Non-predaceous visitors

Several insects were associated with the plant that were obviously not predators on the aphids. Some of these, such as Diptera, were attracted to the spilled honeydew that was trapped in the tomentose surface of the Cirsiun plant. Some of these flies (Orellia occidentalis Snow, Diptera, Tephritidae and Eupeodes volucris D.S., Diptera, Syrphidae) were visiting the plant long before any of the flowers had opened. These were observed to move among the aphids on the leaves and the stems but no actual observation of their taking honeydews was noted. They proved to be radioactive before the flowers opened, thus establishing a relationship that had not been observed before. That is, these flies come to the source of honeydew and take it up directly from the surface of the leaves where it has been spilled by the aphids.

After the flowers had opened, a number of pollinating insects were observed in the vicinity, and some of these were captured and their radioactivity counted. It was found that some small bees (Halictus sp., Hymenoptera, Halictidae) and a small wasp (Xylocclia sp., Hymenoptera, Sphecidae) contained 10 to 171 cpm. of radioactivity.

Flowers that were tested indicated that the pollen contained considerable radioactivity, possibly because of the large quantities of nucleo-proteins in which the phosphorus would be incorporated. After removing the pollen and stamens, these flowers were centrifuged for 20 minutes at high speed. Although the liquid nectar in the base of the tube was determined by microscopic analysis to be virtually free of pollen, it was also found to be radioactive. Thus, pollinating insects, and nectar-seeking insects, can be traced from source of origin to various other locations by means of radioactive labeling of the plant proper.

Conclusions and Summary

From this study, it is apparent that determination of the phytophagous insect/predator complex and plant pollinator relationships by labeling a plant with radioactivity is a much more accurate ecologic technique than observation alone. This method can be utilized as a refined technique in the verification or rejection of many conjectural concepts in economic entomology. It establishes a method which is simple yet extremely accurate and safe. It is entirely possible that hundreds of investigations can be made this way, each utilizing a different species of plant and thereby revealing the various insects associated with it.

Second, this offers a new method for examining territoriality in insects and possibly it could be applied to the determination of territoriality in vertebrates.

Third, the method offers a clue to the largely unanswered pollination relationships that exist in crop plants as well as in indigenous plants. By this method, the economic importance of various types of insects could be established and the total effective range of the activity and the specificity of various insects could be investigated.

In agriculture, the method offers a possible means of testing the total amounts of tissue or total amounts of plant saps taken by insect pests.

Finally, this method opens up a new field for the entomologist who is concerned with the more intimate relationships between a given species of plant and its insect and vertebrate visitors.

References


Relation between Circulation and Planktonic Populations in Estuaries

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Introduction

The study of planktonic populations in estuaries is complicated by the continuous movement of the water. The tides move the water back and forth, so that at a given location the population at low tide may be quite different from that present at high tide. In addition to the obvious flood and ebb tidal movements, the water masses have a net motion which results from inequalities of the tidal movements. The seaward drift of the diluted water must be adequate to remove the fresh water constantly added to the estuary from the rivers.
The landward drift of more saline-water must supply enough sea water to maintain the salt balance by bringing into the estuary an amount of salt equal to that entrained with the fresh water. It is obvious that planktonic populations will be distributed throughout the estuary by these water movements.

If the circulation were the only process influencing the size of the population throughout the estuary, the problem would be very simple. For a population originating in the seaward end of the estuary the expected distribution would be directly proportional to the salt content of any water sample. If the population originated at the fresh water end of the estuary its distribution would be proportional to that of the fresh water, i.e. inversely proportional to the salt content. These simple relationships are never found because the population grows or dies within the estuary, and frequently the reproduction rate or the death rate is very different in different parts of the estuary.

The rates of reproduction or of death of a planktonic population within the estuary can be derived only when the rate of circulation is taken into account. It is the purpose of this paper to indicate how this may be done, and to illustrate how the circulation may impose minimum requirements for the rate of reproduction of a population if it is to survive within the estuary.

**Theoretical Considerations**

A basic assumption in the analysis is that the populations considered are distributed at random by the same processes that control the distribution of fresh and salt waters. The distribution of populations which exhibit vertical gradients, by means of vertical migrations for example, may be unpredictable by these methods. High concentrations of the population in the surface, fresher water would result in more rapid dispersion than the average, since this is the route by which the fresh water escapes seaward. High concentrations in the deeper, more saline water, which is the location of the landward counterdrift, would result in a slower dispersion than the average. Since vertical distribution may vary with time, and vertical migrations may be diurnal in character, and thus out of phase with the flood and ebb of the tide, generalizations concerning the distribution of such populations are not attempted in this paper.

