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ABSTRACT. Homozygous, homogeneous \( F_5 \)-derived soybean lines tracing through an \( F_3 \) selection to a single \( F_2 \) plant were evaluated. Similarity of performance of genetically related lines indicated appreciable fixation of six agronomic and chemical characters in the \( F_2 \) generation with further fixation occurring in the \( F_3 \). \( F_2 \)- and \( F_3 \)-derived lines were simulated by mixing equal amounts of seed from each related \( F_5 \) sister line. Yield evaluation indicated that testing \( F_2 \)-derived lines in advanced generations may be a useful procedure in selecting superior homozygous lines of soybeans.

INTRODUCTION

Genetic variability in segregating populations is essential for the improvement of self-pollinated species. Simply inherited characters are rapidly fixed and can be selected in early generations. However, early selection for a complex character such as seed yield may be difficult due to lack of fixation in early generations. Leffel and Hanson (3) indicated that high yielding progenies may not be recognized in early generations because of: (1) genotype x environment interaction; (2) inadequate testing in time and space; (3) heterosis attributed to dominance or epistasis not fixable in homozygous lines; (4) heterozygosity and heterogeneity in the progenies; and (5) interplant and interplot competition.

Frey (2) suggested the use of \( F_2 \)-derived lines as estimators of progeny performance. In a given \( F_2 \) plant, an average of 50% of the segregating genes are fixed so that its progeny will have 50% common alleles. The success of \( F_2 \)-derived line testing will depend upon the amount of character fixation in the \( F_2 \) generation and the effect of interplant competition on the performance of a heterogeneous \( F_2 \)-derived line.

Mahmud and Kramer (4) reported that detectable segregation occurred until \( F_5 \) for yield, \( F_7 \) for height, and \( F_8 \) for maturity in soybeans (Glycine max (L.) Merrill). The components of variance for lines within

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1 Joint contribution from the Crops Research Division, ARS, USDA, as No. 523 of the U. S. Regional Soybean Laboratory, and the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa 50010, as Journal Paper No. J-6034, Project No. 1179. Received August 1, 1969.
2 Research Associate, Department of Agronomy, Iowa State University; Director of Research, Peterson Seed Company, Waterloo, Iowa (formerly Agronomist, Crops Research Division, ARS, USDA, and Professor, Iowa State University); and Assistant Professor, Iowa State University, Ames, Iowa.
families were smaller in each successive generation for all three characters. Bartley and Weber (1) found larger differences among $F_3$ families than within families for yield, height, maturity, and lodging in three soybean crosses. Raeber and Weber (5) reported an appreciable degree of genic fixation for yield in soybeans by the $F_4$ generation, with relative homozygosity in the $F_5$.

The purpose of this study was to determine the approach to fixation for six characters in several elite soybean populations and to evaluate the $F_2$-derived line method of breeding.

**MATERIALS AND METHODS**

All lines discussed herein were derived from the following crosses made at Ames, Iowa. Parents were chosen for agronomic desirability.

<table>
<thead>
<tr>
<th>Cross</th>
<th>No. of $F_2$ families</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Hawkeye' x 'Clark'</td>
<td>5</td>
</tr>
<tr>
<td>Hawkeye x 'Harosoy'</td>
<td>3</td>
</tr>
<tr>
<td>'Adams' x Harosoy</td>
<td>4</td>
</tr>
<tr>
<td>'Lincoln' x Harosoy</td>
<td>2</td>
</tr>
<tr>
<td>Harosoy x Clark</td>
<td>1</td>
</tr>
</tbody>
</table>

Seventy-five $F_2$ plants were selected in each cross. All selections made in this study were for midseason (Hawkeye) maturity and phenotypic desirability. Three $F_3$ plants were selected from each of the 75 $F_2$-derived lines. The progeny of each $F_3$ plant were grown as a plant row in an $F_4$ yield test by Voigt and Weber (6). The three sister $F_4$ rows were considered replications in evaluating the performance of their respective $F_2$ family. The highest yielding 15 families from the 375 evaluated were chosen for the study reported herein. The number of families from each cross is indicated above. $F_3$ seeds from each of the three $F_2$-derived lines from each $F_2$ family were planted, and at maturity three $F_5$ plants were selected from each line. Each selection was increased as an $F_6$ plant row prior to the first yield evaluation.

Homogeneous pure lines and reconstituted lines at two levels of heterogeneity were evaluated in 1962 and 1966. $F_5$-derived lines, hereafter referred to as $F_5$ lines, were considered homogeneous. Equal amounts of seed from three $F_5$ lines tracing to an $F_3$ plant were mixed to form a reconstituted $F_3$-derived line. Equal amounts of nine $F_5$ lines tracing to an $F_2$ plant were mixed to form a reconstituted $F_2$-derived line. Reconstitution as used herein does not imply genetic recombination, but simply genotypic heterogeneity.

The 1962 yield test was grown at the Agronomy Farm, Ames, Iowa. A split-plot design in three replications was used, with $F_2$ families as whole plots and lines within $F_2$ families as subplots. Rows 5 m long were planted and end-trimmed to 4 m at harvest. There were 102 cm between rows and 30 plants per meter of row. Seed yield, lodging score, and plant height were measured on a plot basis; seed size, protein, and oil content were measured on a composite sample of three replications.

The second yield evaluation (1966) was the same as the one described above with the following exceptions: lines were in $F_3$ instead of $F_7$; the
test was conducted at the Squaw Creek Bottom, Ames, Iowa; the test was irrigated when the lines were at full bloom; and rows 4 m long were planted and end-trimmed to 3 m at harvest. Coefficients of variability were low and acceptable for all characters in both tests.

Analyses of variance were computed within each environment for yield, height, and lodging. Combined analyses were conducted for all characters. Analyses of individual environments were impossible for seed size, protein, and oil content since these characters were evaluated on a composite sample of three replications in each environment. Fixed effects were assumed for families, while lines within families and environments were assumed random. The combined analysis of variance and expected mean squares for \( F_5 \) lines are presented in Table 1. Estimates of variance components and effects were obtained by equating appropriate mean squares to their expectations.

Similarity of \( F_5 \) lines within subgroups was evaluated by use of intraclass correlations, calculated from the formula:

\[
 r = \frac{s_{A}^{2}}{s_{A}^{2} + s_{W}^{2}}
\]

where \( s_{A}^{2} \) is the variance among groups of related individuals and \( s_{W}^{2} \) is the variance within groups. Correlations were obtained for \( F_5 \) lines within \( F_2 \) families and for lines within \( F_3 \) sets. The magnitude of these correlations was assumed to be indicative of character fixation in the \( F_2 \) and \( F_3 \) generations, respectively.

RESULTS AND DISCUSSION

Estimates of genotypic variance components and effects for all characters are presented in Table 2. There were no significant genetic effects for yield in the combined analysis because of a large genotype x environment interaction. These results were not entirely unexpected since intense selection of \( F_2 \) families for high yield drastically reduced genetic variability for this character.

Genetic components for \( F_2 \) family effects were generally larger than components for lines in \( F_2 \) families for all characters, indicating appreciable character fixation in the first segregating generation. Variability which was not fixed in \( F_2 \), but which was fixed in the second segregating generation (\( F_3 \)) was indicated by variance among \( F_3 \) sets (Table 2). Variances within \( F_3 \) sets indicated variability which was fixed subsequent to \( F_3 \). For seed size and protein and oil content, variability within \( F_3 \) sets was small in comparison with the variability among sets, which indicated that little fixation occurred subsequent to the \( F_3 \). For height and lodging the component estimates for among \( F_3 \) sets were smaller than those for lines in sets. For these characters, less fixation occurred in \( F_3 \) than remained to be fixed in later generations. For yield the components for among and within \( F_3 \) sets were similar in magnitude in both environments, suggesting the amount of fixation in \( F_3 \) was similar to that for all subsequent generations.

The degree of similarity among lines within \( F_2 \) families and within \( F_3 \) sets was estimated by calculating intraclass correlations (Table 3). For
Table 1. Analysis of variance and expected mean squares for \( F_5 \) lines tested in two environments.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>D.F.</th>
<th>Symbol*</th>
<th>Expected mean square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environments (E)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Replications in E (R/E)</td>
<td>4</td>
<td></td>
<td>( \sigma^2 ) A + 9j ( \sigma_{EF}^2 ) + 9ij ( \theta_F )</td>
</tr>
<tr>
<td>Families (Fam)</td>
<td>14</td>
<td>( F )</td>
<td>( \sigma^2 ) + j ( \sigma_{EM}^2 ) + ij ( \sigma_M^2 )</td>
</tr>
<tr>
<td>Lines in Fam</td>
<td>120</td>
<td>( M )</td>
<td>( \sigma^2 ) + j ( \sigma_{EL}^2 ) + 3j ( \sigma_{ES}^2 )</td>
</tr>
<tr>
<td>Among ( F_3 ) Sets(^+)</td>
<td>30</td>
<td>( S )</td>
<td>( \sigma^2 ) + j ( \sigma_{EL}^2 ) + ij ( \sigma_L^2 )</td>
</tr>
<tr>
<td>Within ( F_3 ) Sets</td>
<td>90</td>
<td>( L )</td>
<td>( \sigma^2 ) + j ( \sigma_{EL}^2 ) + ij ( \sigma_L^2 )</td>
</tr>
<tr>
<td>Fam X E</td>
<td>14</td>
<td>( EF )</td>
<td>( \sigma^2 ) A + 9j ( \sigma_{EF}^2 )</td>
</tr>
<tr>
<td>Lines in Fam X E</td>
<td>120</td>
<td>( EM )</td>
<td>( \sigma^2 ) + j ( \sigma_{EM}^2 )</td>
</tr>
<tr>
<td>Among ( F_3 ) Sets X E</td>
<td>30</td>
<td>( ES )</td>
<td>( \sigma^2 ) + j ( \sigma_{EL}^2 ) + 3j ( \sigma_{ES}^2 )</td>
</tr>
<tr>
<td>Within ( F_3 ) Sets X E</td>
<td>90</td>
<td>( EL )</td>
<td>( \sigma^2 ) + j ( \sigma_{EL}^2 )</td>
</tr>
<tr>
<td>R/E X Fam</td>
<td>56</td>
<td>( A )</td>
<td>( \sigma^2 ) A</td>
</tr>
<tr>
<td>R/E X Lines in Fam</td>
<td>480</td>
<td></td>
<td>( \sigma^2 )</td>
</tr>
</tbody>
</table>

* Denotes the variance component or effect related to each source of variation

\(^+\) Three \( F_5 \) lines tracing to a single \( F_3 \) plant constitute an \( F_3 \) set.
Table 2. Estimates of genotypic variance components and effects for six characters in individual and combined environments.

<table>
<thead>
<tr>
<th>Sources of variation</th>
<th>Yield 1962</th>
<th>Yield 1966</th>
<th>Yield Comb</th>
<th>Height 1962</th>
<th>Height 1966</th>
<th>Height Comb</th>
<th>Lodging 1962</th>
<th>Lodging 1966</th>
<th>Lodging Comb</th>
<th>Seed size</th>
<th>Protein</th>
<th>Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Families (Fam)¹</td>
<td>12984</td>
<td>8685**</td>
<td>0</td>
<td>90.2**</td>
<td>71.1**</td>
<td>77.0**</td>
<td>.077**</td>
<td>.086**</td>
<td>.049**</td>
<td>2.14**</td>
<td>.49**</td>
<td>.16**</td>
</tr>
<tr>
<td>Lines in Fam</td>
<td>9067**</td>
<td>6328**</td>
<td>1264</td>
<td>25.8**</td>
<td>17.2**</td>
<td>19.9**</td>
<td>.015**</td>
<td>.021**</td>
<td>.014**</td>
<td>0.96**</td>
<td>.26**</td>
<td>.16**</td>
</tr>
<tr>
<td>Among F₃ Sets²</td>
<td>5545**</td>
<td>3901*</td>
<td>2278</td>
<td>9.0**</td>
<td>8.0**</td>
<td>6.5**</td>
<td>.007**</td>
<td>.011**</td>
<td>.005**</td>
<td>0.83**</td>
<td>.32**</td>
<td>.12**</td>
</tr>
<tr>
<td>Within F₃ Sets</td>
<td>5109**</td>
<td>3402</td>
<td>0</td>
<td>19.0**</td>
<td>11.2**</td>
<td>15.1**</td>
<td>.010**</td>
<td>.013**</td>
<td>.010**</td>
<td>0.33**</td>
<td>.02**</td>
<td>.07**</td>
</tr>
</tbody>
</table>

*, ** Corresponding mean square exceeds the 5%, 1% level of probability, respectively

¹ Estimates genetic effect, since a fixed model was assumed for families

² Three F₅ lines tracing to a single F₃ plant constitute an F₃ set
Table 3. Intraclass correlations of $F_5$ lines in $F_2$ families and $F_3$ sets for all characters in individual and combined environments.

<table>
<thead>
<tr>
<th>Character</th>
<th>Lines in $F_2$ Families</th>
<th>Lines in $F_3$ Sets*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield</td>
<td>.59</td>
<td>.58</td>
</tr>
<tr>
<td>Height</td>
<td>.78</td>
<td>.80</td>
</tr>
<tr>
<td>Lodging</td>
<td>.84</td>
<td>.80</td>
</tr>
<tr>
<td>Seed Size</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Protein</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Oil</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

* Three $F_5$ lines tracing to a single $F_3$ plant constitute an $F_3$ set.

seed size and protein and oil content the correlation of lines in $F_3$ sets was higher than the correlation of lines in $F_2$ families. This was expected because of the large degree of character fixation by $F_3$.

