THE ECOLOGY OF MICE AND MEN

I. The Population Problem.

II. The Preservation of Rare Species.

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I. The Population Problem.

On the islands of Penobscot Bay (fig. 1) for the last four years I have been studying one of ecology's more intriguing questions: what determines the number of species which can live together in a community?

The map shows East Penobscot Bay bounded by Deer Isle on the east and Isleboro on the west. To the north lies the mouth of the Penobscot River at Bucksport, and Isle au Haut is to the south. The islands on which I am working lie 1/4 to 2 miles miles off Deer Isle; and not more than 1/2 milefromthe nearest small island. There are about 50 islands in the group less than 100 acres.

Major plant communities are as follows: in open areas grass forb communities occupy more xeric sites, with aster and goldenrod being dominant. Crowberry mat is common on shores, and cranberry-spagnum meadow forms in poorly drained areas. Shrub communities are dominated by raspberry, bay, or poison ivy. Forest is white spruce-balsam fir with no hardwoods. It may be subdivided according to ground cover. These subtypes, in approximate order from xeric to mesic, are cladonia lichen on rocky areas, grass in open woods, bare needle litter in dense stands, Mianthemum and other forbs, and feather mosses and forbes in the wettest sites.

The only mouse is Microtus, the meadow vole. We'll return to the mice in a minute. Other Mammals in the terrestrial vertebrate community are occasional red squirrel and deer at the primary consumer level, and mink and shrew (S. cinereus) as secondary consumers. There are several passerine birds, most of them summer residents, and the great horned owl, probably the most important predator of the mice. Other vertebrates present, but having little effect on the terrestrial

community are the osprey, blackbacked and herring gulls, spotted seals, eider ducks, cormorants, and transient shore birds.

So it's a relatively simple community. This is the first of two generalizations we can make about island ecology -- islands possess fewer species than do comparable mainland areas. This is certainly not a new observation -- it dates back to Darwin and Wallace, but the question remains -- what limits the number of species?

Returning now to the mice, there are three families native to Maine. The subfamily of voles are distinguished by their plump bodies and short tails. The meadow vole makes the familiar tunnels in grass roots where during the daylight hours it is occupied feeding on vegetation and storing up miniature piles of hay. The red-backed vole (Clethrionomys) a second member of the subfamily of Microtinae, is found in ferny glades in the woods, and may not be familiar, although it is also common. In addition to succulent vegetation it feeds on seeds, fruits, and berries. Also found in the woods is the deer mouse (Peromyscus) the common mouse of barns and camps. Like other members of its subfamily, Cricetinae, it is longtailed, has large ears, and is nocturnal. It is also partly arboreal, and feeds on insects as well as seeds and fruits. A third family, the jumping mice, will not concern us.

All three of the species described above are found on Deer Isle, but only Microtus is found on the smaller islands. There, in addition to inhabiting open areas, it is common in woods, usually near some ground cover. In some instances, however, they are found in dense woods with no herbaceous cover.

Apparently, then, Microtus had invaded the vacant niches of the woods-dwelling Peromyscus and Clethrionomys. This replacement of one species by another is our second generalization about insular

faunas. Over and over we find this pattern of species A and B occupying different habitats on the mainland, but on islands where B is absent, A occupies both habitats.

I am interested in islands because study of their simplified, and perhaps exaggerated, patterns should give insight into factors shaping all communities. This is what I am doing in Penobscot Bay: I am introducing the missing species of mice onto the small islands in order to

1) determine under what conditions a new species can become established, and

2) to see what effect such an introduction may have on the population density and habits of the indigenous Microtus.

The islands are ideal for this in that they are small, numerous, reasonably alike, and relatively undisturbed by man. And most important, we have both our situations -- Microtus is the only mouse present, and it has invaded the habitats of the missing species.

With regard to how I go about this, we use Sherman live taps baited with apple and peanut butter-oatmeal. The traps are set within five feet of grid stakes placed 50 feet apart. Mice are marked with a numbered ear tag and released. Each island is trapped for about 6 days. Population density can then be estimated by the Lincoln Index -- from the ratio of captures to recaptures in the last 2 days times the number marked in the first few days, or you can simply use mice per trap night. Sex, breeding condition, and weight and length are taken. The latter will be used as an index of age for calculating life table data.

