife species had largely been confined to the temperate zone or to high elevation cool climate areas of tropical zones. The situation has begun to change since vaccines and/or insecticides have come into being that control yellow fever or the vectors of malaria, sleeping sickness, river blindness and chagas, etc.

The vast, diversified and fascinating reservoir of wildlife species in Central and East Africa will come under ever-increasing pressure (Borlaug, 1971 a). Myers in 1971 pointed out the need for extending the area in the game parks and game reserves so as to include wider habitats. He also indicated the increasing importance of tourism as a winner of foreign exchange to the governments of Uganda, Kenya and Tanzania. Moreover, he indicates the increasing problem with poaching in game reserves and parks.

The expansion of tourism will help solve the problem of foreign exchange but little benefit will accrue to the masses of rural hungry peoples. The amount of poaching will continue to increase despite controlled cropping and sale of meat from reserves. It would appear to me that it is important and urgent to use science and technology to increase the yields and production of both agriculture and animal husbandry in both the humid tropical band in Central Africa and in East Africa, if the wildlife is to be preserved. Unless this is done, human population pressure will soon build to a level where no government—regardless of their interest in preserving wildlife—will be able to withstand the demands and pressures of their hungry people.

The indirect value of science and technology in agriculture and animal husbandry toward assisting in the conservation of wildlife in the USA illustrates this principle. A recent study (Barrons, 1971) clearly indicates the increase in efficiency in food, feed, oil and fiber crops during the past 30 years. This study included all of the 17 food, feed, oil and fiber crops grown on a million acres or more during the 1968-70 period. The average figures for area sown, yield per acre, and total production for each of these crops were calculated. Comparable calculations were made for each of the same crops for the 1938-40 period.

Using the average yield and production figures for each of the crops in the 1968-70 period as a base, calculations were made for each crop to determine the area that would have been required to provide the same output using the 1938-40 figures. The results are startling. The area of 281 million acres cultivated to these crops in 1968-70 produced enough to meet the domestic needs of the USA, plus an additional amount of produce for export valued at 7.8 billion dollars. The amount of land that would have been required to produce the same quantities of these products, using 1938-40 yields and technology, would have been 572.9 million acres, more than double the area under cultivation in 1970. Much of the increase in yields and total production in 1970 over 1940 was due to the use of agricultural chemicals, especially fertilizers, weed killers, and insecticides. Improved cultural practices and improved seed also played important roles.

Within the past decade, because of improved technology and higher yields, it has been possible to remove 50 million acres from cultivation and still meet both the domestic and export needs for agricultural products. Were the country still relying on the 1940 technology, however, not only would the 50 million acres now held in reserve be back under the plow, but, moreover, an additional area of 241.9 million acres by necessity would have been opened to cultivation. In fact, it would have required considerably more than 241.9 million acres of additional land since the quality of the land would have been poorer than that now in cultivation. In order to have been able to have brought this additional area under the plow, it would have been necessary to have opened to cultivation lands that in a large part would have been rolling or semi-arid, and consequently vulnerable to erosion by water and wind. It would also have meant clearing the forests from large areas so as to meet the food, feed, oil and fiber needs of the nation. Now, reflect on the additional havoc that this expansion of cultivated area would have done to wildlife habitat, and especially to rare and endangered species of animals and birds that are already on the brink of extinction.

Looking at it from another angle, 291.9 million acres of land, an area roughly equivalent to the total land area of the USA east of the Mississippi River and South of the Ohio River is today available for other uses, because of the improvements in crop production technology that has taken place in the past 30 years. These uses include wildlife, forestry and recreation. Although Barrons' studies were made in the USA, it behooves all mankind to increase the efficiency of agriculture, animal industry and forestry, if we wish to alleviate human suffering, conserve wildlife, and improve recreational opportunities.

I marvel and admire the progress that you have made in wildlife biology and game management during the last few decades. You have re-established a number of species, such as the wild turkey that was nearly extinct. You have successfully introduced foreign species, among them the Chinese ring-necked pheasant, which has taken over the niche vacated by the prairie chicken, who could not adapt to the selection pressure of modern agriculture. Wildlife biologists have developed expertise for successfully rearing many species of fish and birds, for restocking rivers and lakes, and fields and woodlands. You have developed controls for certain diseases, parasites and predators of fish, birds and animals, all of which have contributed to helping wildlife programs. The research that led to the control of the lamprey which threatened the existence of the lake trout is monumental; equally fascinating have been the spectacular recent results of the introduction of Coho salmon into Lake Michigan and Lake Superior. Wildlife biologists have developed excellent systems for monitoring and understanding the population dynamics of many species. These data permit the establishment and implementation of realistic cropping or harvesting game laws. The result of all of this is that there is, in many parts of the USA, more game now than there was 20 or 40 years ago. One can only marvel at the resilience of wildlife when it is given reasonable protection. When I return now to the small farm in Iowa where I was born, I see deer, bobwhite quail, Chinese ringnecks, and opossum where there were none 40 years ago. In the vast, newly irrigated, highly productive agricultural areas of the coast of Sonora and Sinaloa there are large numbers of a diverse group of bird species that did not inhabit the coastal area 20 years ago.