The lines in an $F_2$ family were highly correlated for height and lodging indicating that most of the variability among lines for height and lodging could be accounted for by the variability among $F_2$ families.

For yield, the intraclass correlations were about 0.5 for both $F_2$ families and $F_3$ sets. These values are consistent with expected genetic relationships assuming a large number of genes acting additively.

The results suggest that substantial fixation occurs in the $F_2$ generation for all characters. Selection of homogeneous lines on the basis of $F_2$-derived line performance should be highly successful for height, lodging, seed size, and protein content with reasonable success for yield and oil content.

The $F_2$-derived line method of breeding for yield was evaluated by assuming that heterogeneous $F_2$ and $F_3$ reconstituted lines estimated the performance of their respective $F_2$- and $F_3$-derived lines. The validity of these assumptions depends upon the degree to which the selected lines sampled the original $F_2$ and $F_3$ progenies. The most severe limitation in sampling was the restriction placed upon maturity. However, this was not considered to bias the results greatly since most segregates in the original bulk population were in the maturity range subject to sampling. The number of genotypes used in reconstituting the populations was minimal but was considered adequate for our purpose.

Artificial selection pressures were applied to the reconstituted $F_2$- and $F_3$-derived lines and the proportion of the highest yielding $F_5$ lines saved was obtained. Selection pressures of 67%, 47%, 33%, and 20% were applied to the reconstituted lines. The results are summarized in Table 4. These results must be interpreted in light of the inconsistency
Table 4. Percentage of highest yielding $F_5$ lines retained with various selection pressures applied to 15 reconstituted $F_2$-derived lines and 45 reconstituted $F_3$-derived lines.

<table>
<thead>
<tr>
<th>Selection intensity (%)</th>
<th>Number of lines saved</th>
<th>% top $45 F_5$ lines saved</th>
<th>% top $27 F_5$ lines saved</th>
<th>% top $5 F_5$ lines saved</th>
<th>% top $1 F_5$ lines saved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_2$-derived</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>66.7</td>
<td>10</td>
<td>93.3</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>46.7</td>
<td>7</td>
<td>75.6</td>
<td>77.8</td>
<td>80.0</td>
<td>100.0</td>
</tr>
<tr>
<td>33.3</td>
<td>5</td>
<td>55.6</td>
<td>51.8</td>
<td>60.0</td>
<td>100.0</td>
</tr>
<tr>
<td>20.0</td>
<td>3</td>
<td>40.0</td>
<td>40.7</td>
<td>40.0</td>
<td>100.0</td>
</tr>
<tr>
<td>$F_3$-derived</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>66.7</td>
<td>30</td>
<td>97.8</td>
<td>96.3</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>46.7</td>
<td>21</td>
<td>84.4</td>
<td>92.6</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>33.3</td>
<td>15</td>
<td>57.8</td>
<td>77.8</td>
<td>80.0</td>
<td>100.0</td>
</tr>
<tr>
<td>20.0</td>
<td>9</td>
<td>40.0</td>
<td>48.1</td>
<td>80.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>
of yield performance in the two years. However, the plant breeder must often base his selections on mean performance in spite of the masking effect of genotype x environment interaction. Therefore, the results were considered to have practical applications.

Selection of the highest yielding F₅ lines based on heterogeneous line performance was successful. Selection based on F₃-derived line performance was somewhat more successful than selection based on F₂-derived line performance, but three times as many F₂-derived lines were yield tested. The results suggest that yield testing of F₂-derived lines in advanced generations may be a productive breeding method for soybeans. Advancing F₂-derived lines to homozygosity would provide sufficient seed for testing in several environments. Furthermore, non-additive gene action and heterosis would not be expressed in the performance of the F₂-derived line in advanced generations. The evaluation of F₂-derived lines would permit the evaluation of a wide genetic base with a minimum of yield testing.

LITERATURE CITED

ABSTRACT. The Iowa State University Museum of Zoology has a collection of 1786 mammals. Only 6 of the 59 species accepted as state records are not in the collection. This list gives a general statement on the distribution of each species in Iowa, and accession numbers of each specimen are listed by county so that distribution maps may be prepared by interested individuals. Subspecies are considered only nominally because of the small sample sizes involved and the lack of adequate correlative data.

Only 4 counties are not represented in the collection but numerous others need to be sampled more intensively.

The mammalian fauna of Iowa represents a cross-section of mammals derived from northern, eastern and western faunal elements. However, most species are statewide in distribution.

Several species of highly localized distribution and accidental status are considered.

Although there has been little intensive survey work done on small mammals in Iowa since Scott’s publication (1937), we have acquired a significant number of specimens that provide a better picture of distribution of the mammals within the state and in relation to adjacent states. Most of these records have been acquired through the efforts of students in our mammalogy classes. In addition to guiding this effort, the authors have collected in various parts of the state to substantiate species of localized distribution. The number of species collected in each county and counties not represented in the collection by specimens are shown in Figure 1. No records from furbuyers or other untraceable sources have been used. The systematic list is presented in the appendix.

This summary is not intended as a synoptic work of the mammals of Iowa in the sense of Scott’s review or Polder’s (1953) list. Such a work is in preparation by Emmett Polder of Dyersville, Iowa. This list is a means of making public a resumé of records of species acquired recently but not previously reported. It is hoped that this summary will encourage additional effort by showing grossly what is available and what remains to be done.

The taxonomic order and nomenclature used in this list follows Hall and Kelson (1959) as modified by Jones (1964) and Anderson and Jones (1967). Little emphasis has been placed on subspecies here because too few specimens are available for most species to provide a reliable measure of variation. Polytypic species are indicated with presently recognized subspecies listed under each heading. In all instances, we have accepted the subspecific nomenclature of Hall and Kelson (1959).

Several species reported in the state are not represented in the collection. These are listed in Table 1 and constitute 6 of the 59 accepted state records. In addition, the Wapiti or American Elk (Cervus canadensis) and Bison (Bison bison) were known to have occurred in Iowa and have been extirpated. Several other species that were once more abundant (Table 1) are still reported occasionally, but no specimens have been taken.

We are indebted to many persons for their assistance and contributions to the collection. Scott's (1937) effort formed the base of the collection; all accession numbers bearing an "a" were collected by or for him. Glen Sanderson of the Illinois Natural History Survey contributed a diverse group of interesting specimens based on research conducted while he was a biologist for the Iowa State Conservation Commission. Those students who did some special collecting and helped in accessioning were: Leigh Fredrickson, Vernon Wright, Roger Siglin, Merlin Shoesmith, David Trauger, Robert Bergman, Devere Burt, Douglas Thompson, and Larry Dau. Robert Dodd summarized the records from the files and cross-checked many records for accuracy.
Table 1. Mammals reported recently in Iowa but not represented in the Iowa State University collection.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>COUNTY</th>
<th>AUTHORITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryptotis parva, Least Shrew</td>
<td>Story, Marion</td>
<td>Scott, 1937</td>
</tr>
<tr>
<td>Myotis keeni, Keen's Myotis</td>
<td>Story ?</td>
<td>Scott, 1937</td>
</tr>
<tr>
<td>Myotis subulatus, Small-footed Myotis</td>
<td>Story</td>
<td>Scott, 1939</td>
</tr>
<tr>
<td>Tadarida molossa, Big Free-tailed Bat</td>
<td>Linn, Marshall</td>
<td>Scott, 1937</td>
</tr>
<tr>
<td>Lynx canadensis, Canada Lynx</td>
<td>Shelby</td>
<td>J. Rasmussen, 1969</td>
</tr>
<tr>
<td>Odocoileus hemionus, Mule Deer</td>
<td>Decatur, Fremont, Lyon</td>
<td>Sanderson, 1956; Kline, 1959</td>
</tr>
</tbody>
</table>

1 This does not include occasional recent but unsupported reports of Ursus americana, Black Bear; Felis concolor, Cougar; Canis lupus, Gray Wolf; and Erethizon dorsatum, Porcupine.

2 Documented by specimens not in the I. S. U. collection.

GENERAL PATTERNS OF MAMMALIAN DISTRIBUTION

Because of Iowa's central location and its combination of grassland and woodland habitats (Figure 2), the mammalian fauna, while not large, is diverse. An indication of general distribution in Iowa is provided in the Systemtic List. This is the best available concept of range based on records presented here and on maps of ranges in adjacent states. Obviously, ecological factors are minimized in these general statements, and some species are much more habitat-restricted than others.

Assuming that present ranges reflect optimal habitat and relative geographic areas of origin, certain species clearly have invaded Iowa from different directions. Species that range over only part of Iowa and that clearly have major ranges in adjacent states in the same direction can be segregated as in Table 2. Table 3 lists species presently assumed to be statewide in distribution. Presumably, some of the latter have origins outside the state and directions of entry can be estimated for the Opossum, Flying Squirrel and others. The ranges of several species are still uncertain and have not been included in these two tables.

Special attention should be called to certain species of uncommon occurrence. These fall into two categories: relicts, or habitat-limited species, and stragglers. The distribution of the very isolated Redbacked Vole and Grasshopper Mouse are shown in Figure 3 with recent records.
Figure 2. Plant communities of Iowa, after Kuchler (1964).

Figure 3. Distribution of relict species and species of accidental occurrence: 1 = Onychomys leucogaster, 2 = Clethrionomys gapperi, 3 = Lynx canadensis, 4 = Gulo luscus.
Table 2. Species with ranges in part of Iowa which infer direction of origin.

**Species with major ranges in northern Iowa**

- *Sorex cinereus*, Masked Shrew
- *Microsorex h. hoyi*, Pigmy Shrew
- *Tamiasciurus hudsonicus*, Red Squirrel
- *Clethrionomys gapperi loringi*, Gapper's Red-backed Vole
- *Microtus p. pennsylvanicus*, Meadow Vole
- *Zapus hudsonius intermedius*, Meadow Jumping Mouse
- *Mustela erminea bangsi*, Ermine
- *Mustela nivalis campestris*, Least Weasel

**Species with ranges in western Iowa (often NW)**

- *Lepus townsendii campanius*, White-tailed Jack Rabbit
- *Onychomys leucogaster breviauritus*, Northern Grasshopper Mouse
- *Canis latrans thamnos*, Coyote

**Species with major ranges in southern Iowa**

- *Nycticeius h. humeralis*, Evening Bat
- *Synaptomys cooperi gossii*, Southern Bog Lemming
- *Microtus o. ochrogaster*, Prairie Vole
- *Microtus pinetorum nemoralis*, Woodland Vole

**Species with major ranges in eastern Iowa**

- *Pipistrellus s. subflavus*, Eastern Pipistrelle
- *Tamias striatus griseus*, Eastern Chipmunk
- *Sciurus carolinensis pennsylvanicus*, Gray Squirrel
- *Urocyon cinereoargenteus ocythous*, Gray Fox
Table 3. Native terrestrial species with statewide distribution.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Didelphis marsupialis virginiana</td>
<td>Opossum</td>
</tr>
<tr>
<td>Blarina brevicauda</td>
<td>Short-tailed Shrew</td>
</tr>
<tr>
<td>Scalopus aquaticus</td>
<td>Eastern Mole</td>
</tr>
<tr>
<td>Myotis l. lucifugus</td>
<td>Little Brown Myotis</td>
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<tr>
<td>Lasionycteris noctivagans</td>
<td>Silver-haired Bat</td>
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<tr>
<td>Eptesicus f. fuscus</td>
<td>Big Brown Bat</td>
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<tr>
<td>Lasiurus b. borealis</td>
<td>Red Bat</td>
</tr>
<tr>
<td>Lasiurus c. cinereus</td>
<td>Hoary Bat</td>
</tr>
<tr>
<td>Sylvilagus floridanus mearnsii</td>
<td>Eastern Cottontail</td>
</tr>
<tr>
<td>Marmota m. monax</td>
<td>Woodchuck</td>
</tr>
<tr>
<td>Spermophilus franklinii</td>
<td>Franklin's Ground Squirrel</td>
</tr>
<tr>
<td>Spermophilus t. tridecemlineatus</td>
<td>Thirteen-lined Ground Squirrel</td>
</tr>
<tr>
<td>Sciurus niger rufiventer</td>
<td>Fox Squirrel</td>
</tr>
<tr>
<td>Glaucomys v. volans</td>
<td>Southern Flying Squirrel</td>
</tr>
<tr>
<td>Geomys bursarius</td>
<td>Plains Pocket Gopher</td>
</tr>
<tr>
<td>Castor canadensis</td>
<td>Beaver</td>
</tr>
<tr>
<td>Reithrodontomys megalotis dychei</td>
<td>Western Harvest Mouse</td>
</tr>
<tr>
<td>Peromyscus leucopus noveboracensis</td>
<td>White-footed Mouse</td>
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<tr>
<td>Peromyscus maniculatus bairdii</td>
<td>Deer Mouse</td>
</tr>
<tr>
<td>Ondatra zibethicus</td>
<td>Muskrat</td>
</tr>
<tr>
<td>Vulpes fulva regalis</td>
<td>Red Fox</td>
</tr>
<tr>
<td>Procyon lotor hirtus</td>
<td>Raccoon</td>
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<tr>
<td>Mustela frenata</td>
<td>Long-tailed Weasel</td>
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<tr>
<td>Mustela vison</td>
<td>Mink</td>
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<tr>
<td>Taxidea t. taxus</td>
<td>Badger</td>
</tr>
<tr>
<td>Spilogale putorius interrupta</td>
<td>Spotted Skunk</td>
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<tr>
<td>Mephitis mephitis</td>
<td>Striped Skunk</td>
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<tr>
<td>Lutra c. canadensis</td>
<td>Otter</td>
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<tr>
<td>Lynx r. rufus</td>
<td>Bobcat</td>
</tr>
<tr>
<td>Odocoileus virginianus macroura</td>
<td>White-tailed Deer</td>
</tr>
</tbody>
</table>

Other species of erratic or uncertain distribution in the state are Free-tailed Bat (*Tadarida molossa*), Pigmy Shrew (*Microsorex hoyi*), Least Shrew (*Cryptotis parva*), and Plains Pocket Mouse (*Perognathus flavescens*).