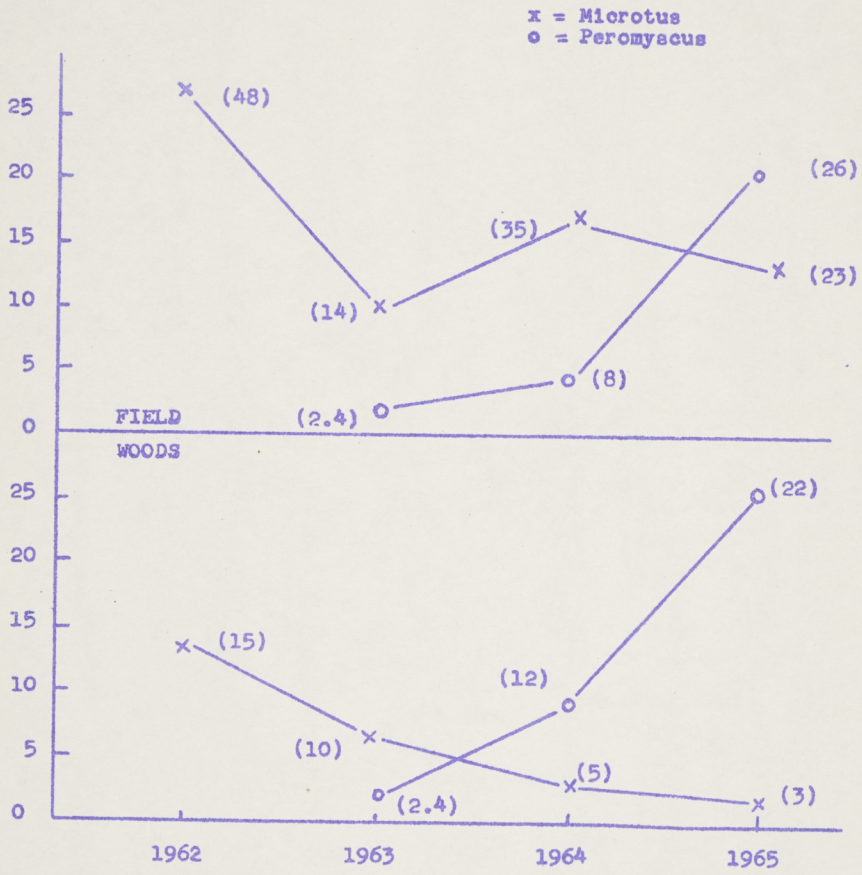
In 1963 I made 3 introductions in order to see if the missing species could in factsurvival and reproduce on the islands. As I was a bit sceptical of their chances of success, I introduced enough individuals to constitute approximately a normal population density for each island. The next year all populations were found to have produced new individuals.

One of these, Mark Island, is 5.3 acres in size. It is ideal in that 1.7 acres open habitat are sharply demarcated from 3.5 acres woods, broken by two small areas blown down and raspberry bushes. In 1962 it was evident from the number of runways that the open end supported a high density of Microtus -- about 48 per acre. This had caused considerable damage to the plant cover. In ecological terminology they had exceeded the carrying capacity. In the woods Microtus numbers were lower, about 15 per acre. Here, as mentioned previously, they tunneled along branches, into moss, and under stumps.

I explain this invasion of woods by Microtus as being due to population pressure exaggerated by restricted dispersal, and implemented of course, by absence of competing species. That is, on the mainland a young mouse looking for a home can pass up marginal habitats in search of greener pastures. On an island there clearly are no greener pastures.

In August, 1962, I introduced 8 female and 12 male deer mice. The course of the populations of the two species during the next three years is shown on the chart. Note the sharp decrease of Microtus in the field -- from 48 to 14 per acre --during the next winter. Such cyclic changes are characteristic of this species. Peromyscus populations then increased faster and faster, while in the woods Microtus declined to only 1/5 its original density.

Trapping maps for 1965 show all but 9 individuals of Microtus


x = Microtus
o = Peromyscus
25
20
15
10
5
0
(48)
(14)
(35)
(23)
(26)
(8)
(2.4)
FIELD
WOODS
25
20
15
10
5
0
(15)
(10)
(5)
(3)
(12)
(22)
(2.4)
1962
1963
1964
1965

restricted now to the open areas while Peromyscus not only displaced Microtus from the woods, but under pressure of it's own increasing populations, it has invaded the field. This is amazing, exciting and perplexing. First, Peromyscus are even less known in fields, than are meadow voles in woods. Second, Microtus is supposedly the more aggressive species, yet here is Peromyscus reaching densities in the preferred habitat of the vole several times those normal for woods. NOTE 1

These results have some rather interesting implications for the interactions of population pressure, competition, and habitat selection -- a subject in itself. Tonight we shall pass over them as manifestations of the Harvard Law of animal behavior-- that under carefully regulated conditions, animals do as they darn well please.