The net result of the circulation in each estuary must be to move seaward, across any complete cross section, during each tidal cycle, a volume of fresh water equal to that introduced by the river during the same period of time. It has been shown that, for selected segments of an estuary, an exchange ratio can be defined as the proportion of the water which moves seaward and does not return on a following flood tide. This same proportion of any planktonic population must also be lost downstream. There is, thus, a constant drain on the population, and enough new individuals to balance this drain must be produced if the population is to maintain itself.

Let us first consider the case of an endemic population, by which is meant specifically a population which is maintaining itself within the estuary and is not receiving recruits from upstream or downstream during the tidal cycle. For such a population the standard growth equation and a simplified circulation equation can be combined. The growth equation is:

\[ P_t = P_0 e^{kt} \]  

in which \( P_0 \) and \( P_t \) are the size of the population initially and after time \( t \), and \( k \) is the coefficient of reproduction rate.

As a result of the circulation alone, the population remaining after being depleted by a series of tidal cycles is given by:

\[ P_m = P_0 (1 - r)^m \]  

in which \( m \) is the number of tidal cycles, and \( r \) is the exchange ratio, defined as the proportion of the water moving seaward during each tidal cycle, which does not return on the following flood tide (Ketchum 1951).

Expressing time in the growth equation in terms of tidal cycles, the combination then gives:

\[ P_m = P_0 (1 - r)^m e^{mk} \]  

If the population remains constant, \( P_m = P_0 \), and the growth rate required to balance the depletion by circulation can be defined in terms of the exchange ratio, i.e.:

\[ e^{mk} = \frac{1}{(1 - r)^m} \]  

or

\[ k = - \ln (1 - r) \]

This equation thus defines the rate of reproduction necessary to maintain a population in the estuary in spite of continuous depletion by the circulation. Obviously, if the rate of reproduction is greater than this value the population will increase; if less, the population will decrease.

The relative size of a population in a tidal segment of an estuary as a result of various growth rates is given in Figure 1. For this example an exchange ratio of 0.5 has been used. A similar pattern would be obtained for any other exchange ratio, except that the time scale would be changed. The numbers on the chart indicate the size which would be attained by the population if the circulation were not constantly depleting it. If the population did not reproduce at all it would de-
direct observations of the population in the water would indicate no change in population size. The other two lines in this figure indicate the net effect of a reproduction rate greater than, and less than, that required to balance the depletion by the circulation.

It is clear that organisms which can maintain a constant population in some estuaries may be unable to do so in other estuaries where the circulation is more vigorous. For each estuary the rate of reproduction required to maintain a population may be defined in terms of the appropriate exchange ratio, with the results shown in Figure 2. The line drawn in this figure indicates the rate of reproduction required to balance the depletion by the circulation, but does not, of course, indicate what any population will actually do in any estuary. If the growth rate is greater than that required, the population will increase; if less, it will decrease. The average exchange ratios for various estuaries are indicated on this figure.

Moriches Bay, on the south shore of Long Island, has a small exchange ratio and a population should be able to maintain itself with a very low rate of reproduction. In Barnstable Harbor, on the other hand, the tidal exchange is very great, and a population would have to increase rapidly to maintain itself. It is of interest that in the former estuary the population is endemic and characteristic, whereas in the latter the population is strikingly similar to that of the adjacent ocean water outside the limits of the harbor.

In every estuary there must be some region beyond which the organism considered is unable to grow, because of reduced salinity or some other unfavorable condition. The population in this region will not be augmented by new members from upstream, and the foregoing discussion will apply. For all parts of the estuary downstream, however, new members are being introduced into the population from upstream while other members are being carried downstream during each tidal cycle. To take account of both the increment to the population from upstream and loss downstream a different calculation is required. The derivation of the expression for this process has been given by Ketchum, Ayers, and Vaccaro (1952). It is based upon the combination of the equation for the steady-state accumulation of river water in a tidal excursion segment and the growth equation. The former is (Ketchum 1951):

$$Q_n = R \left\{ 1 + (1 - r_n) + (1 - r_n)^2 + (1 - r_n)^3 + \ldots + (1 - r_n)^m \right\}$$