**LITERATURE CITED**


APPENDIX

A systematic list of the Iowa mammals in the Iowa State University Museum of Zoology

SYSTEMATIC LIST

CLASS MAMMALIA

ORDER MARSUPIALIA

Family Didelphidae

Didelphis marsupialis virginiana Kerr - Opposum

General distribution in Iowa: Entire state

I. S. U. Records: Benton Co. 1474; Decatur Co. 1209; Emmet Co. 1121; Greene Co. 1706; Hamilton Co. 301; Story Co. 1304, 1329; Van Buren Co. 169a; Warren Co. 1786; Worth Co. 1754.

ORDER INSECTIVORA

Family Soricidae

Sorex cinereus - Masked Shrew

Subspecies: S. c. haydeni Baird, S. c. leseuerii (Duvernoy)

General Distribution in Iowa: Mainly northern two-thirds.

I. S. U. Records: Black Hawk Co. 1784; Boone Co. 1484, 1512; Cerro Gordo Co. 21a; Clay Co. 156a, 157a, 158a, 174a, 179a, 180a, 181a, 184a, 185a, 186a, 1132; Dickinson Co. 2a; Delaware Co. 886, 887; Emmet Co. 203a, 204a, 205a, 209a, 220a, 1117, 1126; Fayette Co. 1280; Franklin Co. 1515; Guthrie Co. 1767; Hamilton Co. 7a, 14a; Hancock Co. 1483, 1485, 1742, 1743; Henry Co. 1713; Howard Co. 917; Humboldt Co. 1340; Keokuk Co. 1783; Linn Co. 1266; Lyon Co. 517a, 525a; Pocahontas Co. 1726; Story Co. 1335, 1520; Warren Co. 1727, 1763; Winnebago Co. 29a.

Microsorex hoyi (Baird) - Pigmy Shrew

General Distribution in Iowa: Possibly northern one-half.


Blarina brevicauda - Short-tailed Shrew

Subspecies: B. b. brevicauda (Say), B. b. carolinensis (Bachman)

General Distribution in Iowa: Entire state.

I. S. U. Records: Allamakee Co. 1498; Black Hawk Co. 1637; Boone Co. 110, 1626; Bremer Co. 324; Buena Vista Co. 1283; Carroll Co. 716a, 720a; Clay Co. 105, 170a; Crawford Co. 710a; Delaware Co. 831, 1739; Dickinson Co. 192a; Dubuque Co. 81a, 88a, 92a; Emmet Co. 207a, 216a, 1118, 1119; Franklin Co. 1561; Fremont Co. 1778; Greene Co. 745a, 746a; Guthrie Co. 665, 832, 840; Hamilton Co. 3a, 17a, 340; Hancock Co. 1248 (skull only), 1736; Hardin Co. 1288; Henry Co. 1710; Humboldt Co. 1521, 1555; Ida Co. 1272; Jasper Co. 1519; Keokuk Co. 1782; Linn Co. 666, 843, 844, 850, 859, 860; Louisa Co. 1516; Lucas Co. 1618; Lyon Co. 243a, 529a, 544a, 547a, 548a, 563a, 567a, 585a, 616a; Mitchell Co. 1688; Monona Co. 680a, 688a, 692a; Pocahontas Co. 1720; Polk Co. 1502, 1732, 1753;
ISU COLLECTION OF IOWA MAMMALS

Poweshiek Co. 1479; Sioux Co. 1524, 1568; Story Co. 51a, 150a, 257, 311, 1513, 1522, 1608, 1616, 1620, 1651, 1686, 1687; Warren Co. 1711, 1764; Webster Co. 1546; Winnebago Co. 1237; Worth Co. 1173, 1358; Wright Co. 1488, 1507.

Family Talpidae

**Scalopus aquaticus** - Eastern Mole

**Subspecies:** S. c. machrinus (Rafinesque), S. c. machrinoides Jackson

*General Distribution in Iowa:* Entire state.

*I. S. U. Records:* Boone Co. 769a; Carroll Co. 718a, 725a, 730a, 731a, 735a, 739a; Crawford Co. 711a; Dickinson Co. 196a, 197a; Emmet Co. 215a, 218a; Greene Co. 738a; Hamilton Co. 18a; Hancock Co. 1245, 1296; Jackson Co. 1337; Johnson Co. 484a; Keokuk Co. 1751; Linn Co. 663; Louisa Co. 1607; Lucas Co. 498a; Lyon Co. 230a, 233a, 510a, 538a, 557a, 565a, 572a, 575a, 589a, 590a, 602a, 621a; Monona Co. 682a, 689a, 699a, 700a, 702a; Scott Co. 1419; Story Co. 24a, 66, 759a, 760a, 761a, 764a, 1598, 1614; Wayne Co. 1420; Wright Co. 1677.

ORDER CHIROPTERA

Family Vespertilionidae

**Myotis l. lucifugus** (Le Conte) - Little Brown Myotis

*General Distribution in Iowa:* Entire state.

*I. S. U. Records:* Delaware Co. 884, 885; Dubuque Co. 478a, 481a; Hancock Co. 1339, 1356; Kossuth Co. 413a.

**Lasionycteris noctivagans** (Le Conte) - Silver-haired Bat

*General Distribution in Iowa:* Probably entire state.

*I. S. U. Records:* Greene Co. 751a, 753a; Guthrie Co. 67.

**Pipistrellus s. subflavus** (F. Cuvier) - Eastern Pipistrelle

*General Distribution in Iowa:* Eastern one-half; probably southern one-half.

*I. S. U. Records:* Clayton Co. 1435; Dubuque Co. 116a, 154a, 479a, 480a; Jackson Co. 90a, 867, 868; Polk Co. 1368.

**Eptesicus f. fuscus** (Palisot de Beauvois) - Big Brown Bat

*General Distribution in Iowa:* Entire state.

*I. S. U. Records:* Boone Co. 504a; Dubuque Co. 69a, 122a, 123a, 128a, 129a; Emmet Co. 909, 1115; Greene Co. 752a; Jackson Co. 124a, 125a, 126a, 127a, 863, 865, 883; Jefferson Co. 1225; Marshall Co. 1434; Polk Co. 1369, 1370; Story Co. 58, 64, 91, 168a; Wright Co. 1517.

**Lasiurus b. borealis** (Müller) - Red Bat

*General Distribution in Iowa:* Entire state.

*I. S. U. Records:* Carroll Co. 740a, 741a, 742a, 743a; Emmet Co. 1116, 1165; Lyon Co. 519a, 551a, 573a; Monona Co. 691a; Pottawattamie Co. 781a; Story Co. 118a, 146a, 312, 765a, 766a, 1354; Van Buren Co. 779a; Wapello Co. 1777; Winneshiek Co. 342a.
Lasiurus c. cinereus (Palisot de Beauvois) - Hoary Bat
  General Distribution in Iowa: Entire state.
  I.S.U. Records: Dickinson Co. 1768; Greene Co. 754a; Linn Co. 866; Lyon Co. 518a; Monona Co. 690a; Pottawattamie Co. 780a; Story Co. 1346, 1353.

Nycticeius h. humeralis (Rafinesque) - Evening Bat
  General Distribution in Iowa: Probably southern one-half.
  I.S.U. Records: Polk Co. 1367.

ORDER LAGOMORPHA
Family Leporidae

Sylvilagus floridanus mearnsii (J. A. Allen) - Eastern Cottontail
  General Distribution in Iowa: Entire state.
  I.S.U. Records: Appanoose Co. 400a; Boone Co. 772a; Dubuque Co. 138a, 145a; Emmet Co. 1110; Fremont Co. 22a, 261a; Hancock Co. 1351; Jefferson Co. 1758; Linn Co. 1267; Lyon Co. 514a, 535a, 568a, 611a; Muscatine Co. 1317; Story Co. 1330, 1670.

Lepus townsendii campanius Hollister - White-tailed Jack Rabbit
  General Distribution in Iowa: Northern two-thirds.
  I.S.U. Records: Boone Co. 1227; Dubuque Co. 98a; Emmet Co. 814, 1131; Kossuth Co. 353, 1130; Linn Co. 889; Lyon Co. 516a, 553a, 622a; Palo Alto Co. 167, 1129; Shelby Co. 1576; Story Co. 1703; Worth Co. 1179.

ORDER RODENTIA
Family Sciuridae

Tamias striatus griseus Mearns - Eastern Chipmunk
  General Distribution in Iowa: Mainly eastern two-thirds; relicts in north and northwest.
  I.S.U. Records: Allamakee Co. 1605, 1631; Benton Co. 1473; Boone Co. 19, 57, 349a, 1681; Clayton Co. 1497; Dickinson Co. 1535, 1682, 1683; Dubuque Co. 121a; Emmet Co. 219a, 1112, 1113; Fayette Co. 1278; Hancock Co. 1171, 1238; Jackson Co. 1333; Johnson Co. 1475; Linn Co. 660; Mitchell Co. 1472; Polk Co. 1738; Story Co. 94, 1577, 1699; Winnebago Co. 1411; Worth Co. 1359.

Marmota m. monax (Linnaeus) - Woodchuck
  General Distribution in Iowa: Entire state.
  I.S.U. Records: Appanoose Co. 396a; Carroll Co. 744a; Crawford Co. 714a; Dickinson Co. 200a; Emmet Co. 1125; Fayette Co. 1294; Fremont Co. 288a; Keokuk Co. 1316; Kossuth Co. 422a; Lee Co. 355a; Linn Co. 816, 824; Monona Co. 685a; Montgomery Co. 409a; Story Co. 770a; Van Buren Co. 381a.

Spermophilus franklinii (Sabine) - Franklin's Ground Squirrel
  General Distribution in Iowa: Possibly entire state; less common in eastern one-half.
  I.S.U. Records: Boone Co. 108a; Fremont Co. 274a; Guthrie Co. 59;
Linn Co. 367, 662; Lyon Co. 520a, 531a, 536a, 603a, 608a, 610a; Monona Co. 687a; Page Co. 282a, 285a; Polk Co. 815; Story Co. 76.

Spermophilus t. tridecemlineatus (Mitchill) - Thirteen-lined Ground Squirrel
General Distribution in Iowa: Entire state.
I. S. U. Records: Boone Co. 1714; Cedar Co. 401; Clay Co. 173a; Clinton Co. 670, 671; Dallas Co. 1578, 1684; Emmet Co. 893, 894; Hancock Co. 1239; Linn Co. 402; Louisa Co. 1537; Lyon Co. 526a, 564a, 584a, 597a; Page Co. 279a; Scott Co. 1423; Shelby Co. 1586; Story Co. 52, 1534, 1556, 1595, 1621.

Sciurus carolinensis pennsylvanicus Ord - Gray Squirrel
General Distribution in Iowa: Eastern and southern.
I. S. U. Records: Allamakee Co. 134a, 135a; Fayette Co. 48, 382; Henry Co. 358a, 359a; Jackson Co. 136a; Jones Co. 1704; Kossuth Co. 624a; Van Buren Co. 383a, 389a, 390a; Winnebago Co. 428a.

Sciurus niger rufiventer E. Geoffroy St.-Hilaire - Fox Squirrel
General Distribution in Iowa: Entire state.
I. S. U. Records: Adair Co. 1542; Benton Co. 1471; Boone Co. 56, 1157; Butler Co. 37; Cerro Gordo Co. 1158; Clayton Co. 1702; Clinton Co. 34; Crawford Co. 706a; Delaware Co. 1707; Dickinson Co. 1128; Emmet Co. 914, 915; Fremont Co. 269a, 270a; Grundy Co. 1270; Guthrie Co. 50; Hancock Co. 1701; Hardin Co. 1775; Humboldt Co. 1331; Iowa Co. 387; Jackson Co. 1332; Johnson Co. 1685; Jones Co. 1749; Keokuk Co. 1559; Linn Co. 386, 822, 828; Louisa Co. 1560; Lyon Co. 591a, 604a; Monona Co. 683a; Polk Co. 1295; Poweshiek Co. 1756; Story Co. 1063, 1064, 1065, 1066, 1350; Union Co. 1424; Van Buren Co. 377a; Wayne Co. 1425; Winnebago Co. 1772; Woodbury Co. 1228; Worth Co. 1705.

Tamiasciurus hudsonicus - Red Squirrel
Subspecies: T. h. loquax (Bangs), T. h. minnesota (J. A. Allen)
General Distribution in Iowa: Possibly entire state; most common in northern one-half.
I. S. U. Records: Black Hawk Co. 636a; Butler Co. 776a, 778a; Cerro Gordo Co. 1422; Emmet Co. 217a, 222a, 910; Hancock Co. 1235; Kossuth Co. 412a, 625a; Winnebago Co. 411a; Worth Co. 956.

Glaucomys v. volans (Linnaeus) - Southern Flying Squirrel
General Distribution in Iowa: Probably entire state.
I. S. U. Records: Dubuque Co. 80a, 83a, 130a, 131a, 132a; Jackson Co. 1334; Lee Co. 356a, 357a; Linn Co. 1700; Story Co. 23.