We have seen that dispersal to marginal habitats is a manifestation of crowding. Therefore there should be a high selective advantage for a self-regulating, or density-dependent, mechanism of population control. Let us now look more closely at the growth pattern of natural populations, and then make some extrapolations to human populations.

We all have heard that organisms are capable of exponential increase, or the potential to rapidly cover the earth with flies or elephants as the case may be. Just what does this mean? Growth conforms to the equation $N_t = N_o e^{rt}$. You may recognize this as the formula for compound interest. To the principal in your account the bank adds during each period (t) an amount obtained by multiplying this principal by some constant interest rate. This increment is expressed by the relationship $\frac{dN}{dt} = rN$. Perhaps a more intuitive way of expressing this is the amount of time necessary to double the population. Human populations are currently growing at the rate of 2%, which means that they will double in the next 35 years; while

the population of 250 million in 1 AD required the next 1650 years to double (9).

To calculate the rate of increase of the mice on Mark Island we take the $N = 12$, the number in 1963, and $N_t = 120$, the number in 1965. Time is measured in generations, and as I estimate there to be three generations a year, the t is eight. Applying out formula gives a rate of increase of 1.23 or 23%. Now a high rate of increase does not necessarily reflect a high birth rate. In fact, I find half my deer mice living a year or more. This life span is several TIMES average life spans for a mouse exposed to the rigors of nature, is perhaps due to lack of predators. NOTE 2

Nevertheless, the population is increasing rapidly. How long can we expect this to last? There is already evidence that natural controls are setting in and reproduction is dropping off.

Crowding acts through the adrenal cortex to produce a syndrome crudely resembling hypertension, with reprecussion through the endocrine system upsetting reproduction, and metabolism. First, fertility in female mice may be reduced through failure to reach estrous, pseudo-pregnancy, or fetal resorbtion (14). Such effects may be acting in deer mice on Mark Island . Alternatively, the litter may be born, but under crowded conditions the mother does not provide adequately (5). Aggressive encounters increase under crowding, and the socially subordinate individuals suffer most. Such social stress makes the animal more prone to mortality factors such as disease, starvation, cold. While the role of these effects in nature is not yet understood, they may have been responsible for the sudden crash of Microtus populations on mark islands after the peak populations of 1962.

What perspective can our studies of the numbers of mice lend to an understanding of populations of men? Clearly, if each

couple leaves more than two children who also bear children, the population will increase. The recent surge in the human rate of increase is primarily due to decrease in death rate, which has more than offset any small decline in birth rate. Increased life expectancy of adults has little effect on population size once the age distribution has stabilized. However, that many more female babies now live throuhg the reproductive age has increased population growth considerably. The trend toward early marriages in this country has as great an effect on rate numbers of increase as does the family size.

Note that in our equation, population size is an exponential function of both generation time and rate of increase. Slobodkin states that a hypothetical female who has twins at 19 and only one child thereafter contributes much more to future generations than a woman who begins a family of five at age thirty (14).

What are the demographic prospects for the future? Will populations increase until they exceed the carrying capacity of the land to create a catastrophe such as witnessed in the Microtus of Mark Island? Will natural controls set in as appears to be occuring with the Peromyscus of Mark? Or will the rest of the world be able to instigate artificial controls as Japan has done? I can only say that if we do not yet fully understand the population dynamics of mice, we know far less about those of men. Compare the soaring populations of Asia with the decline occuring in Europe during the last 80 years. The web of biological, emotional and economic factors influencing human fertility has yet to be untangled.

It is clear that we face a new problem. Throughout history as man has approached the carrying capacity he has been able to raise it (7). First primative man discovered tool making and then

agriculture. Next the colonial era and industrial revolution left the warnings of Malthus forgotten. But now geographic frontiers are gone, and though technological frontiers remain, those countries which are in the most desperate straits are those with the poorest development of resources. Their population growth quickly offsets any economic growth.