(6)
in which \( Q_n \) is the quantity of river water accumulated in the \( n \)th tidal excursion segment, and \( R \) is the river water introduced to the estuary during a tidal cycle. The combined circulation and growth equation gives:

\[
P_n = (P_0) R \frac{R}{Q_n} \left( 1 + (1 - r_n) e^k + (1 - r_n)^2 e^{2k} + (1 - r_n)^3 e^{3k} + \ldots + (1 - r_n)^{m e^{nk}} \right) \tag{7}
\]

in which \( (P_0)_n \) is the increment of population to the \( n \)th segment during a tidal cycle, \( P_n \) is the steady-state level of population achieved as a result of a series of tidal cycles, and the ratio \( R/Q_n \) is the exchange ratio, \( r_n \). As the number of tidal cycles becomes large this series approaches:

\[
P_n = (P_0) e^{r_n} \frac{1 - (1 - r_n)^{m e^{nk}}}{1 - (1 - r_n) e^k} \tag{8}
\]

Let us consider what will be the result of such a regime within an estuary. Under these conditions a steady-state population level can be maintained with a variety of rates of reproduction rather than with one alone. For example, if the population did not grow at all within the part of the estuary under consideration the population would nevertheless tend to increase until it approached the size of the population being introduced from upstream, as shown in Figure 3. The rate of reproduction which is necessary to maintain a steady-state endemic population, as discussed above, will theoretically permit the population to increase indefinitely in a location where an increment from upstream is available. Since the reproduction of the population balances the depletion by the circulation, the population will increase by the amount introduced each tidal cycle. To be ecologically more precise, it could be stated that this rate of reproduction would permit the population to increase until crowding or some other factors operated to decrease the reproduction rate.

Any reproduction rate less than that required to maintain an endemic population will produce a steady-state population if increments are also being introduced from upstream. Positive reproduction rates will produce populations greater than the increment from upstream. Even a negative reproduction rate, or in other words an excess of death over reproduction, will permit the attainment of a steady-state population which,
April, 1954

CIRCULATION AND PLANKTTONIC POPULATIONS IN ESTUARIES

reason for this is that the population is present in the estuary for a shorter period of time if the exchange is great, and consequently the population is not so greatly depleted by death.

Reproduction Rates

The foregoing discussion has advanced the thesis that the circulation of the estuary defines the minimum rate of reproduction which will permit the existence of a population in an estuary. It is pertinent to inquire whether populations can be expected to grow at such rates.

For the micro-organisms which reproduce by simple division there is a wealth of information available. Among the bacteria the division rate may be very great and a single cell can, under favorable conditions, produce many thousands of offspring during the course of one tidal cycle. Bacteria can easily replace the depletion resulting from the exchanges if conditions for growth are suitable. Under unfavorable conditions, however, such as are encountered by pollution bacteria in estuaries, the population may fail to grow, or may die at an appreciable rate as a result of the bactericidal action of sea water and predation (Ketchum, Ayers, and Vaccaro 1952). In such cases the circulation has a pronounced effect on distribution.

Some reproduction rates which have been observed with phytoplankton populations are given in Table I. From these rates the relative size of the population after a complete tidal cycle, and the fraction of the population which can be replaced by reproduction during a complete tidal cycle have been computed. This fraction is a direct indication of how vigorous the exchange may be without depleting an endemic population within the estuary. In general it may be said that local phytoplankton populations may be expected to maintain themselves within estuaries where the exchange ratios are about 0.5 or less. Greater exchanges would tend to deplete the population more rapidly than it can reproduce itself.

Most animal populations do not reproduce by simple division, and one may be interested in considering the rate of production of one of the planktonic larval stages, or in the rate of reproduction of the population as a whole. A great deal of basic information is needed before generalizations about the effects of the circulation on various stages of the life cycle of animal populations can be made.

Clarke (1946) and Riley (1947) have analyzed the production of zooplankton populations over Georges Bank. They derive a maximum net production rate of about 5% per day. This is only

Fig. 3. The effect of the rate of reproduction on the relative size of a population which is being augmented by increments from upstream for various times, as tidal cycles, in a segment of an estuary having an exchange ratio of 0.5. The numbers indicate the size the population would have attained if it were not depleted by the circulation.

However, will always be smaller than the increment from upstream. The steady-state population size under these conditions is given by:

\[ p_n = \frac{(P_0)_n r_n}{1 - (1 - r_n)e^k} \] (9)

This simplification of equation (8) is valid only when \( e^k \) is less than \( 1/(1 - r) \).

