suffice. What seems most needed are constructive and progressive contributions toward the solution of definite problems that are ready for experimental attack, and the central office of such an organization as is here considered would plan to undertake these. Preliminary presentations might be prepared and submitted to all cooperators. Out of the correspondence thus developed would eventually come a presentation that might measurably approach a truthful one, whereas single individuals could not hope to do more than make incomplete and more or less one-sided contributions in the desired direction, their papers being similar to most of those that now appear in the scientific publications.

From the last paragraph it will be appreciated that the writer's idea of cooperation in research involves the union of a number of minds in planning the attack on a problem, in working out the different parts, and in bringing the several component results together into a well-considered presentation that might really mark a tangible advance in scientific knowledge. Cooperations of this sort would bring it about that many of the experimental mistakes that cause so much discussion in scientific literature might be avoided at the start (through cooperative planning) and that most of the adverse criticism that leads to such wasteful polemics in many scientific fields might be already past before the main publication occurred, for each cooperator—and perhaps others also—would act as critic regarding the general presentation while it was still in manuscript form.

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SUGGESTIONS FOR ECOLOGIC INVESTIGATIONS IN VERTEBRATE ZOOLOGY[1]

IN a recent message transmitted to local administrators throughout the country praising them for their efforts during the war Food Administrator Hoover declared that the American people now "are summoned to a still larger task—to provision the Allies and the liberated nations of Europe, which face not their civilization together unless a steady stream of food supplies can be kept flowing to hunger alone, but the collapse of all that holds them to repair their gravest deficiencies, and in far greater volume than by utmost stress was sent last year."

As is well known to everyone, under the continuous and effective stimulus of the United States Department of Agriculture there has taken place a speeding-up process on the farms throughout the nation, a process which must apparently be continued and even augmented if we are to succeed in our wrestlings with the problem of world food shortage.

It is obvious that one very practical way in which to increase food production is to cut down the losses due to plant or animal pests. The department has addressed itself with extraordinary vigor to this problem and a comprehensive program in pest control is being administered by the different bureaus. That portion of the program concerned with reduction of losses due to rodents and other mammalian or bird pests devolves upon the Bureau of Biological Survey.

Current estimates place damage done to the carrying capacity of the open range and to cultivated crops generally by rodents in the western states at $300,000,000 annually. Add to this the destruction of live stock by predatory mammals, estimated at some $20,000,000 every year, and the damage done to goods in warehouses and stores throughout the United States by rats and mice, an additional $200,000,000, and we have an impressive total. Particular interest attaches to these figures at this time in view of the comprehensive plans for the reclamation of arid and other lands in behalf of returned soldiers recommended by the Secretary of the Interior and given favorable mention by the President of the United States in his latest address to Congress. Potential or actual rodent pests exist on nearly every acre of the arid land which it is proposed to reclaim. In some sections effective

[1] Read before the Ecological Society of America, Johns Hopkins University, Baltimore, December 28, 1918.

rodent control will be an absolute prerequisite to successful dry land agriculture.

Important as this side of the work undoubtedly is, the destructive or pest-control aspect of the work is not the only one to which attention is given. Constructive measures under consideration include such items as game protection, with its multitudinous perplexities, biological and legislative; further domestications of wild species, as ducks and other game birds, deer, elk, buffalo and fur-bearing mammals; possible use for food of available wild animals not now so utilized; artificial stimulation and increase of beneficial wild species of birds and mammals; introduction and acclimatization of birds and mammals; administration of bird and mammalian resources of zoological parks, national forests, game preserves, bird reservations and national parks.

It will be readily realized that problems of extreme difficulty arise in connection with both the program of pest eradication and that of the development and increase of beneficial species, problems the solution of which depends upon a much more adequate knowledge of and control of the balance of nature than man has yet been able to acquire.

Years ago Spencer F. Baird called attention to the fact that the only rational basis for fisheries administration is the complete knowledge of aquatic creatures to be acquired by intimate investigation. He emphasized the fact that it would be of doubtful value to study only the major forms which supported fisheries and that "useful conclusions must needs rest upon a broad foundation of investigations purely scientific in character." This generalization applies with at least as much force to the terrestrial vertebrate fauna as it does to fishes. With this thought in mind, the Biological Survey has for more than thirty years been carrying forward investigations in North America dealing primarily with the geographical distribution and habits of birds and mammals.

It seems to be clear that this work should not only be continued but should be expanded; and that expansion may well take place in the direction of a more intensive investigation of the relation of animal to environment on a dynamic as well as static basis.

The expansion of ecologic activities by the Biological Survey and other agencies engaged in biologic researches does not, of course, exclude the prosecution of the faunal natural history investigations. On the other hand work in ecology implies a fairly thorough knowledge of faunas and floras. It is not unlikely that new methods of the ecological type may be utilized profitably in connection with natural history surveys. In addition to this the ecologic point of view should be tried out in the interpretation of distributional data.