Short of world resource planning, the outcome will be as diverse as our societies. In Asia and Latin America only a major breakthrough can prevent nature's grimly efficient controls of starvation, disease, and aggression from stepping in. In this country the problem is not one of outright survival. Technology can keep the wolf from the door, though our material standard will certainly suffer. With the emergent nations demanding to use their own resources, our 7% of the world population can no longer continue to use the lion's share of the world's feul and minerals (60% petroleum, 25% coal)(6). A fixed supply of resources can not indefinitely support a rising standard of living for increasing numbers of people.

But if we can resign ourselves to less material wealth, the changes threatening our political and social institutions will be even more drastic. To use an immediate, if trivial example, the recent zoning controversy proved Marlboro residents reluctant to recognize that what we do has become our neighbor's business. If our endocrines can withstand the stress of crowding, what of our spirits? Can we accept the regulation of the individual necessary to cram 8 billion people into a brave new world?

II. The Ecology of Rare Species

I shall now consider just one reprecussion of our expanding populations -- the effects on the populations of other species. Man does not utilize natural habitats for food and shelter, he modifies them for his own purposes. Herein arises a conflict of interests. The world's 250 currently endangered species and 200 species which have gone extinct during the last 300 years, have suffered from loss of habitat, as well as direct slaughter. To the nearly-extinct ivory-billed woodpecker, old growth cypress is habitat; to man it is a valuable source of lumber. To the passenger pigeon the oak forests were room and board rolled into one; to man they occupied land more profitably cleared and farmed . Hence the question: what are the biological reasons for species going extinct? How are these pressures related to man's changing social and economic structures?

I shall approach these problems in a roundabout manner by returning to my work on the islands. In my studies, on competition I have taken advantage of our first phenomenon, that islands have fewer species. In fact in previous studies on Bermuda (3), I at first took for granted that oceanic islands are depauperate by virtue of their isolation -- that is, because fewer species have had an opportunity to reach them. However, it became evident that this was naive, and that insular faunas do not represent the results of random colonization.

There are only 6 native land birds in Bermuda. During the last centruy 14 species have been introduced, of which 9 have succeeded, and but 4 have maintained stable populations. Further, several North American species, swept off their paths during migration, arrive by the hundreds or thousands each year, yet never breed. Why?

There appears to be certain relationships between the opportunities for specialized and generalized professions, or niches, in nature which determine the relative numbers of common and rare species. This, in turn, produces the species-area relationship -- that as additional increments of area or individuals are sampled, the number of species increases but at a decreasing rate. Thus, the number of species varies with the 1/2 - 1/4 power of the area. Preston has recently provided us with an equation relating the number of species to the area of an isolated land mass (12). Applying this to Bermuda, there should be 12-14 species. (This happens to be the present number, however some newcomers such as the housesparrow occupy habitats altered by man, while we do not know how long others will survive). Why, then, are there but 6 native species?

Rare species on islands are subject to periodic extinction, and chances for recolonization depend on the distance from the source area. Further, those species which find their preferred habitats will be favored. I was able to account to some extent for the success of the native Bermuda species by comparing the foliage profiles of their habitats in eastern North America to available habitats in Bermuda (4). These species were, in fact, among the more common ones in these habitats. On the other hand, some species which have been introduced and failed, or absent species which one might expect to find in Bermuda, prefer foliage profiles less common in Bermuda. In view of this, I hypothesized that since rare species are unable to maintain stable populations and are subject to extinction, successful species can occupy vacated habitats as well as their own. On smaller islands, other things equal, fewer species will be able to maintain populations, while more remote islands will also have fewer species. Thus the number of species depends on both island size and proximity to other land masses.

If we look at the distribution of our three species of mice, we can see that there are interactions of island size and isolation, of liklihood of colonization and extinction. Recall that Deer Isle being large and near, possesses all three species. Isle au Haut is large, but more remote. It supports Peromyscus and Microtus but not Clethrionys which we have seen to be least successful. Monhegan Island is of moderate size and extreme isolation. It lacks even Microtus (I might add that the [illegible] fauna of even such conspicuous islands as Swans, Marshalls, and Vinal Haven are apparently not known).

But why is Microtus the only species found on the smaller islands, inasmuch as the habitats are often more appropriate to the other two species?