It is clear from the foregoing statements that a single simple figure cannot be presented to describe conditions in an estuary where the population is both being augmented from above and decreased by losses seaward. A family of curves is presented in Figure 4 which relate the population size expected after a large number of tidal cycles to the rate of reproduction of populations for estuaries having various exchange ratios. All of the curves cross at a reproduction rate of zero and a relative population size of unity, indicating that the population is the same as that being introduced by the circulation during each tidal cycle. When the reproduction rate is positive, the population developed will be larger in those estuaries with smaller exchange ratios. If, however, the population is dying within the part of the estuary considered, larger populations will be obtained in estuaries having the larger exchange ratios. The

This conversion has been made only for the semi-diurnal tidal cycle of 12.4 hours.
about half as large as the minimum value given in Table 1 for phytoplankton populations.

Johnson and Olson (1948) have studied the reproduction of *Tisbe furcata*, a marine harpacticoid copepod. On the average, broods consisting of 57 eggs were produced at intervals of three days. In their experiments there was 80% survival. It can be concluded that two individuals of *Tisbe furcata* can produce 46 viable eggs every three days during the breeding season. The coefficient of the "rate of production" of eggs calculated from these values is 0.522 per tidal cycle, and the fraction of eggs replaced each tidal cycle is 0.406. This is comparable to the rate of reproduction of phytoplankton populations. Johnson and Olson found that the brood of *T. furcata*, however, required between 15 and 31 days to reach maturity. The coefficient of the rate of reproduction of the population as a whole is only 0.106 per tidal cycle for a generation time of 15 days, or about half of that rate for a 31 day period. Thus five to ten per cent of the population can be replaced each tidal cycle.

These estimates of the rate of reproduction of animal populations are admittedly sketchy, but they do indicate, on the whole, that such populations reproduce more slowly than the phytoplankton and are thus less capable of maintaining a unique, endemic population in the upper reaches of the estuary. The planktonic larvae may, however, exhibit vertical migration which could greatly modify their distribution and the effects of the circulation. It would be easy, for example, to postulate that the larvae have a tendency to migrate downwards away from the light and into the more saline water. This would place them in the counterdrift and transport them up the estuary. Such a migration would clearly lead to a higher concentration of the larvae than is calculated from the exchanges of river water. Altogether too little is known about the physiology and rate of production of various stages of the larvae and rate of reproduction of the population as a whole to permit any definite conclusions concerning the importance of the circulation in their life cycle.

**APPLICATION TO NATURAL CONDITIONS**

From the foregoing theoretical considerations it appears that different sorts of populations may be expected in natural estuaries solely as a result of the vigor of the circulation. A few examples may serve to clarify the general application.

An endemic phytoplankton population, consisting of small chlorophytes, develops year after year in Moriches Bay, Long Island, New York (Fig. 5). During the summer months these algae are the predominant members of the phytoplankton population within the bay, though they are rare or absent in nearby waters. The bay is heavily fertilized by drainage from duck farms around the banks of the tributary rivers.

The circulation is slow, and only about 12% of the volume of water present in any tidal excursion segment is exchanged during a tidal cycle. For the bay as a whole the rate of exchange is only about a tenth of this value.

Ryther (1954) has shown by physiological experiments on pure cultures of these algae that they are uniquely suited to grow under the conditions found in Moriches Bay. They are able to grow in nearly fresh water, and optimum growth was obtained in salinities indicative of about 50% sea water. The temperature of the bay water is at or near the optimum (25° C.) for their growth most of the summer. The proportion of phosphorus to nitrogen in the duck farm wastes is close to the optimum ratio for these species.

This is clearly a case of rapid multiplication of a population which is uniquely adjusted to the ecological conditions which exist in the upper, less saline part of the estuary. The slow rate of the circulation permits the accumulation of a large population which is thus placed in a favorable competitive position and maintains superiority in numbers over large areas.

