PROJECTED ASSESSMENT OF NEW PHYSIOLOGICAL INDICATORS OF POPULATION CONDITIONS IN DEER

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Christian, Flyger and Davis (1960) found the adrenals of Sika deer on James Island, Maryland, to be larger during a year of maximal population density during which a population crash occurred than in years immediately before or after. Similiarly, Welch (1962) reported the adrenals of White-tailed deer in North Carolina to be larger on a densely populated management area than on a sparsely populated one during the same hunting season, and to increase with increasing population density from one hunting season to the next on a single management area. These studies with deer follow upon numerous studies conducted in the laboratory and in the field with various species of animals in which the adrenal glands have been found to hypertrophy as population density increased (see Christian, Lloyd and Davis, 1965, for review).

There are sound basic endocrinological reasons for thinking that, in general, the increases in adrenal weight which occur with increased population density are indicative of increased functional activity of the adrenal cortex in secretion of its steroid hormones. It is well known that large sustained increases in the level of glucocorticoid releases from the adrenal cortex may result in an adaptive increase in its size. Where careful histological studies have been made of adrenals from animals in different sized populations and where the rate of formation of adrenal steroid hormones from their precursors have been determined in *in vitro* incubations, the results have supported an interpretation of an adaptation to increased secretion in the adrenals from the higher density populations.

It is also likely that functional increases in the activity of the adrenal cortex with increases in population density are paralleled by increases in the basal level of secretion of the catecholamines, adrenaline and noradrenaline, from the adrenal medulla. Christian interpreted his histological studies of adrenals from Sika deer during the year of overpopulation to be indicative of hyperactivity of the adrenal medulla; and increases in adrenal medullary content of catecholamines suggestive of increased secretion of these hormones was found to parallel the increases in adrenal weight occurring in high density populations of white-tailed deer in my studies conducted jointly with officials of the North Carolina Wildlife Resources Commission (in preparation).

When the basal level of secretion of the hormones from the adrenal cortex and the adrenal medulla is increased it can be predicted from the known metabolic effects of these hormones that the general health of the animal and the function of virtually every metabolic process will be importantly affected as well. Resistance to disease will be decreased; utilization of food will be poorer; less new protein will be made and more will be broken down; a higher level of lipid will likely be maintained in the circulation; blood pressure will tend to be higher; and reproductive condition and lactation will be impaired. It is useful, therefore, for game managers and others who have a scientific interest in the condition of deer populations to know when such changes are occurring.

Granted that it is useful to know if the basal level of secretion of the adrenal hormones is going up or going down in the average animal of a population, the practical question becomes, "What are the most reliable and economically feasible measures to make in order to assess the trend of the pattern of physiological responses associated with increased adrenal function in a population of wild animals?" Not only should the measures be relatively uncostly and amenable to rather straightforward and clearcut interpretation once they are obtained, but they should be simply enough obtained for it to be practical to collect from large numbers of animals under field conditions, preferably, by relatively inexperienced personnel.

Adrenal weight is not such an indicator. While an increase in adrenal weight is generally indicative of increased activity of the gland in secreting adrenalcortical hormones, it is also true that a rather substantial increase in hormone secretion may occur without a detectable increase in weight of the gland. In other instances of most severe increases in demand for adrenal hormone secretion, the gland may fail to adapt and its weight may actually *decrease.* It is too expensive and too slow to make histological sections of adrenals for routine assessment of populations conditions and, indeed, a professional pathologist would be needed to properly evaluate them. Although chemical analyses can be made of the adrenaline and noradrenaline content of adrenals, the meaning of the catecholamine content of the gland is not subject to unequovical interpretation. It would be well to have better indicators of the physiological condition of animals within populations than the weight of adrenals and their content of adrenaline and noradrenaline.

My purpose today is to suggest the possibility of measuring the activity of certain liver enzymes which are specifically induced by adrenal hormones as indices of the level of secretion of these hormones from the adrenal into the bloodstream.

Enzymes, of course, are the protein molecules that do the work of converting one chemical compound into another in the body. Enzymes like all other proteins are in continual turnover; the amount of an enzyme actually present at any given time is the result of a balance between the process of new formation and degradation. Although not widely recognized by ecologists, it is now well established that the amount of active enzyme available for conducting a given reaction in the body is not constant. Instead, the levels of enzymatic activities vary in an adaptive manner as part of the over-all physiological adaptation that an animal makes to a changing environment.

Enzymes can be *induced* to increase in animal tissues by two principal means: (1) By increasing the amount of substrate available on which the enzyme may act. (2) By increasing the amount of a hormone or other metabolites which directly causes more of the enzyme to be made.