Yet, despite this progress, there is trouble ahead for some species. In the USA, three to four dozen species each of mammals, birds and fish and about a dozen species of reptiles and amphibians are considered rare or endangered. There are probably several hundred species that are facing extinction in other parts of the world. Almost certainly some of these species are about to flunk the imperative "evolve and adapt or perish" as their habitat is destroyed by the relentless pressure of human numbers. I am of the opinion that wildlife biologists and game managers, and forest biologists and forest geneticists are at a great disadvantage compared to agricultural crop scientists and domestic animal scientists. The number of agricultural crop plants of major importance does not exceed 20 species, and the major animal species on which our modern civilization depends, does not exceed 10. Consequently they can concentrate their research budget and production effort on a few species. You have been unable to do this.

It would seem to me that wildlife biologists and game managers must prepare a list of the threatened species and establish an order or priority for research and protection. Unless this is done—with the limitations of budgets and trained scientists available—an attempt will be made to save all threatened species, with the end result that many rather than a few species will become extinct.

The same danger exists in the environmental movement. There is a tendency today to try to correct immediately all abuses of the environmental without establishing priorities. Within the past two years, 344 environmental bills have been passed and funded by state and federal governments. Almost certainly such poorly planned precipitous uncoordinated legislation will produce disappointing results; disenchantment will follow.

In closing, I urge you to make every effort to attempt to take advantage of the principles, methods, and techniques that have been developed and used successfully in domestic animal and human reproductive biology to increase reproduction. I refer to artificial insemination, the freeze-storage of semen, the inducement of estrus with hormones, diet and photoperiodism, the inducement of superovulation, and embryo transplant.

Artificial insemination is used today on 60 million cows, 50 million ewes, 125,000 mares, 56,000 goats, 4 million turkey hens and large numbers of sows and hens. I urge you to explore the feasibility of using one or more of these techniques to try to save some of our threatened rare species.

As the number of individuals in a rare species is reduced, it becomes increasingly more vulnerable to decimation by diseases and pests, because of the narrowing of the genetic base. Conceivably artificial insemination, employing semen from the rare individuals that are widely separated geographically, might be used to broaden the genetic base and minimize dangers from epidemics which might arise and threaten to eliminate the species.

Moreover, I urge you to attempt to use, not only artificial insemination, but also all of the other techniques imaginatively, without preconceived reservations. Artificial inducement of estrus and artificial insemination may help circumvent problems of breeding territorial animals in captivity. They may be useful both for zoos and for restocking. Do not be fearful of developing a strain that will only be adapted to life in a zoo and will not reproduce in nature. The mustang of the USA, the present "wild" asses of Egypt, the Chillingham "wild cattle" of Britain are all feral—animals which were once domesticated but have returned to the wild. All reproduce and survive normally in the wild. But to me, if there are any fears along this line, they can be dispelled by observing the evolution of the water buffalo. The domestic water buffalo is perhaps the most docile, lethargic, dull, spiritless and sluggish animal in "captivity"; yet, it has reverted successfully to the "wild" or feral state, and occurs in large numbers in northern Australia. Moreover, in Assam, the native home of the wild water buffalo, wild bulls often kill the domestic bulls and sometimes mate with the sluggish domestic cows of peasant farmers. The calves from such matings are more difficult to handle and are very difficult to make use of for plowing or pulling a cart (Gee, 1964).

There is also circumstantial evidence in plants that rust resistant genes can persist for hundreds or even perhaps hundreds of thousands of years in populations of maize (*Zea mays*) and western white pine (*Pinus monticola*) respectively in the absence of the selection pressure of their respective pathogens, *Puccinia polysora* and *Cronantium ribicola* (Borlaug, 1971 b). The persistence of genes in such populations, together with how well many domesticated animal species have "returned to the wild" should reassure us of the great flexibility in the genetic system.

I have learned from 27 years of experience in wheat breeding and wheat production that ultra-conservatism in methods is not recommendable. The non-conservative methods used in our wheat breeding program produced the high-yielding Mexican varieties that were equally as well adapted in India and Pakistan as they were in Mexico where they were bred. They gave rise to the so-called Green Revolution. We are now making good progress toward developing a new commercial cereal crop—Triticale—derived from a wide cross between wheat and rye. Many competent scientists, only five years ago, believed this field of research offered little promise of success. You too should at least dream about the feasibility of certain wide crosses, and dream about the introduction of rare wild species into some of the lesser crowded areas of the world.

I would also encourage you to attempt to establish close working international scientific teams, as we have done and found highly effective in our wheat work. I realize you have had excellent results already in international cooperative efforts on migratory waterfowl programs.

I am convinced you have a great future ahead in wildlife programs if we can all collectively convince the Naked Ape to use his brain and mind to anticipate the catastrophe that will result if he does not voluntarily restrict his increase in human numbers.

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