The effect of a rapid circulation on the dispersal of planktonic larvae may be inferred from investigations which have been made in Barnstable Harbor, Cape Cod, Mass. (Fig. 6). As shown by Ayers (unpub.) the exchange ratio for each tidal excursion segment is about 0.9, and for the harbor as a whole the rate of exchange is about one third of this value. The brackish-water planktonic

### Table 1. Some reproduction rates of Phytoplankton populations.

<table>
<thead>
<tr>
<th>Population</th>
<th>Time to double</th>
<th>Coefficient of reproduction rate</th>
<th>Relative popula tion after tidal cycle</th>
<th>Fraction replaced per tidal cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytoplankton 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>minimum</td>
<td>7.5</td>
<td>0.06</td>
<td>0.047</td>
<td>1.05</td>
</tr>
<tr>
<td>maximum</td>
<td>0.67</td>
<td>1.03</td>
<td>0.53</td>
<td>1.70</td>
</tr>
<tr>
<td>mean</td>
<td>1.38</td>
<td>0.50</td>
<td>0.26</td>
<td>1.30</td>
</tr>
<tr>
<td>Phytoplankton 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>minimum</td>
<td>1.50</td>
<td>0.46</td>
<td>0.24</td>
<td>1.27</td>
</tr>
<tr>
<td>maximum</td>
<td>0.75</td>
<td>0.02</td>
<td>0.48</td>
<td>1.62</td>
</tr>
<tr>
<td>mean</td>
<td>1.12</td>
<td>0.02</td>
<td>0.32</td>
<td>1.38</td>
</tr>
<tr>
<td>Cultures</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biddulphia</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>minimum</td>
<td>0.42</td>
<td>1.05</td>
<td>0.86</td>
<td>2.36</td>
</tr>
<tr>
<td>maximum</td>
<td>0.005</td>
<td>1.14</td>
<td>0.50</td>
<td>1.81</td>
</tr>
<tr>
<td>mean</td>
<td>0.38</td>
<td>1.10</td>
<td>0.62</td>
<td>1.86</td>
</tr>
</tbody>
</table>

1 Riley et al. 1949; 2 Harvey et al. 1955; 3 Gran 1927; 4 Jenkins 1937; 5 Ketchum & Redfield 1938.
forms, therefore have very little opportunity to establish dominance, since they would have to multiply at enormous rates in order to maintain the population. It is not surprising, therefore, that in this location the planktonic population is similar to that of the adjacent ocean waters.
One of the interesting problems in Barnstable Harbor is that the clam population has decreased to negligible proportions and, as shown by Turner (1949, 1950), efforts to re-establish it have been largely unproductive. According to Belding (1930) a pair of two and one half inch clams can produce about three million larvae, which have a pelagic life of about fourteen days or twenty-eight tidal cycles. From the average exchange ratio of Barnstable Harbor as a whole (0.30) is can be calculated that, as a result of circulation alone, neglecting larval mortality, about 150 spat would be the most which could remain for each pair of clams. Ayers (unpub.) has concluded that mortality between spatfall and maturity alone would leave less than one mature clam annually to replace the population, and considering the possible decimation of larvae by predation and mortality it is not surprising that only rarely indeed is a substantial set obtained.

The distribution of coliform bacteria in the Raritan River estuary is an example of the changes in a population which is both augmented and depleted by the circulation, while being subject to biological changes. In this case the population is introduced at the freshwater end of the estuary at a high level and a nearly constant rate by the sewage effluents of the city of New Brunswick and other municipalities upstream. Because of the bactericidal effect of sea water, which was measured under laboratory conditions independently, and of the predation resulting from the zooplankton population in the river, we could account for more than 99% of the observed decrease (Ketchum, Ayers, Vaccaro 1952). A correct interpretation of the observed distribution could be obtained only when both the biological processes and the circulation were taken into account.

The final example is drawn from the unpublished work of Barlow (1952) who has studied the zooplankton population of a small estuary, Great Pond, near Woods Hole, Mass. (Fig. 7). Barlow observed that Acartia tonsa was apparently endemic in the estuary during the early summer, since maximum numbers of both nauplii and copepodid larvae were found near the head of the main pond where the salinity was about 10-20 parts per thousand. These populations were maintained at high concentrations for weeks in spite of the continuous depletion by the circulation.