Family Geomyidae

Geomys bursarius - Plains Pocket Gopher
Subspecies: G. b. majusculus Swenks
General Distribution in Iowa: Probably entire state.
I. S. U. Records: Adair Co. 1653; Allamakee Co. 1689, 1692, 1697; Boone Co. 106a, 1773; Buchanan Co. 1336; Carroll Co. 729a, 734a;
Cerro Gordo Co. 1216; Crawford Co. 708a; Dallas Co. 1569, 1769; Decatur Co. 1212; Delaware Co. 1708; Dickinson Co. 1428, 1696; Emmet Co. 211a, 212a, 221a, 890, 891, 892; Greene Co. 1655; Grundy Co. 1547; Guthrie Co. 49; Hamilton Co. 330a; Hancock Co. 1244, 1734; Humboldt Co. 1328; Jasper Co. 1175; Kossuth Co. 95; Linn Co. 361; Lyon Co. 505a, 511a, 512a, 513a, 533a, 534a, 556a, 560a, 576a, 583a, 596a, 615a; Madison Co. 1231; Mahaska Co. 1299; Marshall Co. 1427; Mitchell Co. 1476, 1557; Monona Co. 693a; Muscatine Co. 1548, 1694; O'Brien Co. 1214; Polk Co. 1652, 1693, 1746; Shelby Co. 1698; Sioux Co. 1599, 1690, 1691; Story Co. 53, 1580, 1612, 1627; Webster Co. 1654; Wright Co. 1556, 1695.

Family Heteromyidae

Perognathus flavescens perniger Osgood - Plains Pocket Mouse

General Distribution in Iowa: Unknown; probably erratic along prairie-woods ecotone.

I. S. U. Records: Boone Co. 627a; Guthrie Co. 1069; Pottawattamie Co. 658a.

Family Castoridae

Castor canadensis - Beaver

General Distribution in Iowa: Entire state in suitable habitat.

I. S. U. Records: Appanoose Co. 830; Davis Co. 818; Emmet Co. 1120; Palo Alto Co. 1306; Sac Co. 43a.

Family Cricetidae

Reithrodontomys megalotis dychei J.A. Allen - Western Harvest Mouse

General Distribution in Iowa: Entire state.

I. S. U. Records: Black Hawk Co. 1635, 1646; Boone Co. 93, 109a, 767a, 1493; Carroll Co. 715a, 719a, 738a; Crawford Co. 703a, 709a, 713a; Dallas Co. 1492, 1508; Dubuque Co. 75a; Emmet Co. 919, 1114, 1181; Fremont Co. 271a, 275a, 1645, 1741; Guthrie Co. 880; Hamilton Co. 339; Ida Co. 1281; Kossuth Co. 1154; Lucas Co. 1565; Lyon Co. 227a, 240a, 521a, 532a, 540a, 578a, 601a; Marion Co. 1398; Mills Co. 294a, 295a, 296a, 297a; Monona Co. 678a, 694a, 695a; Montgomery Co. 308a, 309a; Page Co. 286a; Story Co. 115a, 258, 323, 325, 476a, 477a, 639a, 640a, 1170, 1615; Wapello Co. 888, 1206; Warren Co. 851, 1640; Woodbury Co. 1287.

Peromyscus leucopus noveboracensis (Fischer) - White-footed Mouse

General Distribution in Iowa: Entire state.

I. S. U. Records: Adair Co. 1544; Allamakee Co. 1355; Appanoose Co. 392a, 397a; Boone Co. 79, 86, 346a, 347a, 351a, 1482; Carroll Co. 717a, 724a; Clay Co. 183a; Clayton Co. 1491, 1539; Crawford Co. 705a; Dallas Co. 1490, 1735; Decatur Co. 650a, 651a, 652a, 653a, 654a, 1314; Delaware Co. 667, 802, 805, 838, 839, 848, 852, 862, 870, 871; Dickinson Co. 187a, 189a, 191a, 194a, 195a; Dubuque Co. 62a, 63a, 72a, 77a, 78a, 84a, 89a, 96a, 104a; Emmet Co. 206a, 210a, 213a, 214a; Fayette Co. 1282; Fremont Co. 265a, 266a; Greene Co. 750a; Guthrie Co. 853; Hamilton Co. 1a, 4a, 5a, 8a, 15a, 16a; Hancock Co. 1352; Henry Co. 1716; Humboldt Co. 1342; Jackson
Peromyscus maniculatus bairdii (Hoy and Kennicott) - Deer Mouse

General Distribution in Iowa: Entire state.

I. S. U. Records: Appanoose Co. 394a, 395a; Black Hawk Co. 1636, 1643; Boone Co. 33a, 1477, 1740; Bremer Co. 315, 333; Carroll Co. 721a, 722a, 723a, 737a; Cass Co. 1604; Clay Co. 159a, 171a, 175a, 176a, 246a, 247a; Crawford Co. 712a; Dallas Co. 1487, 1585; Decatur Co. 405a, 407a, 644a, 645a; Delaware Co. 1722; Dickinson Co. 193a, 198a; Dubuque Co. 1430; Emmet Co. 902, 903, 904, 905; Franklin Co. 1584; Fremont Co. 262a, 263a, 268a, 272a, 1644; Grundy Co. 1589; Guthrie Co. 1757; Hamilton Co. 338; Hancock Co. 1189; Hardin Co. 1297; Henry Co. 1730; Ida Co. 20a, 363a, 364a, 365a, 366a; Linn Co. 558, 836, 837, 846, 874; Louisa Co. 1550; Lucas Co. 1552; Lyon Co. 226a, 235a, 508a, 509a, 527a, 550a, 552a, 566a, 569a, 571a, 579a, 581a, 612a; Madison Co. 1240; Mahaska Co. 1242; Mills Co. 292a; Mitchell Co. 1478; Monona Co. 677a, 681a, 684a, 697a, 698a; Muscatine Co. 1246; Page Co. 276a, 278a, 290a; Pocahontas Co. 1719; Polk Co. 1625; Scott Co. 1396; Shelby Co. 1596; Story Co. 35a, 99, 102, 155, 259, 299, 307, 310, 313, 318, 336, 337, 643a, 646a, 1486, 1545, 1587; Wapello Co. 1204, 1205; Warren Co. 1641, 1745; Wayne Co. 1718; Winnebago Co. 1186; Woodbury Co. 1241, 1526; Wright Co. 1563.

Onychomys leucogaster breviauritus Hollister - Northern Grasshopper Mouse

General Distribution in Iowa: Few northwestern counties.

I. S. U. Records: Lyon Co. 228a, 229a, 232a, 234a, 237a, 238a, 241a, 244a, 245a, 528a, 530a; Plymouth Co. 1190; Sioux Co. 1591.

Synaptomys cooperi gossii (Coues) - Southern Bog Lemming

General Distribution in Iowa: Mainly southern two-thirds.

I. S. U. Records: Boone Co. 500a, 501a, 502a, 782a; Bremer Co. 317; Greene Co. 756a; Lucas Co. 1623; Marion Co. 1421; Pottawattamie Co. 1134; Van Buren Co. 384a.

Clethrionomys gapperi loringi (V. Bailey) - Gapper's Red-backed Vole

General Distribution in Iowa: Restricted to relict communities in 3 north-central counties.

I. S. U. Records: Hancock Co. 71, 1665, 1666, 1669; Winnebago Co. 1667; Worth Co. 1668.

Microtus o. ochrogaster (Wagner) - Prairie Vole

General Distribution in Iowa: Possibly entire state; mainly southern two-thirds.

I. S. U. Records: Appanoose Co. 391a, 393a, 398a; Boone Co. 345a,
Microtus p. pennsylvanicus (Ord) - Meadow Vole

**General Distribution in Iowa:** Possibly entire state; mainly northern three-fourths.

_I. S. U. Records:_ Allamakee Co. 1573, 1606, 1610; Black Hawk Co. 1217; Boone Co. 1271; Carroll Co. 726a, 727a, 728a, 732a, 733a; Clay Co. 113, 160a, 161a, 162a, 163a, 172a, 177a, 182a, 256, 1147, 1148; Clinton Co. 111; Dickinson Co. 10a, 11a, 190a, 199a; Dubuque Co. 65a, 74a, 85a, 87a; Emmet Co. 208a, 907, 908; Hamilton Co. 320a, 343; Hancock Co. 1236, 1249, 1731, 1748; Hardin Co. 1243; Henry Co. 1776; Howard Co. 806, 918, 1309, 1310; Ida Co. 1230, 1273; Jasper Co. 1247; Jones Co. 847, 872; Keokuk Co. 1781; Linn Co. 804, 834, 873, 881; Lyon Co. 224a, 225a, 523a, 545a, 554a, 555a, 558a, 574a, 586a, 587a, 588a, 593a, 595a, 606a, 617a, 618a; Madison Co. 1279; Mahaska Co. 1285; Marion Co. 1397; Palo Alto Co. 9a; Polk Co. 1592, 1737; Poweshiek Co. 314; Scott Co. 1433; Sioux Co. 1499, 1530, 1583; Story Co. 6a, 60, 73, 1389, 1549, 1579, 1611, 1619; Wapello Co. 1286; Webster Co. 1510, 1601; Woodbury Co. 1232; Worth Co. 1307, 1183; Wright Co. 1528.

Microtus pinetorum nemoralis V. Bailey - Woodland Vole

**General Distribution in Iowa:** Southern and eastern

_I. S. U. Records:_ Boone Co. 757a, 758a; Linn Co. 857; Van Buren Co. 380a, 388a.

Ondatra zibethicus - Muskrat

**Subspecies:** O. z. zibethicus (Linnaeus), O. z. cinnamominus (Holliester)

**General Distribution in Iowa:** Entire state.

_I. S. U. Records:_ Allamakee Co. 423a; Boone Co. 787a; Clark Co. 1426; Clay Co. 249a, 250a, 251a, 252a, 253a, 254a, 255a, 430a, 431a, 432a; Dubuque Co. 141a, 142a, 151a, 152a; Emmet Co. 911, 1109; Greene Co. 755a; Grundy Co. 1613; Hamilton Co. 321, 637a, 933; Iowa Co. 825; Johnson Co. 1469; Jones Co. 826; Kossuth Co. 319, 416a, 1581; Lyon Co. 259a, 599a; Story Co. 236a, 316a, 932; Winnebago Co. 415a; Winneshiek Co. 424a; Worth Co. 414a.

**Family Muridae**

Mus musculus Linnaeus - House Mouse

**General Distribution in Iowa:** Entire state.

_I. S. U. Records:_ Adair Co. 1501; Black Hawk Co. 1218, 1633; Boone Co. 13, 1532; Buena Vista Co. 1290; Decatur Co. 1210; Delaware Co. 1292; Des Moines Co. 100; Dubuque Co. 101a; Emmet Co. 906, 920; Fayette Co. 1234; Floyd Co. 12; Franklin Co. 1593; Fremont Co. 1717,
Rattus norvegicus (Berkenhout) - Norway Rat

General Distribution in Iowa: Entire state.

I. S. U. Records: Adair Co. 1597; Boone Co. 331; Cerro Gordo Co. 1222, 1721; Delaware Co. 370; Emmet Co. 912, 913, 1107; Jackson Co. 114a; Jasper Co. 1728, 1759; Linn Co. 856; Lyon Co. 614a; Madison Co. 1284; Mitchell Co. 1527; Polk Co. 1678, 1750; Story Co. 1338, 1575, 1600; Wayne Co. 1429; Woodbury Co. 1567, 1570; Worth Co. 1752.

Family Zapodidae

Zapus hudsonius intermedius Krutzsch - Meadow Jumping Mouse

General Distribution in Iowa: Mostly northern one-half; rare in south.

I. S. U. Records: Allamakee Co. 1349, 1676; Calhoun Co. 1622, 1632; Cerro Gordo Co. 1200; Clay Co. 103, 117, 659a, 1149, 1150, 1151, 1152; Delaware Co. 842; Dickinson Co. 188a, 201a, 202a; Emmet Co. 223a, 898, 899, 900; Hamilton Co. 326a, 327a, 328a, 329a, 335a, 341a; Hancock Co. 25, 1174; Kossuth Co. 1153; Lyon Co. 515a, 539a, 549a, 561a, 570a, 598a, 600a; Palo Alto Co. 1155; Pocahontas Co. 1733, 1765; Sioux Co. 1541; Union Co. 1432; Winnebago Co. 1480; Worth Co. 1671.

ORDER CARNIVORA

Family Canidae

Canis latrans themnos Jackson - Coyote

General Distribution in Iowa: Probably entire state; mainly western counties.

I. S. U. Records: Adams Co. 1780; Cherokee Co. 1122; Davis Co. 813; Decatur Co. 46a; Harrison Co. 44a.

Vulpes fulva regalis Merriam - Red Fox

General Distribution in Iowa: Entire state.

I. S. U. Records: Cerro Gordo Co. 133a; Decatur Co. 54a; Dubuque Co. 137a; Emmet Co. 45a, 1123; Harrison Co. 47a; Story Co. 143a.

Urocyon cinereoargenteus ocythous Bangs - Gray Fox

General Distribution in Iowa: Possibly entire state; mainly eastern and southern.

I. S. U. Records: Adams Co. 1785; Dubuque Co. 144a.
Family Procyonidae

Procyon lotor hirtus Nelson and Goldman - Raccoon

General Distribution in Iowa: Entire state.
I.S.U. Records: Boone Co. 496a, 794a, 795a; Howard Co. 486a; Muscatine Co. 1318; Van Buren Co. 379a.