As compared with the plant ecologist, the animal ecologist is working at a considerable advantage. Though many problems of method and approach peculiar to the animal side of the work are bound to present themselves, much of the way over which the animal ecologist must go has been traversed already by his botanical colleague; and by virtue of this fact it should be possible for him to avoid many missteps and false leads. Instrumental studies of the environment have been carried forward to a very considerable extent by the botanist, thus relieving the zoologist of some, at least, of this fundamental labor. Furthermore, many of the guiding principles for research work in plant ecology, already enunciated by the botanist, can be adapted to the field of animal ecology.

Of course, with animals, the factor of mentality introduces a host of new problems into the study which are almost wholly lacking with plants. To a certain extent the new difficulties resulting from this factor neutralize the advantages derived from the fact that the botanists have done pioneer work.

The comprehensive demands of the ecologic program peculiarly emphasize the desirability of cooperative effort. The association of individual investigators who are specialists in botany, chemistry, geology and meteorology, as well as in zoology, will often be necessary to the adequate organization of the work; and it may often be advantageous for institutions as well as individuals to work together. It is

obvious that many universities and colleges, by virtue of their locations and resources, have abundant opportunity to perform valuable work in the ecology of vertebrates.

Although for some of the more detailed researches in the physiology, chemistry, habitat relations and psychology of animals a considerable amount of apparatus is necessary, investigations of the highest importance may be carried forward with relatively simple equipment. The field is sufficiently comprehensive to afford promising opportunities to any sincere and resourceful student with proper training.

Suggestions as to equipment needed in the different lines of work indicate the wide latitude of choice open to the prospective investigator. For the prosecution of field work there should be provided camp outfit, traps and collecting materials, photographic apparatus, balances and if possible, equipment for field study of habits, such as shovel, axe, trowel or large spoon, brush cutter, tape-line, sketch pad, coordinate paper, and writing materials. For more detailed study of the habitat apparatus such as thermometers and thermographs, wet-bulb thermometers and psychrographs, rain gauges, geotomes, etc., are required. Investigations of the chemistry and physiology of the animals in question call, of course, for special equipment; and in connection with many of the studies it is necessary to provide some cages, pens, yards or other enclosures for breeding and keeping terrestrial vertebrates under close observation.

The richness and attractiveness of the field may be amply demonstrated through the simple device of a tentative program of work.[2] It is fully realized, I may add, that a program of research may be outlined with comparative ease, but that it is often relatively difficult to get results. But the drawing up of this program, embracing, as it does, material for many investigations, is doubtless justified in that it indicates the immensity of the field, implies the necessity for widespread cooperation in the exploration of its resources, and points out some comparatively neglected fields of research in vertebrate zoology which are full of promise.

I. Close analysis of the animal community.
  1. Community reactions.
    (*a*) Origin.
    (*b*) Migration.
    (*c*) Invasion and reinvasion.
    (*d*) Establishment.
    (*e*) Competition.
    (*f*) Dominance.
    (*g*) Extinction.
  2. Primary and secondary succession in the animal community.
    (*a*) Primary succession as illustrated by zonation in selected localities.
      (1) In deserts.
      (2) In areas of moderate humidity.
      (3) In regions of excessive humidity.
    (*b*) Secondary succession as illustrated by results of interference with the natural balance by man.
      (1) Permanent changes in animal population.
      (2) Reinvasions of abandoned areas.
      (3) The animal assemblages of over-grazed areas; of areas denuded by deforestation; of forest burns; of flooded areas; of drained areas; of reclaimed areas in general.
    (*c*) Climax assemblages of animals.
      (1) Significance for game protection.
      (2) Significance in animal control.
    (*d*) Factor control of distribution and succession among animals.
      (1) Physical factors.
      (2) Biotic factors.
  3. The animal community and climatic cycles.
    (1) Interrelations with forest reproduction.

[2] I am indebted to Dr. Frederic E. Clements, of the Carnegie Institution of Washington, for helpful suggestions in this connection.

(2) Interrelations with forage production on the open range.
(3) Interrelations with crop production.
(4) Climate and fluctuations in animal populations.

II. Analysis of relation of individual animal to its environment.
1. Breeding habits.
2. Migration.
3. Hibernation and estivation.
4. Nests, shelters and other structures.
5. Interrelationships of species.
6. Adaptation of particular life forms to the environment.
7. Controlled investigations.
(1) In the laboratory.
(*a*) Behavior.
(*b*) Food.
(*c*) Adaptation and response.
(*d*) Domestication.
(2) In the field.
(*a*) Fenced areas for special study, *e. g.*, of damage done to forage.
(*a*) Rodent inclosures; exclosures.
(*b*) Eradication plots; reinvasion plots.
(*c*) Census and burrow investigation areas.
(*d*) Reseeding plots.
(*b*) Comparison of animal responses in different measured habitats.

III. Analysis of broad movements of animal populations through time.
(1) The paleontologic record.
(2) Present distribution.
(3) Relationships of animals to the envirments of the past.
(4) Successional communities of animals.