The rate of production of these larvae was calculated from the natural distribution by equation 8, and was also determined from experiments in which samples of the water were isolated from the circulation in several 5-gallon jugs which were re-suspended in the estuary. Throughout most of the estuary the rates of production of both nauplii and copepodid larvae as determined by the two independent methods were in close agreement. Both sets of data showed a decrease in the rate of production of larvae with increasing salinity. In the part of the estuary where the salinity was about 10 parts per thousand the production rates indicated that the population of larvae could dou-

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Fig. 6. Barnstable Harbor on the North Shore of Cape Cod, Mass. The mean tidal range is eleven feet, and the average exchange ratio is 0.9.
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deeper
water
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The
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are,
of
course,
only
stages
in
the
development
of
*Acartia
tonsa*.
The
rates
of
production
depend
on
the
rate
of
production
of
eggs
by
the
adult
and
the
rate
of
their
development.
The
negative
values
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the
saltier
parts
of
the
estuary
are
not
necessarily
indicative
of
mortality,
since
similar
results
could
be
obtained
because
of
the
metamorphosis
of
the
nauplius
to
the
copepodid
and
of
the
copepodid
to
the
adult.
The
importance
of
these
observations
is
that
Barlow
has
shown
that
production
rates
derived
from
observed
distributions
in
an
environment
complicated
by
an
active
circulation
of
water
are
comparable
to
the
rates
obtained
in
a
similar
environment
isolated
from
the
circulation.

**Summary**

1. The
rate
at
which
a
planktonic
population
must
reproduce
in
order
to
maintain
itself
in
an
estuary
is
determined
by
the
vigor
of
the
circulation.
The
reproduction
rate
required
for
an
endemic
population
is
defined
in
terms
of
an
exchange
ratio
determined
as
the
proportion
of
water
escaping
seaward
each
tidal
cycle.

2. If
a
population
is
augmented
from
upstream
as
well
as
depleted
by
the
circulation,
the
steady-state
population
will
be
achieved
at
a
level
determined
by
the
rate
of
reproduction
and
the
rate
of
the
circulation.
A
method
for
determining
the
size
of
the
population
expected
under
various
conditions
is
presented.

3. Examples
of
the
application
of
these
calculations
in
various
estuaries
are
presented
for
a
bacterial
population,
a
phytoplankton
population,
the
planktonic
larvae
of
a
sedentary
population,
and
larvae
of
a
zooplankton
population.

**References**


EFFECTS OF MODERATE GRAZING ON THE COMPOSITION AND
PLANT PRODUCTION OF A NATIVE TALL-GRASS PRAIRIE
IN CENTRAL OKLAHOMA

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The composition of the tall-grass prairie in Oklahoma has received some attention from investigators. Bruner (1931) described the true prairie of Oklahoma, listing *Andropogon scoparius*. A. gerardi, *Bouteloua curtipendula*, *Agropyron smithii*, and *Sporobolus asper* as dominants. Duck and Fletcher (1945) reported that the natural vegetation of the tall-grass prairie consisted of a mixture of such species as *Andropogon gerardi*, *A. scoparius*, *Sorghastrum nutans*, *Panicum virgatum*, and *Andropogon saccharoides*. Smith (1940) listed *Andropogon scoparius* and *Bouteloua curtipendula* as the dominant grasses in the prairies of central Oklahoma and designated this region as a part of the mixed-grass association. Nease (1948) described the tall-grass prairie of south central Oklahoma and listed four dominants: *Andropogon scoparius*, *A. hallii*, *Panicum virgatum*, and *Sorghastrum nutans*. Perhaps the first quantitative work on the composition of the true prairie in the state was that of Rice (1952) in south central Oklahoma. On the basis of cover and frequency he found the dominant grasses, in order of decreasing importance, to be *Sorghastrum nutans*, *Panicum virgatum*, and *Andropogon gerardi*.

The purpose of the present investigation was to secure information on grassland dominants and on plant production of a small sample of virgin prairie and a moderately grazed pasture in central Oklahoma. The investigation was initiated in the autumn of 1949 and was continued throughout the entire growing season of 1950.

The writer is indebted to many persons for assistance in the field work and in the preparation of the manuscript. He especially wishes to thank Dr. Wm. T. Penfound and Dr. E. L. Rice under whose joint direction the work was done.

LOCATION AND DESCRIPTION OF STUDY PLOTS

The two plots are located within a few hundred yards of one another on gentle, northeast facing slopes. They are a part of the University of Oklahoma Grasslands Investigation Plots located approximately eight miles southwest of Norman, along State Highway 9 in McClain County, Oklahoma.

The virgin prairie was represented by an area of approximately five acres which has not been burned or grazed in the past twenty-five years. The history of the plot prior to 1926 is not known, but it seems unlikely that it was ever greatly disturbed. Although mowed for hay in 1940 or 1941,