Family Mustelidae

Mustela erminea bangsi Hall - Ermine

General Distribution in Iowa: Northern two-thirds.
I.S.U. Records: Boone Co. 503a; Clay Co. 164a; Dickinson Co. 896; Emmet Co. 895, 897; Hancock Co. 1250; Kossuth Co. 260, 267; Poweshiek Co. 1347; Winnebago Co. 418a, 433a, 434a, 435a, 436a, 437a, 438a; Worth Co. 439a.

Mustela frenata - Long-tailed Weasel

Subspecies: M. f. primulina Jackson, M. f. spadix (Bangs)
General Distribution in Iowa: Probably entire state.
I.S.U. Records: Boone Co. 119a, 120a, 499a, 641, 775a, 799a; Buena Vista Co. 628a; Calhoun Co. 425a; Davis Co. 399; Dubuque Co. 140a; Hamilton Co. 774a; Hardin Co. 475a; Kossuth Co. 55; Lyon Co. 231a, 537a, 541a, 607a; Story Co. 497a, 642a, 1213; Van Buren Co. 474a; Webster Co. 426a, 427a, 440a.

Mustela nivalis campestris Jackson - Least Weasel

General Distribution in Iowa: Northern two-thirds.
I.S.U. Records: Boone Co. 1774; Buena Vista Co. 1268; Butler Co. 629a, 630a, 631a; Clay Co. 112; Hamilton Co. 344, 348; Hancock Co. 1470; Jones Co. 664; Kossuth Co. 417a; Scott Co. 1208, 1308; Story Co. 1159, 1344.

Mustela vison - Mink

Subspecies: M. v. betifera Hollister, M. v. mink Peale and Palisot de Beauvois.
General Distribution in Iowa: Entire state.
I.S.U. Records: Allamakee Co. 449a, 451a, 460a; Boone Co. 36a, 768a, 785a, 786a, 788a, 789a, 791a, 792a, 793a, 796a; Decatur Co. 39a, 40a; Dubuque Co. 82a, 153a; Emmet Co. 1108; Floyd Co. 464a, 465a, 466a, 467a, 468a; Howard Co. 453a, 461a, 462a, 463a; Kossuth Co. 452a; Mills Co. 493a; Mitchell Co. 454a, 455a, 456a; Polk Co. 369; Story Co. 495a, 763a; Winnebago Co. 441a, 442a, 4444a, 445a, 446a, 447a, 448a, 457a, 458a, 459a; Worth Co. 450a; Wright Co. 1649.

Gulo l. luscus (Linnaeus) - Wolverine

General Distribution in Iowa: Accidental
I.S.U. Records: Tama Co. 1657.

Taxidea t. taxus (Schreber) - Badger

General Distribution in Iowa: Probably entire state.
I.S.U. Records: Boone Co. 783a; Clay Co. 166a, 1124; Dickinson Co. 1062; Dubuque Co. 139a; Emmet Co. 1127; Howard Co. 494a; Story Co. 784a.
Spilogale putorius interrupta (Rafinesque) - Spotted Skunk

General Distribution in Iowa: Probably entire state.

I. S. U. Records: Boone Co. 797a; Crawford Co. 707a; Decatur Co. 42a; Emmet Co. 1106; Greene Co. 747a; Lee Co. 360a; Lyon Co. 592a; Marshall Co. 410a; Monona Co. 679a; Story Co. 762a; Van Buren Co. 385a.

Mephitis mephitis - Striped Skunk

Subspecies: M. m. avia Bangs, M. m. hudsonica Richardson.

General Distribution in Iowa: Probably entire state.

I. S. U. Records: Boone Co. 790a, 798a, 800a, 801a; Clay Co. 165a; Fremont Co. 264a; Grundy Co. 485a; Hamilton Co. 61a; Howard Co. 471a, 473a; Kosseuth Co. 419a, 420a, 470a, 482a, 483a; Lyon Co. 522a, 542a, 559a, 577a, 609a, 623a; Mills Co. 304a; Mitchell Co. 429a, 469a, 487a, 488a, 489a; Monona Co. 701a; Ringgold Co. 821; Story Co. 38a; Winnebago Co. 472a, 490a, 491a, 492a; Worth Co. 421a.

Lutra c. canadensis (Schreber) - Otter

General Distribution in Iowa: Rare; probably along large river systems.


Family Felidae

Lynx r. rufus (Schreber) - Bobcat

General Distribution in Iowa: Rare; probably entire state in suitable habitat.

I. S. U. Records: Jones Co. - 929.

ORDER ARTIODACTYLA

Family Cervidae

Odocoileus virginianus macroura (Rafinesque) - White-tailed Deer

General Distribution in Iowa: Entire state.

I. S. U. Records: Clinton Co. 1662; Dickinson Co. 1660; Floyd Co. 1661; Jones Co. 1658; Mitchell Co. 1659; Pottawattamie Co. 1663; Woodbury Co. 1664.
ABSTRACT. The rate of 2nd-brood European corn borer, Ostrinia nubilalis (Hübner), larval mortality was determined for 6 inbred lines of dent corn by dissecting plants 3, 6, 9, 12, 18 and 35 days after egg hatch. More than 95% 2nd-brood larval mortality occurred on resistant lines such as B52 within 3 days after egg hatch. The data indicate a high degree of antibiosis to the 1st- and 2nd-instar larvae of a 2nd-brood infestation.

Collar and sheath feeding damage were severe on highly susceptible inbred lines such as W22. The majority of 2nd-brood larvae were found feeding around the collar and behind the sheath 3, 6, 9, 12 and 18 days after egg hatch. Therefore, 2nd-brood resistance factors may be associated primarily with collar and sheath tissue; however, the husks and silks were also favorite larval feeding sites through 18 days of age.

Most research on the resistance of the host plant to the European corn borer, Ostrinia nubilalis (Hübner), has involved the 1st-brood. Factors that inhibit 1st-brood borer establishment and survival on resistant lines are operative against the early larval instars in the whorl stage of plant development and can be measured directly in terms of the extent of leaf blade feeding. Resistance in some inbred lines has also been evaluated by leaf sheath and collar feeding by 3rd- and 4th-instar larvae of the 1st-brood (Guthrie et al. 1960). Methods for rapidly evaluating leaf feeding resistance are available (Guthrie et al. 1960). A considerable number of inbred lines used in hybrid combination are resistant to leaf feeding (Stringfield 1959; Guthrie et al. 1960). Many hybrids contain at least an intermediate degree of resistance; some hybrids are highly resistant.
Methods of screening inbred lines of corn for resistance to a 2nd-brood infestation have been determined, and a source of dent corn germ plasm resistant to a 2nd-brood infestation has been located (Pesho et al. 1965).

Biological relationships between the corn borer and the corn plant are not the same for both broods. During the period of egg deposition by the 1st brood, most of the dent corn in the Corn Belt States is in the whorl stage of plant development; tassel emergence occurs primarily after the 1st-brood hatching period. On such corn, the primary point of establishment and survival of the young larvae is in the whorl on the spirally rolled leaves. As long as the tassel remains well surrounded by the whorl leaves it is not involved in establishment of the newly hatched larvae (Dicke 1954).

During the period of egg deposition by the 2nd brood, early planted corn in the Corn Belt States has tasseled and has completed the pollen shedding stage of plant development; late-planted corn is in the pollen shedding stage during part of the 2nd-brood oviposition period. The initial establishment by the 1st-instar larvae of the 2nd brood is on pollen accumulation at the axils of the leaves and behind the sheath and on ear shoots, husks, and silks (Dicke 1950; Guthrie et al. 1969).

In host plant resistance investigations, the whorl leaf feeding type of resistance must be considered separately from a 2nd-brood infestation until breeding methods for selecting for both broods in the same plant population can be determined. Inbred lines resistant to leaf feeding (1st brood) are not necessarily resistant to a 2nd-brood infestation. For example, Oh43 is resistant to a 1st-brood infestation (Guthrie et al. 1960) but susceptible to a 2nd-brood infestation (Pesho et al. 1965). Inbred B52 is highly resistant to a 2nd-brood infestation (Pesho et al. 1965) but intermediate in resistance to a 1st-brood infestation (Klun and Brindley 1966).

Considerable information has been obtained on the genetic basis of leaf-feeding resistance by the European corn borer (Patch et al. 1942; Schlosberg and Baker 1948; Singh 1953; Ibrahim 1954; Penny and Dicke 1956, 1957; Scott et al. 1964, 1966). The genetic basis of 2nd-brood resistance is unknown, although data from 45 diallel crosses among 10 inbred lines (5 resistant and 5 susceptible) indicate that the high resistance of B52 is transmitted in hybrid combination (Scott et al. 1967). The study reported herein was designed to determine the rate of 2nd-brood larval mortality in 6 inbred lines of dent corn.

METHODS AND MATERIALS

These studies were begun in 1966 and concluded in 1968. The experimental methods were similar for the 3 years. The 6 inbred lines (B52, B49, R101, WF9, W22 and Oh43) were planted in randomized blocks consisting of 5 3-plant hills 6-row plots. The distance between rows and between hills within a row was 40 in. Six-fold replication was used in 1966 and 1968; 3-fold replication was used in 1967. To avoid a 1st-brood infestation, plots were planted late (June 3, 1966, June 22, 1967, and May 29, 1968). Nine plants in each plot were artificially infested with 9 egg masses, or approximately 180 eggs per plant. Moths originating
from larvae reared on a meridic diet for 3 to 8 generations were used for egg production. The infestation was made in 3 applications of 3 masses, each spaced 1 day apart. Egg masses incubated to near the hatching point were pinned through the leaf midrib under the ear leaf and under the leaf above and below the ear during the active pollen-shedding stage as described by Pesho et al. (1965). The pollen-shedding date was 14 to 22 days later for B52 and B49 than for Oh43, depending on the season. Variability was introduced by applying egg masses over a period of time under varying bioclimatic conditions. However, since increased survival of 2nd-brood larvae is associated with anthesis (Dicke 1950; Guthrie et al. 1969), egg masses were applied at a comparable stage of plant development rather than at a constant environment.

The pattern of larval survival on the inbred lines was determined by dissecting a sample of 9 plants in each plot 3, 6, 9, 12, 18 and 35 days after egg hatch. The samples in each of the dissection intervals were taken at random from all plots in a split plot arrangement.

Lesions and cavity counts were made in 1968 on the 35-day dissection interval. Lesions in the sheath were calculated on the basis of the number and size of the lesion; i.e., a lesion 1 in. long was counted as 1 lesion, but a lesion 6 in. long was counted as 6 lesions (Fig. 4). Likewise, a lesion that girdled 1/3 of the collar was counted as 1 lesion, a lesion that girdled 2/3 of the collar was counted as 2 lesions, and a lesion completely girdling the collar, as in Fig. 2, was counted as 3 lesions. A lesion completely girdling the sheath at the point of attachment to the node, as in Fig. 3, was counted as 3 lesions.

Since the plots were planted in randomized blocks and plant dissections were made in a split-plot arrangement, the data on surviving larvae were analyzed according to split-plot procedure (Cochran and Cox 1950). The inbred lines were on the whole-plot area, and the dissection intervals of 3, 6, 9, 12, 18 and 35 days after egg hatch were on the split-plot area. The lesion and cavity data were analyzed according to randomized block procedure (Cochran and Cox 1950).

**RESULTS AND CONCLUSIONS**

The analysis of variance showed highly significant differences between inbreds, dissection intervals, and the interaction of inbreds X dissection intervals for larvae during each of the 3 years, and highly significant differences between inbreds for lesions and cavities.

The performance of the inbred lines for each dissection interval of 3, 6, 9, 12, 18 and 35 days after egg hatch (interaction of inbreds X dissection intervals), which measures the rate of 2nd-brood larval mortality on each inbred line, is of greatest interest. These data are recorded in Tables 1, 2 and 3 for 1966, 1967 and 1968, respectively. The data on the main effect of inbred lines and the main effect of dissection intervals are of little interest and are not recorded.

A high level of larval establishment and survival resulted from the artificial infestation in 1966. A much lower level of larval survival resulted from the artificial infestation in 1967; the corn plants were stunted because of dry weather conditions during the growing season. Egg deposition by the natural moth population was negligible in 1966 and 1967.
Table 1. Mean number of 2nd brood larvae per plant by inbred line and dissection interval (6 replications). Ankeny, Iowa 1966.

<table>
<thead>
<tr>
<th>Inbred line</th>
<th>3</th>
<th>6</th>
<th>9</th>
<th>12</th>
<th>18</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>B52</td>
<td>4.4</td>
<td>3.8</td>
<td>4.2</td>
<td>3.3</td>
<td>4.1</td>
<td>3.4</td>
</tr>
<tr>
<td>B49</td>
<td>4.4</td>
<td>1.9</td>
<td>2.0</td>
<td>2.8</td>
<td>4.8</td>
<td>3.2</td>
</tr>
<tr>
<td>R101</td>
<td>15.9</td>
<td>12.2</td>
<td>8.5</td>
<td>7.7</td>
<td>7.9</td>
<td>9.2</td>
</tr>
<tr>
<td>WF9</td>
<td>10.2</td>
<td>9.5</td>
<td>11.0</td>
<td>9.2</td>
<td>9.8</td>
<td>11.6</td>
</tr>
<tr>
<td>W22</td>
<td>15.0</td>
<td>11.4</td>
<td>10.7</td>
<td>15.7</td>
<td>13.3</td>
<td>15.9</td>
</tr>
<tr>
<td>Oh43</td>
<td>26.9</td>
<td>13.9</td>
<td>21.8</td>
<td>21.5</td>
<td>17.0</td>
<td>19.8</td>
</tr>
</tbody>
</table>

Standard error of difference between:

Any 2 means between dissection interval for the same inbred. 1.58

Any 2 means between inbreds for the same dissection interval. 1.62

LSD .05

Any 2 means between dissection intervals for the same inbred. 3.13

Any 2 means between inbreds for the same dissection interval. 3.24

*Number of days plants were dissected after egg hatch.
Table 2. Mean number of 2nd brood larvae per plant by inbred line and dissection interval (3 replications). Ankeny, Iowa, 1967.