IV. Analysis of data of geographical distribution of higher vertebrates.
1. Realms, regions, life zones, faunal areas, formations, associations, animal communities in general.

V. Economic aspects of analysis of the animal community.
1. Animals and products of the farm.
(1) Rodents and crops.
(2) Relation of birds to agriculture.
(3) Predatory animals and the stock industry.
(4) Economics of fur bearing animals.
2. Animals and reforestation.
(1) Effect of rodents on natural or artificial seeding.
(2) Big game and the forest.
(3) Birds and insect tree enemies.
(4) Animals and forest burns.
(5) Animals and logged over areas.
3. Animals as related to the grazing problem.
(1) Effects of rodents on carrying capacity of the range.
(2) Elucidation of the relations of cattle, sheep, goats, big game, predatory animals, rodents and plants in the disturbed conditions now prevailing on the open ranges of the West.
(*a*) Comparison with conditions in northern Africa, Europe, Asia, Australia.
(3) Permanent vegetative changes produced by the unrestricted grazing of cattle and rodents, and their significance from the standpoint of range maintenance and the future maximum productivity of the land.
4. Further domestications of wild species of animals.
(1) Ducks and other game birds.
(2) Deer and elk.
(3) Fur bearing mammals.
5. Statistics of animal economics.
(1) Estimates of numbers of rodents and other mammals and birds of economic significance in different types of country.
(2) Estimates and determinations of extent of different types of country in the United States.
(3) Estimates of benefits or losses conferred by different species of vertebrates.
(*a*) As individual animals.
(*b*) Aggregate for species as a whole.
(4) Estimates of total losses from rodents and other harmful mammals in the United States.

(5) Estimates of cost of complete control of noxious species, together with amount of probable saving that would result.

6. Beneficial animals and their preservation.
   (1) What animals are beneficial?
   (2) Relation of age of species to problem of its preservation.
   (3) Effect of occupation by man on animal community.
   (4) Essentials for conservation.
      (*a*) Maintenance of seed-stock; determination of annual toll permissible; unfair methods of destruction; effect of legislation on game conservation.

7. Noxious animals and their destruction.
   (1) What animals are noxious?
   (2) Methods of control; rodents, predatory animals, other groups.
   (3) Effects of extirpation of wild species on the natural balance.

By way of summary, may I repeat that present day world politics emphasize in unmistakable terms the vital necessity of increase in food production. For permanent increase in the productivity of the land further study is called for of the scientific fundamentals on which agricultural practise is based. The ecologic method of approach promises much of value. The problems are vast and lead inevitably to the stressing of the strategy of cooperation as an essential to their successful solution.[3]

WALTER P. TAYLOR
BIOLOGICAL SURVEY

[3] The symposium on the relations between government and laboratory zoologists held in connection with the meeting of Section F at the sessions of the American Association for the Advancement of Science, Johns Hopkins University, Baltimore, December 28, 1918, emphasized the desirability of better coordination and cooperation between these two large and active bodies of scientific investigators. In this connection the Bureau of Biological Survey solicits correspondence from all who contemplate researches in the ecology of the higher vertebrates, and will be glad to assist with suggestions, advice, or otherwise as opportunity may be given.

THE ATTAINMENT OF HIGH LEVELS IN THE ATMOSPHERE

IT is a far cry from January 7, 1785, to February 27, 1920. On the earlier date Dr. John Jeffries ascending from the cliffs at Dover, made his way through the air over the English Channel to France, landing after an eventful three hours, on the French coast in the forest of Guines.

During the flight his barometer ranged from 1,006 kilobars (29.70 inches) to 789 kilobars (23.30 inches) indicating at the lower reading a height of nearly 2,012 meters (6,600 feet).

On Friday, February 27, this year, Major R. W. Schroeder, chief test pilot of the Air Service, rose from McCook Field at Dayton, Ohio and reached an elevation of 10,979 meters (36,020 feet).

Jeffries of course used a balloon; Schroeder an airplane designed for climbing, and with a supercharger, *i. e.*, a gas turbine centrifugal compresser to offset the loss at the carbureter due to diminished density of the air at such heights.

The history of the attack upon the high levels of the atmosphere may then be said to extend over a period of one hundred and thirty-five years. Various methods and agencies have been employed. Within twenty years from the time of the first ascension, heights of 4,000 meters had been attained. Indeed Gay-Lussac made certain scientific observations at a height of 7,400 meters in 1804.

On September 5, 1862, Glaisher and Coxwell reached a height of 11,200 meters or practically the same level as that reached by Schroeder with an airplane. Three other noteworthy records by manned balloons are those of Tissandier, Spinelli and Sivel, acting for the French Academy, who reached a height of 8,530 meters, on April 15, 1875; Dr. A. Berson who on December 4, 1894, reached 9,600 meters; and later (1901) Berson and Süring to a known elevation of 10,500 meters and probably 10,800 meters, both men being unconscious at the higher level. In all of these high balloon flights, the observers became unconscious, and this even in the