Let us look at my experimental introductions. We have seen earlier that the missing species can survive and reproduce if introduced. But how small a contingent need be introduced to assure success? In order to determine this, we simulated natural colonizations by introducing from 1 to 3 pairs of other deer mice or redbacked voles. The islands used were, for the most part, of mixed habitat, and less than 4 acres in size. On Dave's, our smallest at 3/4 A we are trying to see how small an island can support an additional species. On Ram we have introduced both species in order to see how many species can coexist. Our batting average for all introductions to date is as follows:

Peromyscus:	8 pairs -- one trial,	one success
	3 pairs -- two "	two "
	2 pairs -- one "	one "
	1 pair -- three "	one "
Clethrionys:	6 pairs -- one trial	one success
	2 pairs -- one "	0 "
	1 pair -- three"	0"

why did some of these attempts fail? And again, why is Microtus the

more successful species? It has been suggested that Microtus gets there first; and, once established, holds a competitive advantage over newcomers. Perhaps it was the first mouse to occupy habitats developing after the Pleistocene glaciation. Unless this does account for the situation, it would seem that since Peromyscus is found on Isle au Haut, it might have reached one of the intervening islands before Microtus. And if success is merely a question of squatter's rights, then subsequent colonization by Microtus would have been prevented.

Instead, I believe that once there, Microtus is better able to establish and maintain itself. First, the herbaceous food of Microtus may be more stable than the seed and fruits on which Peromyscus and Clethrionys depend. If this is so, they are more subject to extinction from climatic fluctuations. Second, Microtus may be more likely to colonize through being cast adrift on logs or ice, and its pioneer populations are thus more likely to be bolstered by subsequent immigrants. Third, Microtus maintains a greater population density. Since there are more individuals per acre, an island of a given size will support a larger population, whereas Peromyscus and Clethrionys with larger home ranges and lower population densities may be too few to maintain populations. Last, Microtus has a greater reproductive capacity. The breeding season is longer, the litter size is greater, and the generation time, or age at which the females can first breed, is 6 weeks as opposed to 9 for Peromyscus.

Mac Arthur and Wilson (10) have recently proposed an equation expressing the probability of extinction of a population in terms of these same factors -- population size and rate of increase. Thus we have a quantitative standard against which the results of our experimental introductions may be compared (see note). Such a formulation is a model, as was Preston's equation relating number of

of species to area. It is a simplified description, and may not incorporate all the complexities of nature. Nevertheless it provides an approximation to reality by which events in nature may be predicted. One of the objects of science is to develop such generalizations. Let's see how our results compare to this model.

Successful one-pair introductions of Peromyscus showed a rate of increase of 1.35. This yields an expected probability of extinction of .5 as opposed to the observed .67, or the observed extinction of .67 would be expected from r= 1.2, rather than the observed 1.35. I find this agreement encouraging since my data are not yet complete and my series rather small. Unless you wish to ascribe it entirely to chance, at least I'm working in the right ball park. NOTE 3

How does all this apply to the preservation of endangered species? It would appear that if we know the abundance and rate of increase of a species, we could then calculate its chances of extinction; and given its natural population density we could estimate that area necessary to support a stable population.

Let's take the California Condor as an example. It once numbered in the thousands over its range extending from northern Lower California to the Columbia River, and east to Nevada and New Mexico. Now the remaining 40 individuals are restricted to the coast ranges of Southern California, with the breeding being concentrated in the 53,000 acre Sespe Sanctuary. Bent wrote (1), "Far from the haunts of man, in the wilder portions of Southern California, among the most rugged and rocky gorges and canyons of the less frequented mountain ranges; this magnificent vulture, the largest and grandest of its tribe, still survives. Here in the remote vastnesses of the untamed wilderness it still finds comparative freedom from the dangers of advancing civilization... the flight of the California Condor is a superb

exhibition of graceful ease and grandure as it floats steadily along on its great wings, a powerful and skillful master of the air."

About two-thirds of the forty birds are of breeding age. Since a pair lays one egg every other year, a maximum of 6 or 7 young could be produced each year. The young require six years to reach breeding age. The application of our formula to these data yields an infinitesimal chance of extinction. Clearly, either the concern over the condor is for naught, or there is something wrong with our calculations.

First, the equation applies only to populations expanding into an unlimited environment. Condors, like most rare species, are restricted by lack of appropriate habitat. Second, the rate of increase should be determined as we did for the island mice; that is, on the basis of new adults added to the breeding population. However, here we used the number of hatched young, and did not allow for the deaths of nestlings or immature birds before breeding age is reached. This sounds as if it is merely a question of using more appropriate figures; but, in fact, these data are known for exceedingly few species. I would guess that for none of our endangered species do we have adequate life table information. Further, even if we had used our formula correctly, it does not take into account all the factors necessary to assure that reproduction will be continued.