<table>
<thead>
<tr>
<th>Inbred</th>
<th>Dissection interval&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>B52</td>
<td>11.1</td>
</tr>
<tr>
<td>B49</td>
<td>9.5</td>
</tr>
<tr>
<td>R101</td>
<td>8.0</td>
</tr>
<tr>
<td>WF9</td>
<td>9.9</td>
</tr>
<tr>
<td>W22</td>
<td>10.2</td>
</tr>
<tr>
<td>Oh43</td>
<td>11.8</td>
</tr>
</tbody>
</table>

Standard error of difference between:

Any 2 means between dissection intervals for the same inbred. 1.62

Any 2 means between inbreds for the same dissection interval. 1.73

LSD .05

Any 2 means between dissection intervals for the same inbred. 3.24

Any 2 means between inbreds for the same dissection interval. 3.57

<sup>a</sup>Number of days plants were dissected after egg hatch.
Table 3. Mean number of 2nd brood larvae, lesions, and cavities per plant by inbred line and dissection interval (6 replications).

Ankeny, Iowa, 1968.

<table>
<thead>
<tr>
<th>Inbred line</th>
<th>Dissection intervala/</th>
<th>Larvae</th>
<th>Lesionsb/</th>
<th>Cavitiesc/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3  6  9  12  18  35  35  35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B52</td>
<td>3.1 3.4 3.2 2.7 3.3 4.1 5.1 0.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B49</td>
<td>5.0 2.9 2.3 2.0 4.3 7.7 4.5 3.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R101</td>
<td>4.9 6.5 4.8 3.5 4.7 6.8 10.9 2.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WF9</td>
<td>6.0 8.4 8.3 8.8 8.6 8.8 12.3 8.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W22</td>
<td>5.7 10.1 9.1 9.9 9.9 16.5 18.5 8.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oh43</td>
<td>6.5 7.3 9.6 9.5 10.7 11.3 16.6 9.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Standard error of difference between:

- Any 2 means between dissection interval for the same inbred (larvae). 0.95
- Any 2 means between inbreds for the same dissection interval (larvae) 1.08

LSD .05

- Any 2 means between dissection interval for the same inbred (larvae). 1.87
- Any 2 means between inbreds for the same dissection interval (larvae) 2.16

a/ Number of days plants were dissected after egg hatch.

b/ Lesions refer to feeding damage on the sheath and around the collar.

LSD .05 for lesions = 4.1

c/ LSD .05 for cavities = 1.5
Moths used for egg production in 1968 were heavily infected with the microsporidian *Perezia pyrausta* Paillot (L. C. Lewis and R. L. Lynch, unpublished data); this microsporidian drastically affects egg production of the European corn borer (Zimmack and Brindley 1957) and hatchability of the eggs (Kira et al. in press). The number of larvae recovered 3 days after egg hatch (Table 3) shows that a low level of larval survival resulted from the artificial infestations in 1968. However, egg deposition by the natural moth population was high; the egg load on plants increased on each successive dissection interval. Therefore, the number of larvae recovered on most inbred lines increased as the season progressed instead of decreasing as in 1966 and 1967. The 1968 data may include the effect of preference of moths from the natural 2nd-brood population for the different inbred lines as oviposition sites.

Larval mortality on inbred line B52 was very rapid. Only 4.4, 11.1, and 3.1 larvae per plant survived 3 days after egg hatch in 1966, 1967, and 1968, respectively, thus resulting in a larval mortality more than 95%. In general, there was no appreciable larval mortality on this line beyond 3 days after egg hatch (except in 1967). The fast rate of larval mortality was also reflected in a low lesion count (5.1 per plant, Table 4) and number of cavities (0.7 per plant, Table 4). A heavy egg load from the natural 2nd-brood moth population in 1968 did not increase larval numbers. These data show that B52 was highly resistant to 1st- and 2nd-instar larvae of a 2nd-brood infestation (Fig. 1), which confirms the results obtained by Pesho et al. (1965). B52 is intermediate in leaf-feeding (1st-brood) resistance (Klan and Brindley 1966).

Larval mortality also was rapid on B49; 4.4, 9.3, and 5.0 larvae per plant survived 3 days after egg hatch in 1966, 1967 and 1968, respectively. There was no appreciable mortality on this line beyond 3 days after egg hatch. A heavy egg load from the natural 2nd-brood moth population in 1968 increased larval numbers (7.7 larvae per plant 35 days after egg hatch compared with 5.0 larvae per plant 3 days after egg hatch). This line also had a low lesion count (4.5 per plant) and low cavity count (3.5 per plant). B49 was resistant to intermediate to the 1st- and 2nd-instar larvae of a 2nd-brood infestation; Pesho et al. (1965) classified B49 intermediate. B49 is also resistant to a 1st-brood (leaf feeding) infestation (Klan and Brindley 1966).

The rate of larval mortality was considerably slower on R101 than it was on B52 and B49; 15.9, 8.0, and 4.9 larvae per plant survived 3 days after egg hatch in 1966, 1967 and 1968, respectively. The heavy egg load from the natural moth population in 1968 increased larval numbers from 4.9 larvae per plant 3 days after egg hatch to 6.8 larvae per plant 35 days after egg hatch. R101 had a relatively high lesion count (10.9 per plant); the low cavity count (2.9 per plant) would indicate that this inbred has resistance to stalk invasion. Compared with B52, R101 was intermediate in resistance to a 2nd-brood infestation; Pesho et al. (1965) classified this inbred resistant to intermediate. Data reported by Klun and Brindley (1966) indicated that R101 is intermediate in 1st-brood (leaf-feeding) resistance. However, Guthrie and Huggans (unpublished data) evaluated R101 for 1st brood resistance in 1965, 1966 and 1967 under a heavy artificial infestation with a total of 10 replications and found it highly susceptible.
WF9 had a considerably slower rate of larval mortality than did B52 and B49; 10.2, 9.9 and 6.0 larvae per plant surviving 3 days after egg hatch in 1966, 1967 and 1968, respectively. In general the larval population did not decrease appreciably beyond 3 days after hatch; a heavy egg load from the natural moth population in 1968 increased larval survival from 6.0 larvae per plant 3 days after egg hatch to 8.8 larvae per plant 35 days after egg hatch. This inbred had 12.3 lesions and 8.0 cavities per plant 35 days after egg hatch. WF9 was susceptible to a 2nd-brood infestation; Pesho et al. (1965) classified this inbred susceptible. WF9 is also highly susceptible to a 1st brood (leaf-feeding) infestation (Guthrie et al. 1960).

W22 had a slow rate of larval mortality; 15.0, 10.2, and 5.7 larvae per plant survived 3 days after egg hatch in 1966, 1967 and 1968, respectively. The larval population remained at a high level and did not
decrease appreciably beyond 3 days after egg hatch. The heavy egg load from the natural moth population in 1968 increased larval numbers from 5.7 larvae per plant 3 days after egg hatch to 16.5 larvae per plant 35 days after egg hatch. Collar and sheath feeding damage was severe on W22 (18.5 lesions per plant). Many lesions almost completely girdled the collar (Fig. 2). Many sheaths were almost completely girdled at the point of attachment to the node (Fig. 3). Figure 4 shows extensive damage to sheath tissue. The cavity count (8.0 per plant) was similar to the cavity count for Wf9. W22 was highly susceptible to a 2nd-brood infestation (Fig. 5); Pesho et al. (1965) also classified this inbred susceptible. W22 is intermediate in resistance to a 1st-brood infestation (Klun and Brindley 1966).

Oh43 had a slow rate of larval mortality; 26.9, 11.8 and 6.5 larvae per plant survived 3 days after egg hatch in 1966, 1967 and 1968, respectively. In 1966, the larval population decreased from 26.9 larvae per plant 3 days after egg hatch to 19.8 larvae per plant 35 days after egg hatch. In 1967, the larval population decreased from 11.8 larvae per plant 3 days after egg hatch to 7.5 larvae per plant 35 days after egg hatch. A heavy egg load from the natural moth population in 1968 increased larval numbers from 6.5 larvae per plant 3 days after egg hatch to 11.3 larvae per plant 35 days after egg hatch. The larval population remained at a high level and did not decrease appreciably beyond 6 days after egg hatch. The high larval population in 1968 also is reflected in a high lesion count (16.6 per plant) and high cavity count (9.6 per plant). Oh43 was highly susceptible to a 2nd-brood infestation; Pesho et al. (1965) classified this inbred intermediate to susceptible. Oh43 is resistant to a 1st-brood (leaf-feeding) infestation (Guthrie et al. 1960).

Larval Mortality in Inbred Lines

Most of the 1st-brood larval mortality on resistant inbred lines occurs during the 1st few days after egg hatch. This high rate of larval mortality is a high degree of antibiosis against the 1st- and 2nd-instar larvae of a 1st-brood infestation (Guthrie et al. 1960).

More than 95% 2nd brood larval mortality occurred on inbred lines resistant to a 2nd-brood infestation within 3 days after egg hatch; these data indicate a high degree of antibiotic to 1st- and 2nd-instar larvae of a 2nd-brood infestation.

Second-Brood Larval Feeding Sites

The data in Table 4 show that the majority of 2nd brood larvae feed around the collar and behind the sheath 3, 6, 9, 12 and 18 days after egg hatch. Approximately 1/4 of the larvae were located behind the sheath on most of the inbreds 35 days after egg hatch. Therefore, 2nd brood resistance factors may be associated primarily with collar and sheath tissue; however, the husks and silks were also favorite larval feeding sites through 18 days of age. Collar and sheath feeding damage were severe on highly susceptible inbred lines such as W22 and Oh43.
Figure 2. W22 high susceptible to 2nd brood. A lesion which almost completely girdled the collar. 1968

Figure 3. W22 susceptible to 2nd brood. Sheath almost completely girdled at attachment to node. 1968.
Figure 4. W22 highly susceptible to 2nd brood. Sheath lesions. 1968.

Figure 5. W22 highly susceptible to 2nd brood. 1968.
Table 4. Feeding sites of 2nd brood larvae (averaged over 3 years). Ankeny, Iowa.

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<sup>a</sup> Days after egg hatch on which the plants were dissected.
FEEDING RESISTANCE OF SOME CORN HYBRIDS

REFERENCES CITED


INFLUENCE OF EGG SOURCE ON THE EFFICACY OF EUROPEAN CORN BORER LARVAE

J. L. Huggans and W. D. Guthrie

Entomology Research Division
Agr. Res. Serv., U.S. D. A.
Ankeny, Iowa 50021

ABSTRACT. In 1965, 1966, and 1967, a comparison was made of infestation produced on a susceptible dent corn inbred, WF9, by progeny from a wild European corn borer, Ostrinia nubilalis (Hübner), population vs. progeny from borers reared for 2 (F₂), 34 (F₃₄), and 45 (F₄₅) generations on a meridic diet. In 1968, progeny from crosses of wild X F₅₄ (reared 54 generations on a meridia diet) moths were compared with progeny from the wild and F₅₄ parents. The 4 to 5 weeks of wild 1st generation moth emergence were divided each year into 4 sections, early to late in the season, and progeny from moths in each section were compared simultaneously with colonized borers that were similarly divided. The oviposition period of moths in each borer type for each moth emergence date was subdivided into 2- or 3-day segments for further comparison of the progeny. Samples of each type of larvae were reared on a meridic diet in the laboratory for comparison of developmental rates and mortality.

Four parameters were used in comparison of borers: 1 and 2) larval survival 7-8 days and 21-30 days after egg hatch, 3) leaf feeding ratings, and 4) lesion counts. In the laboratory, percentage pupation 21 days after egg hatch and final pupation were used in comparing borer types.

Larval establishment and survival from borers reared continuously on a meridic diet for 34, 45 or 54 gen-

1 Lepidopterae: Pyraustidae
2 Journal Paper No. J-6244 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project 1687. A portion of a dissertation presented by James L. Huggans in partial fulfillment of the requirements for the degree Doctor of Philosophy in Entomology at Iowa State University of Science and Technology. Accepted for publication July 1, 1969.
3 Presently Department of Entomology, University of Missouri, Columbia Mo. 65202.
4 Also Associate Professor, Iowa State University of Science and Technology, Ames, Iowa 50010.
erations was at a low level compared with wild and F₂ borers. An intermediate level of larval survival occurred between crosses of wild X F₅₄ parent moths; however, progeny from the wild ♀ X F₅₄ ♂ cross had a higher level of survival than did progeny from the F₅₄ ♀ X wild ♂ cross, indicating a greater maternal than paternal influence on the progeny.

Differences in leaf feeding ratings and in lesion counts between borer type were, for the most part, attributable to 1) poor initial larval survival of the borers reared continuously on a meridic diet and 2) some egg sterility in borers reared on a meridic diet. These data indicate that the European corn borer reared continuously on the meridic diet used in this experiment should not be used for screening inbred lines for resistance because the leaf feeding ratings were too low for measuring differential resistance.

Progeny from moths of different emergence dates differed significantly when measured by the 4 criteria within a particular year but did not differ significantly when averaged over the 3-year period. Larval survival and resulting feeding damage caused by borers that originated at different times within the oviposition period were more uniform for colonized borers than for wild borers. Larvae originating from portions of the oviposition period of colonized borers gave significant differences in survival and damage; however, the magnitude of the differences was low. Wild borers originating from different portions of the oviposition period were not significantly different.