Of particular interest for our purposes are a group of transaminase enzymes in liver which are specifically induced by glucocorticoids from the adrenal cortex. All of you have heard of the "protein catabolic" effects of adrenal steroids. These are the liver enzymes which break down the amino acids that fail to be incorporated into protein or that are freed from protein when it is broken down as a result of increased adrenalcortical secretions (Knox et al., 1956; Knox 1963; 1964; Kenner and Flora, 1961; Rosen et al., 1963). The enzyme which has been most carefully studied in this regard has been tyrosine-alpha-ketoglutarate transaminase. This enzyme may demonstrate up to a twenty-fold increase in activity within five hours after a dose of hydrocortisone or cortisol in the laboratory rodents in which it has been extensively studied. Although tyrosine-alpha-ketoglutarate transaminase does vary more-or-less directly with the level of hormonal stimulus, it is probably not suitable for our purpose because of the rapidity with which it changes in response to a change in hormonal secretion. If we are interested in an indicator of the *basal level* of hormonal secretion elicited by the level of environmental stimulation under which the animal lives, we cannot use an enzyme which varies with every minor pertubation. It must be comparatively stable and slow to respond to changes in hormone content of the plasma.

Alanine-alpha-ketoglutarate transaminase is much more slowly induced, requiring over 48 hours to attain its maximal increase after a large non-physiological dose of cortisol (Rosen et al., 1963). It is specifically induced by glucocorticoids in the animals in which it has been studied and is not apparently induced by substrate, alanine. This enzyme and other transaminases, some of which may prove to be even better indicators of the *basal level* of adrenalcortical activity need to be systematically studied in deer and in other wild animal populations.

When such an enzyme is investigated we should seek to learn:

1. The degree of its dependence upon the hormone which we think it is dependent upon for its induction, and accordingly the degree of its independence of substrate induction, if the hormone itself is not the substrate.

2. The linearity of the relationship between hormone secretion and induced enzymatic activity.

3. The *time-rate of increase and decrease of the enzyme activity* with increases or decreases in environmental stimulation to hormone secretion.

4. The natural seasonal rhythm of variation in enzymatic activity.

5. The relative effects of food shortage and other nutritional factors upon enzyme as compared with the effects of social competition or social stimulation.

At first approximation it may appear to be disadvantageous in using enzymes as indicators of adrenal activity that they should be expected to vary with the season, with sexual cycles and with food deprivation. But the endocrine secretions themselves vary in this manner, and it is most likely that the enzymes will only reflect changes in adrenal secretion caused by seasonal changes, by the sex cycle, and by food deprivation. We must describe and understand the natural and predictable changes which occur and learn to "read" the effects of unusual factors superimposed upon them.

Some of the advantages of using enzymes assays for population studies may be:

1. The simplicity and ease of obtaining a small piece (3-5gm) of liver from animals in the field without the need of gutting them.

2. The fact that autolytic changes in such enzymes should not occur as fast as they occur in the substrate. Tissues will probably be acceptable up to two or three hours after death of the animal.

3. Once the enzyme of greatest indicator value is selected, it should be possible to standardize a simple routine, but reliable, colorimetric assay procedure which a technician could use for the assay 50-100 samples in a day.

4. The indications of hormone activity thus obtained will be many times more sensitive than the weight of the adrenal glands as an indicator of adrenalcortical secretion. Also, they will be independent of the dual interpretation which may be given small adrenals as being indicative of either a low level of stimulation or overstimulation with consequent exhaustion of lipid.

The liver enzymes monoamine oxidase and catechol-O-methyltransferase, which serve to catabolize adrenaline and noradrenaline, apparently may also increase in activity with increases in the amount of these hormones available for them to act upon in the bloodstream (Nukeda et al., 1962; Wurtman and Axelrod, 1963). However, very little to no systematic information is presently available concerning the active inductive response of these enzymes to different basal levels of catecholamine secretion. Information on their inductive responses needs to be obtained. If these enzymes prove to be sufficiently stable to serve as good indicators of the basal level of catecholamine secretion it will be possible to analyze for them in the same piece of liver as that used for the assay of transaminase enzyme activity.

When we develop such simple and reliable means for detecting trends in the level of adrenalcortical and adrenal medullary activity within populations we shall have a powerful tool for furthering our understanding of the natural mechanisms regulating population growth. Accordingly, we will be better equipped to scientifically manage our deer herds and other populations to produce an optimum number of healthy individuals in proper balance with the offerings of their environment.

Preliminary studies directed to this end have begun at the Laboratory of Population Ecology.

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TEN YEARS' CONTROLLED HUNTING ON LOUISIANA'S WILDLIFE MANAGEMENT AREAS

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INTRODUCTION

The Fish and Game Division of the Louisiana Wildlife and Fisheries Commission manages the wildlife on 739,491 acres for public hunting. This acreage is in 28 different hunting areas varying in size from 1,200 to 105,000 acres. The topography varies from the pine-hardwood hills, to Mississippi delta hardwood bottom lands, to coastal marsh near the Gulf of Mexico. Every vegetative type of Louisiana is represented on some of the Management Areas except the southwest prairies and the coastal cypress swamp.

Whitetail deer is the major game animal, with squirrel, water fowl, quail, mourning doves, rabbits, and turkey, in order of importance. The oldest management areas were set up in the late forties primarily for deer. All hunting was prohibited to aid in a speedy build up of the deer herd. This was the beginning and the backbone of Louisiana's deer herd rehabilitation program. From the beginning the objective was to establish, through restocking, a deer herd, build it up to huntable numbers, manage and control these herds through public hunting. The general public from the beginning thought of these areas as refuges where deer herds would build up and overflow on the