First, it may be necessary to maintain some number above the theoretical minimum in order to preserve genetic variability. A natural population possesses a diverse genetic constitution evolved over thousands of generations. When a species becomes rare, its gene pool is diminished and this variability is reduced. Dissection showed steritity to be common in the last of the heath hens, presumably as a result of inbreeding; while other rare species, such as the whooping crane, have apparently suffered little genetic loss.

little genetic loss.

Second, there are some rather relationships between area and numbers not recognized in our model. Previously, I referred to the range of opportunities for ecologic specialization determining the relative abundance of species. Secondarily to this there appear to have evolved behavioral-or psychological, if you will -- requirements for spacing or grouping of individuals.

On the one hand, in gregarious species there appears to be strength in numbers, termed social facilitation. That is, for breeding to occur there must be a certain population density. The passenger pigeon once nested in such large colonies that branches broke under their weight. Why did they die out with the clearing of the forests, if bluejays and squirrels can still find a square meal? Townsend (2) answers this as follows: "... it may be said that a bird accustomed to living together in large numbers and close ranks whether in feeding, migrating, roosting, or nesting, might find it impossible to continue satisfactorily these functions with greatly reduced and scattered ranks."

On the other hand, we have seen that for some species crowding disrupts social and reproductive behavior. Akin to this, some species require undisturbed wilderness for their domestic affairs. Contrast the seclusive condor or fisher with the racoon or white tailed deer which almost thrive on proximity to man.

I have focused on only the factors relating to the species-area relationship or population density, neglecting such equally important factors as predators, parasites, migratory habits, and social structure. But I'm sure you can see that the continued reproduction of rare species depends on a host of ecological and behavioral requirements.

Our methods of conservations must be equally diverse. For species which maintain relatively dense numbers over a limited area

the course is relatively simple -- preserve that area. For example, the entire population of Kirland's Warbler consists of some 500 pairs living in some 86 square miles of jack pine country in Michigan (11). For most species, however, such a status is attained only as a stepping stone to extinction. For species with a wider range, but locally dense populations such as herons and other shore and water birds, a system of widespread but small refuges is in order. But what of such wide-ranging and individualistic species as the grizzly bear and bald eagle? And what of migratory species like the whooping crane? Clearly, refuges in themselves can not be sufficient. Preston (12) carries this question further to ask how realistically we can hope to maintain the diversity of species on restricted natural preserves. From his studies relating number of species to area and total individuals, he predicts that if a refuge is isolated from interchange with other wild areas, rare species will be eliminated until the fauna resembles that of an oceanic island, -- an impoverished derivative of the original community. In his words, " A park can no doubt be 'managed', in some cases, so as to preserve certain particularly attractive species, but the total number of species must in the long run fall to a rather low level. The only remedy is to prevent the area from becoming an 'isolate' by keeping open a continuous corridor with other preserved areas. Even then there will be a nationwide impoverishment due to mere reduction of natural areas as natural conditions are replaced by unnatural ones."

If widespread extinction of wildlife is certain, are conservation efforts futile? Condoning erradication of a species because extinction is ultimately inevitable is hardly more justified than condoning murder because all men are mortal. Because civilization has enabled man to control and modify his environment, it is our obligation

to preserve this environment wherever possible. This to me is frankly a moral obligation; but it is to our advantage, as well, for scientific, economic and asthetic reasons.

First, the natural communities of which man is a part, function as integrated wholes so that each species plays an important though perhaps obscure role; and elasticity conferred by diversity may prove vital in resisting the effects of pesticides and radioactive fallout. Further, it is often from the rare, unusual, or ancient species such as the condor that we learn the most about the workings of nature. Second, the economic value of such species, both through their role in the natural community and their value to the recreation and tourist industry may, in the long run outweigh immediate pressures to the contrary.

And last, as in all manifestations of the population explosion, the choice is ultimately one of human values. The West Virginia moto is "Mountain men are ever free." True, to the pioneer, wilderness was to be conquered, rather than preserved. But pioneer and wilderness become synonomous in their symbolic value to 20th century man, and the superficial freedom expressed in undercut hair and overpowered autos is perhaps but an abortive seeking for the stronger freedom found in the pioneer and the California condor.