Larval development in the field progressed at the same rate for all borer types. In the laboratory, F₃₄ and F₄₅ borers developed slower than wild or F₂ borers on a meridic diet and a greater mortality occurred in the continuously reared colonies.

In host plant resistance investigations, artificial infestations are necessary to obtain a uniform and satisfactory level of larval establishment. Until recently, egg masses for infestations of the 1st and 2nd generation of the European corn borer, Ostrinia nubilalis (Hübner), were obtained by placing infested corn stalks in large outdoor cages and collecting the emerged adults, which were than caged for egg production (Patch and Peirce 1933, Guthrie et al. 1965). Moth emergence of the 1st generation usually extends over a 4- to 5-week period beginning in late May and lasting through June in Iowa.

Dulizibaric (1966) found that maximum fertility of wild European corn borer females occurred toward the middle of the moth emergence period and fertility decreased in both directions from the middle; i.e., being least at the beginning and end of emergence.

Inbred lines are infested during the mid-whorl stage of plant develop-
ment in 1st brood resistance investigations (Guthrie et al. 1960). Late planted corn is infested with egg masses from moths emerging during the last week of the emergence period.

From observation in the field over many years, Pesho et al. (1964) and W. D. Guthrie and F. F. Dicke think that borers from eggs laid at the end of both moth emergence and oviposition periods do not become established on inbred lines or hybrids as well as earlier laid eggs.

Pesho et al. (1964) compared larval establishment and damage incurred to a susceptible dent corn hybrid from artificial infestations by borers reared for 1 generation on a meridic diet with 2nd brood wild populations from Ohio and Iowa, which were confined in cages for egg production; an infestation from a natural 2nd-brood Iowa moth population was also used in this study. Pesho et al. (1964) showed a highly significant difference in number of surviving larvae and in number of cavities among the different sources of egg masses. No difference was shown among the 3 manually applied infestations. But each of the manual treatments differed from the natural infestation. In subsequent tests, differences in number of larvae and cavities were obtained between the wild culture and the laboratory colony, but the authors indicated that the differences were the result of the egg sources not being synchronized properly with respect to moth age. Eggs from the wild culture were from the middle of the oviposition period but those from the laboratory colony were from near the end. Thus borers from the mid-period eggs probably had an advantage. The egg viability data of the borer groups supported this contention.

Techniques for rearing borers on meridic diets have been reported by Beck et al. (1949), Beck (1953), Bottger (1942), Becton et al. (1962), Surany (1957), Wressel (1955), and Guthrie et al. (1965).

Since 1960, the European corn borer has been reared continuously throughout the year on a meridic diet. Egg masses originating from moths reared on a meridic diet are used for field infestations in 1st and 2nd brood studies. The efficacy of laboratory reared borers in relation to their wild counterparts, however, has not been investigated.

The age of the female moth when oviposition occurs has also been thought to contribute to the variability in larval establishment in field tests. As the female moth ages, the eggs produced near the end of her reproductive life have not yielded a satisfactory infestation.

The problem of larval establishment, survival, and efficacy in field and laboratory tests is concerned, in part, by the date on which the parental moth emerges in the spring, the parental source of egg masses (i.e., wild vs. laboratory reared) and the age of the female parent when the eggs are laid.

The purpose of our study has been to compare the rate of larval establishment and damage on a susceptible inbred line of dent corn, WF9, from:

1. Progeny originating from borers reared on a meridic diet with progeny from wild type moths.
2. Progeny from a wild X F$_{54}$ cross with progeny from the wild and F$_{54}$ parents.

5 Consultant for Pioneer Hi-Bred Corn Co., Johnston, Iowa.
3. Moths that emerged at different times in the spring within the normal emergence period.
4. Borers originating from eggs laid at different times within the oviposition period of each source of moths.

Procedure

Wild Borer Source of Egg Production
Each fall, infested corn stalks were placed in large screened emergence cages for a source of wild moths for egg production the following spring. Egg production and artificial infestation techniques as described by Guthrie et al. (1965) were used in these experiments.

Colonized Borer Source of Egg Production
The method of mass rearing European corn borer on meridic diets, as described by Guthrie et al. (1965), was used with some modifications. One modification facilitated collection of pupae from the plastic rearing dishes; 1 X 40 in. corrugated cardboard strips were attached to the inner wall of each dish 12 days after the dishes were "seeded" with borer egg masses. Full-grown larvae migrated to these strips and pupated within the cells of the strips. At 21 days the strips were removed from the dishes and hung in an indoor, screened, walk-in cage for moth emergence. Collection of moths was made daily. Groups of 100 male and female moths were isolated in oviposition cages kept in a large walk-in incubator similar to that used for the wild moths. Equal numbers of laboratory reared males and females were caged together because the moths were essentially virgin at the time of collection. To enhance mating of the laboratory reared moths, temperature in the egg production incubator was cycled with an 18-hour period at 80°F and 80-90% RH alternated with 6 hr at 65°F and 80-90% RH (Sparks 1963). This cycling was unnecessary in the wild borer incubator since many of the female moths had already mated. Both oviposition incubators were kept dark except for 3 hr each morning when the eggs were collected and the moths given water by spraying the cages and for a few minutes in the late afternoon when the moths were again given water.

Another modification of the laboratory rearing technique was made in 1967. Approximately 400-600 larvae were used instead of 200 eggs to "seed" each rearing container because the low number of moths recovered per dish in 1965 and 1966 was primarily due to the low number of eggs used and variability in egg hatch.

Borer Types

In 1965 moths originating from larvae reared for 2 generations (F2) on a meridic diet and wild moths were used for egg production. The microsporidian, Perezia pyraustae Paillot, was partially controlled in the F2 generation colony by using an egg heat treatment described by Raun (1961). In 1966, moths originating from larvae reared for 34 generations (F34) on a meridic diet and wild moths were used for egg production. In 1967, a new colony was developed from wild moths and reared for 2 generations on a meridic diet. The F34 colony used in 1966
had advanced to the 45th generation (F_{45}). In 1968, the F_{45} colony had advanced to the 54th generation (F_{54}).

Moth Emergence Dates

Wild moths were collected on 4 dates, which covered the range of field emergence. The first (I) or early date was selected from the daily collections made within the 1st week of emergence; the 2nd date (II) was selected approximately 1 week later just before the peak of emergence; the 3rd date (III) was selected shortly after the peak of emergence occurred; and the 4th date (IV) was selected near the end of the moth emergence period.

When each emergence date of the wild population was selected, the corresponding laboratory reared moths were also collected for egg production. The production of borers reared on a meridic diet was a continuous process; therefore, there was no actual beginning or end to the emergence period, and it was postulated that there should be no difference in early- and late-emerging borers if standard production methods were followed throughout the test. At periods when moth production was low in the laboratory colonies, 2 days of moth collection were used concurrently for a specific emergence date. In this event, the eggs produced by the 2 different groups of females were handled separately so that proper timing within the oviposition period could be followed. The moth emergence dates and number of female moths cages for egg production are listed in Table 1.

Oviposition Periods

Under conditions used for the production of egg masses at the Corn Borer Laboratory, Ankeny, Iowa, a group of moths usually lay eggs for about 10 days.

In 1965, the oviposition period was divided into three 3-day subperiods. In 1966 and 1967, the oviposition period was divided into four 2-day subperiods. The level of larval establishment on inbred WF9 was determined for each of these oviposition subperiods.

Egg Incubation and Field Infestation

From each day's egg production, approximately 600 egg masses per moth group were incubated at 80°F and 80% RH. Under these conditions the eggs reached the blackhead stage of development, which is within a few hours of eclosion, in 4 days. The eggs of the 1st day of 1 oviposition period, 1 emergence date, and moth colony were taken in the field, and 2 masses of approximately 25 eggs each were placed in the whorl of each of the 24 plants per plot designated for that test unit. A 2nd application of masses was made the following day, the source of which was the 2nd or last day of the same oviposition period.

Occasionally the corn plants to be used for testing a particular moth emergence date were not of desired height. In this event the eggs scheduled for use were incubated at 60°F and 80% RH which prolonged their development to 11 days. Egg masses from each moth colony,
Table 1. Moth emergence dates and number of females caged for egg production.

<table>
<thead>
<tr>
<th>Year</th>
<th>Type</th>
<th>Emergence dates</th>
<th>Number of Collection of Females</th>
<th>Number of Collection of Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>Wild</td>
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<td>6/15 4,550</td>
<td>6/19 6,090</td>
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<td></td>
<td></td>
<td></td>
<td>6/13 1,700</td>
<td>6/18 2,000</td>
</tr>
<tr>
<td>1966</td>
<td>Wild</td>
<td>6/15 1,045</td>
<td>6/18 3,990</td>
<td>6/19 7,840</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6/15 2,455</td>
<td>6/20 7,280</td>
</tr>
<tr>
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<td>Wild</td>
<td>6/13 1,071</td>
<td>6/15 6,585</td>
<td>6/18 11,280</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6/13 7,35</td>
<td>6/18 6,880</td>
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<td></td>
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<td>6/13 652</td>
<td>6/18 4,42</td>
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<td></td>
<td></td>
<td>6/13 6,04</td>
<td>6/18 6,30</td>
</tr>
</tbody>
</table>

An equal number of males were caged with the colonized moths and one-half the number with wild moths.
Field Tests

To allow full expression of damage, the field tests were conducted on a highly susceptible dent corn inbred, WF9. Split plots in a randomized complete block design with 4 replications were used each season. Two-row plots with 5 hills per row and 3 plants per hill made up the smallest test unit. Two-row guards were placed around the whole plot. Guard rows between plots of moth colony, moth emergence period, and oviposition period were not used in these experiments. The experimental units for each year were:

1965 whole plot - date of moth emergence
   subplot - oviposition period
   sub-subplot - moth colony

1966 whole plot - date of moth emergence
   subplot - moth colony
   sub-subplot - oviposition period

1967 whole plot - date of moth emergence
   subplot - oviposition period
   sub-subplot - moth colony

The whole plots were planted at approximately weekly intervals to correspond to the moth emergence dates. The divisions are shown schematically in Figure 1.

In 1968, progeny from a wild X F_{54} cross were compared for larval establishment and survival on WF9 with progeny from the wild and F_{54} parents. Moth matings were made as follows: wild ♀♀ X wild ♂♂, F_{54} ♀♀ X F_{54} ♂♂, wild ♀♀ X F_{54} ♂♂, and F_{54} ♀♀ X wild ♂♂. A randomized complete block with 10 replications was utilized. Two-row plots with 5 hills per row and 3 plants per hill made up the smallest test unit. Two guard rows were placed between each plot to avoid interplot migration of borer types. Four egg masses, or approximately 100 eggs, were manually applied to each plant in 2 applications of 2 masses each. Egg masses used for infesting these plots were from the 5th through the 8th day of the oviposition period for each borer group. Each of the 4 borer groups consisted of 500 pairs of moths.

The pattern of larval survival in these experiments was determined by dissecting at intervals of 7 or 8 and 21 or 30 days after egg hatch. Twelve infested plants from each plot were dissected on each date. Leaf feeding ratings (class 1 = least to class 9 = highest infestation level) and lesion counts, as described by Guthrie et al. (1960), were made 21 days after egg hatch.

Laboratory Tests

The developmental rates of each borer group and their subdivisions were made in the laboratory in a controlled environment. When eggs were ready for field infestation, 10 to 20 egg masses of each type (borer colony, emergence date, and day within an oviposition period) were
1965
Moth emergence dates
3-day oviposition periods

<table>
<thead>
<tr>
<th>Wild Borer</th>
<th>F₂ Borer</th>
</tr>
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<tbody>
<tr>
<td>I 123</td>
<td>I 123</td>
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<td>II 123</td>
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<td>III 123</td>
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1966
Moth emergence dates
2-day oviposition periods

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<th>F₂ Borer</th>
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<td>I 1234</td>
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<td>IV 1234</td>
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</tbody>
</table>

1967
Moth emergence dates
2-day oviposition periods

<table>
<thead>
<tr>
<th>Wild Borer</th>
<th>F₂ Borer</th>
<th>F₄₅ Borer</th>
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Figure 1. Outline of borer types, moth emergence dates, and oviposition periods.

placed in jars for hatching. Samples of the larvae were isolated in 3-dram vials containing a meridic diet and these were incubated at 80°F and 80% RH until pupation occurred. Each oviposition period was represented by 170 individuals. After 13 days of incubation, the vials were inspected daily and the number of pupae recorded.

RESULTS
1965 Season

Comparison of Borer Types and Moth Emergence Dates

The data on larval survival 8 and 30 days after egg hatch, leaf feeding ratings, and lesion counts for the wild and F₂ borer types and moth emergence dates are summarized in Tables 2 and 3. A summary of the statistical analyses for all criteria are presented in Appendix Table A-1.

A relatively low level of larval establishment was obtained by manual infestation in 1965. Larval survival for the wild and F₂ borer types did not differ 8 or 30 days after egg hatch (Table A-1). Moth emergence dates, as measured by the mean number of larvae, differed significantly
Table 2. Larval survival and damage per plant from wild borers on WF9.

Ankeny, Iowa, 1965.\textsuperscript{a/}

<table>
<thead>
<tr>
<th>Moth emergence</th>
<th>3-day oviposition periods</th>
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<td>Average number of larvae at 8-day dissection</td>
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\textsuperscript{a/}Average of 4 replications with 9-12 plants each.
Table 3. Larval survival and damage per plant from F₂ colonized borers on WF9, Ankeny, Iowa, 1965.a

<table>
<thead>
<tr>
<th>Moth emergence date</th>
<th>3-day oviposition periods</th>
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<td>Average number of larvae at 8-day dissection</td>
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</table>

a\ Average of 4 replications with 9-12 plants each.
and there was a highly significant borer type X moth emergence date interaction; in general, larval survival (averaged over oviposition periods 8 and 30 days after egg hatch increased from the 1st to 4th moth emergence date for both borer types (Tables 2 and 3).