Notes

1. (p. 5) The present Peromyscus population of 2 0 per acre is very likely the result of an initial increase before controls take effect. However, the fact that this situation has arisen at all brings into question the classical view of habitat preference. Here, population pressure has overridden habitat preference to eliminate normal species segregation. Even if Peromyscus and Microtus are not strong competitors, with the former occupying the runways of the latter, there may well be some rather direct interspecific encounters taking place -- a marked break from Neo-Darwinian view of competition.

2. (p. 6) I find a similar situation in Bermuda, where birds appear to live longer. Here 5 out of 9 white-eyed vireos survived 4 years, an annual mortality of only .25. In both Maine and Bermuda, a high population density appears to be associated with a low mortality rate, a reduced birth rate, and therefore a lower turnover.

3. (p. 13) Agreement with the MacArthur-Wilson model: The equation was adapted from one of Feller's on the extinction of branching processes. The initial equation for the chances of extinction of one pair is $P = e^{r(1-p)}$. Clearly then, a population of N ~~pairs~~ PAIRS has a probability of extinction of P^N.

For Peromyscus, additional comparisons of expected and observed results are: For 100% chance of success 7 pairs should be required, while introduction of 2 , 3, and 8 pairs were observed to enjoy this success.

For Clethrionomys, the one successful population on Second Island showed a rate of increase from 1962 to 1965 of 1.03. This low value in itself may be the result of this species' competing more directly with Microtus than does Peromyscus. For 6 pairs, a .75 chance of extinction is predicted, while the one such trial succeeded. For 2 and 1 pair, for which all attempts failed, predicted extinction probabilities are .93 and .95 respectively.

Further notes on the biology of endangered species:

The prec-eding has been an attempt to apply one phenomenon, the species-area relationship, to the problem of rare species. During the discussion it became apparent that this was a rather limited approach, that not only the density of a species but its social structure determines its vulnerability to the advance of man. Indeed, abundant species such as the passenger pigeon and species with clumped distributions such as the great auk have proven more vulnerable than rare but widespread species such as the eagle and grizzly. Further, other biological factors such as disease, predation, and habitat preference must be considered. The following notes are made with an eye to discussing them more fully in the future. Comments on their accuracy, aptness, other examples, and sources or individuals which might provide additional information would be greatly appreciated.

Bermuda Petrel or Cahow. If there were a Medal of Honor for consevation it should go to Dave Wingate for his single-handed protection of the nesting cahows. The breeding population has increased under his care from something over 8 pairs in 1957 to 22 pairs in 1964, with the annual production of young increasing from 4 to 8. Since these data are on observed population size, we can more aptly apply our formula for chances of extinction. Using the increase in breeding pairs from 19 to 22 over a 4 year period gives a probability of .33 or 1/3, with $r = 1.03$. Using a less conservative figure of $r = 1.14$, based on 42 chicks produced from 103 pairs in 4 years, and having an estimated survival of 70%, the chances of extinction are very small.

-- American Bison: has recovered from low numbers to produce a surplus on its limited range. However, as a wild animal it is extinct -- its behavior as a nomad of the plains has been lost. Further, the several geographic subspecies adapted to local conditions have vanished.

-- Grizzly Bear: an example of a species with an initially sparse population which is threatened by restricted range limiting its numbers. Also had local races.

-- Key Deer; a particularly interested subspecies with a small range making protection possible.

-- Prairie Chicken: The Heath Hen, an eastern race, became extinct through an interesting, if ill-fated, combination of fire in its breeding grounds, bad weather, unusual predation (from an influx of goshawks), and sterility from genetic decay. Attwater's Prairrie Chicken in a Gulf Coast subspecies in jeapardy through loss of habitat.

-- Everglades Kite: the species is in danger only in its limited range in the U.S., where it depends on a special food (snails) which are affected by changing conditions due to drainage.

*** Bald Eagle, Osprey, and Peregrine Falcon: all have markedly declined in past 5 years due to sterility presumably caused by pesticided obtained through the food chain.

-- Carolina Paroquet: As in the Passenger Pigeon, disruption of flocks may have been as important as destruction of habitat.

-- Whooping Crane: U.S. Fish and Wildlife Service is launching a program of propogation in captivity for this and other species. This approach is not only difficult, but controversial.

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