Conflicting results were obtained for the damage parameters. The borers from the various moth emergence dates differed significantly for leaf feeding ratings (Table A-1). Leaf-feeding ratings did not differ significantly for borer types or for the interaction of moth emergence date X borer type. Borer types were significantly different in mean number of lesions per plant; differences in lesion counts between moth emergence dates were not significant. The borer type X moth emergence date interaction was not significant for either of the damage criteria.

Averaged over the 4 moth emergence dates, leaf feeding ratings 30 days after egg hatch were 7.3 and 6.7 for the wild and F₂ colony, respectively (Tables 2 and 3). In resistance investigations these ratings would classify the susceptible host plant, WF9, susceptible to corn borer feeding. By the leaf-feeding parameter the lowest average value for both borer types was obtained with the 1st moth emergence date (I). The F₂ colony borers produced consistently higher leaf-feeding ratings in successive moth emergence dates with the highest average of 7.5 obtained in date IV. Leaf-feeding ratings for the wild borer varied erratically among the moth emergence dates, but the highest ratings of 8.2 was obtained in date IV. WF9 plants rated 5.5 and 5.6 when infested with eggs from the wild and F₂ borers of the 1st moth emergence date, respectively; these ratings in date I would be considered intermediate in leaf feeding damage. In the 2nd, 3rd, and 4th moth emergence dates, the leaf feeding ratings were in the susceptible to high intermediate category for both wild and F₂ borers.

Lesions per plant for the 2 borer types were low for a borer susceptible inbred line of corn; averaged over all moth emergence dates, lesion counts for wild and F₂ borers were 6.8 and 4.2, respectively.

Comparison of Oviposition Periods and Moth Emergence Dates within Borer Types

The data for the 4 parameters for oviposition period X moth emergence date for the 2 borer types are given in Tables 2 and 3. A summary of the statistical analyses of these data is presented in Tables A-2 and A-3. Since moth emergence dates and oviposition periods are specific attributes of the borer type, comparisons were made within rather than between types.

Wild borers. Moth emergence date X oviposition period interaction for the wild borer was significant in the damage parameters and in number of larvae present at the 8-day dissection (Tables A-2 and A-3). Larval survival 30 days after egg hatch was not statistically different for moth emergence date or oviposition period. Leaf-feeding ratings differed significantly for moth emergence dates, but lesion counts did not differ statistically. Conversely, differences in leaf feeding ratings were not significant for borers from different oviposition periods but lesion counts were significantly different. The average number of larvae per plant 8 days after egg hatch differed significantly among moth emergence dates and oviposition periods.
In general, larval survival (averaged over oviposition periods) increased at each successive moth emergence date (Table 2). The magnitude of the difference in larval survival 8 days after egg hatch between the 1st and last moth emergence date was 5.6 borers per plant; the difference in larval survival 30 days after egg hatch was only 1 borer per plant.

Leaf feeding ratings (averaged over oviposition periods) of 8.1, 7.4, and 8.2 for moth emergence dates II, III, and IV, respectively, indicate a high degree of plant damage. The intermediate rating of 5.5 for date I is low for measuring plant damage of inbred lines with a high degree of susceptibility. Lesion counts in different moth emergence dates fluctuated erratically.

F2 colony borers. There was a significant moth emergence date X oviposition period interaction for the damage parameters and for larval survival 8 days after egg hatch (Tables A-2 and A-3). Larval survival and plant damage produced by borers from the different moth emergence dates were significantly different. Oviposition periods differed significantly for larval survival and for leaf feeding ratings, but not for lesion counts.

Inspection of larval survival or lesions per plant for moth emergence dates in Table 3 reveals no meaningful trends. The leaf feeding ratings (averaged over oviposition periods) increased over successive moth emergence dates, but the actual difference between dates I and IV was only 1.9 per plant. In emergence dates I and II, the average leaf feeding ratings of 5.6 and 6.5 classify the susceptible inbred WF9 as intermediate in resistance.

The magnitude of differences between oviposition periods for each parameter were low for F2 borers, and even though the differences were statistically significant in larval survival and in leaf feeding ratings they were too small to be of practical value. Averaged over moth emergence dates, larval survival and plant damage were slightly higher for the middle portion of the oviposition period.

1966 Season

Comparison of Borer Types and Moth Emergence Dates

The data for larval survival 7 and 21 days after egg hatch, leaf feeding ratings, and lesion counts for the wild and F34 borer types and moth emergence dates are summarized in Tables 4 and 5. A summary of the statistical analyses for all criteria are presented in Table A-1.

A higher level of larval establishment and survival resulted from the artificial infestation of wild borers in 1966 than in 1965. Meaningful differences for larval survival 7 and 21 days after egg hatch, leaf-feeding ratings, and lesion counts were obtained in 1966 between the wild and F34 colony (Tables 4 and 5). Of particular interest was the difference in initial survival 7 days after egg hatch; averaged over the 4 moth emergence dates, survival for the wild population was 8.9 larvae per plant compared with 2.1 larvae per plant for the F34 colony. This difference is substantial and is reflected in a high leaf feeding rating of 7.7 with 5.6 lesions per plant for the wild borers and a low intermediate leaf-feeding rating of 3.7 with 2.5 lesions per plant for the F34 colony. The lesion counts obtained for both borer types were low for borer susceptible WF9.
Table 4. Larval survival and damage per plant from wild borers on WF9. Ankeny, Iowa, 1966.

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<th>Average of leaf feeding ratings at 21-day dissection</th>
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\(^a\) Each emergence date X oviposition period mean is based on 48
Table 5. Larval survival and damage per plant from \( F_{34} \) borers on WF9.

Ankeny, Iowa, 1966.a/

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a/ Each emergence date X oviposition period mean is based on 48
Comparison of Oviposition Periods and Moth Emergence Dates within Borer Types

The data for larval survival and for the damage parameters in each oviposition period and moth emergence date for the wild borers and the F$_{34}$ colony are presented in Tables 4 and 5. A summary of the statistical analyses for these data is given in Tables A-2 and A-3.

Wild borers. In 1966, significant differences between moth emergence dates were obtained in the level of larval establishment and resulting plant damage (Tables A-2 and A-3). Averaged over the 4 oviposition periods, moth emergence dates fluctuated erratically in larval survival 7 and 21 days after egg hatch, but were nearly constant for leaf-feeding ratings (Table 4). The progeny from moth emergence dates I, II, and III produced an average of 3 more lesions per plant than those from moth emergence date IV. Averaged over the 4 moth emergence dates, larval survival for the 1st oviposition period was significantly greater 7 days after egg hatch than larval survival for the 2nd, 3rd, and 4th oviposition periods. There were no significant differences between oviposition periods for larval survival 21 days after egg hatch or for leaf feeding ratings and lesion counts.

F$_{34}$ borers. Significant interactions of moth emergence dates and oviposition periods were obtained in all parameters for the F$_{34}$ colony (Tables A-2 and A-3). The variability was due primarily to the moths collected on the various emergence dates since progeny obtained from the oviposition periods did not differ significantly in larval survival or in plant damage as evaluated by leaf feeding ratings. The oviposition periods for lesions per plant differed at the 5% level of confidence (Table A-3) but the differences were not sufficient to be biologically important (Table 5).

1967 Season

Comparison of Borer Types and Moth Emergence Dates

In 1967, wild borers were compared with F$_2$ and F$_{45}$ generation colonies. A high level of larval establishment in the wild and F$_2$ colony resulted from the artificial infestations. A summary of the data for the borer types and their respective moth emergence dates is presented in Tables 6, 7, and 8, and a summary of the statistical analysis is given in Table A-1.

There were significant interactions between borer types and moth emergence dates for all criteria (Table A-1). There was little difference between wild borers and borers from the F$_2$ colony for larval survival 7 and 21 days after egg hatch, leaf feeding ratings, and lesion counts, which agrees with the 1965 data (Tables 6 and 7). Larval survival 7 and 21 days after egg hatch, leaf feeding ratings, and lesion counts were considerably lower for the F$_{45}$ colony compared with the wild and F$_2$ colony (Tables 6, 7 and 8). The difference between wild borers and the F$_{45}$ colony is consistent with the 1966 data between wild borers and the F$_{34}$ colony.

Larval survival 7 and 21 days after egg hatch declined somewhat from moth emergence date I to date IV for the wild and F$_2$ colony; differences between moth emergence dates for leaf-feeding ratings and lesions were significant (Table A-1), but the magnitude of the difference was small.
Table 6. Larval survival and damage per plant from wild borers on WF9. Ankeny, Iowa, 1967.a

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a/ Each emergence date x oviposition period mean is based on 48
Table 7. Larval survival and damage per plant from F2 borers on WF9.
Ankeny, Iowa, 1967.*

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</table>

* Each emergence date X oviposition period mean is based on 48 plant observations. */ each emergence period mean is based on 48 plant observations.
Table 8. Larval survival and damage per plant from F₄₅ borers on WF₉, Ankeny, Iowa, 1967.¹

<table>
<thead>
<tr>
<th>Moth emergence</th>
<th>2-day oviposition periods</th>
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<th>2nd</th>
<th>3rd</th>
<th>4th</th>
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</tr>
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<tr>
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<td>4.6</td>
<td>5.8</td>
<td>6.2</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Average number of larvae at 7-day dissection

| I              | 4.7 | 6.4 | 7.9 | 7.2 | 6.5 |
| II             | 3.1 | 4.5 | 3.8 | 3.3 | 3.7 |
| III            | 1.6 | 2.4 | 3.2 | 4.0 | 2.8 |
| IV             | 1.6 | 1.4 | 1.4 | 2.4 | 1.7 |
| Average        | 2.8 | 3.7 | 4.0 | 4.2 | 3.7 |

Average number of larvae at 21-day dissection

| I              | 5.4 | 7.2 | 7.4 | 7.7 | 6.9 |
| II             | 6.3 | 6.4 | 6.0 | 5.8 | 6.2 |
| III            | 2.8 | 5.0 | 6.6 | 7.4 | 5.4 |
| IV             | 3.7 | 3.3 | 3.3 | 5.1 | 3.8 |
| Average        | 4.5 | 5.5 | 5.8 | 6.5 | 5.6 |

Average of leaf feeding ratings at 21-day dissection

| I              | 5.2 | 6.7 | 7.9 | 7.8 | 6.9 |
| II             | 5.0 | 6.0 | 6.0 | 5.0 | 5.5 |
| III            | 2.4 | 5.2 | 6.8 | 7.1 | 5.4 |
| IV             | 1.9 | 1.9 | 2.5 | 3.9 | 2.4 |
| Average        | 3.6 | 5.0 | 5.7 | 5.9 | 5.0 |

¹/ Each emergence date X oviposition period mean is based on 48
INFLUENCE OF EGG SOURCE ON CORN BORER LARVAE

Larval survival 7 and 21 days after egg hatch, leaf feeding ratings, and lesion counts declined considerably from moth emergence date I to date IV for the F_{45} colony (Table 8).

The wild and F_{2} borers produced an over-all susceptible leaf feeding rating for each moth emergence date; leaf feeding ratings for the F_{45} colony ranged from a high intermediate to low intermediate.

Comparison of Oviposition Periods and Moth Emergence Dates within Borer Types

Oviposition period means, by moth emergence dates for the wild, F_{2}, and F_{45} borer types, are presented in Tables 6, 7, and 8, respectively. A summary of the statistical analyses for these data is given in Tables A-2 and A-3. The borer types were again treated separately because oviposition period within borer type was of greater interest than between borer types.

Wild borers. Progeny of wild borers originating from the different oviposition periods did not differ significantly when compared by larval survival at 7 or 21 days or by the plant damage criteria. The oviposition period X moth emergence date interaction was not significant except in the 7-day larval survival parameter. Borers originating from moths of different emergence dates were significantly different when compared by each of the parameters (Tables A-2 and A-3). Averaged over oviposition periods, there was a consistent downward trend from moth emergence date I to moth emergence date IV in larval survival 21 days after egg hatch, with a difference of 4.6 borers per plant between emergence dates I and IV (Table 6); leaf-feeding ratings (averaged over oviposition periods) though statistically different between moth emergence dates, were all within the susceptible category ranging from 7.8 to 8.6.

F_{2} borers. There was an oviposition period X moth emergence date interaction for F_{2} borers based on larval survival 7 days after egg hatch and in leaf-feeding ratings (Tables A-2 and A-3). Borers from the different moth-emergence dates were significantly different for each parameter except leaf feeding ratings. Averaged over oviposition periods, the leaf feeding ratings were all in the susceptible category ranging from 7.7 to 8.3 (Table 7). Although differences between oviposition periods (averaged over moth emergence dates) for larval survival 7 and 21 days after egg hatch, leaf-feeding ratings, and lesion counts were highly significant (Tables A-2 and A-3), most of the differences were too small to be of practical value in host plant resistance studies (Table 7).

F_{45} borers. There was an oviposition period X moth emergence date interaction for F_{45} borers in larval survival 7 days after egg hatch and in leaf feeding ratings (Tables A-2 and A-3). Borers from the different oviposition periods were significantly different when compared by each of the criterion. F_{45} borers from the different moth-emergence dates differed for the damage parameters and for larval survival 21 days after egg hatch.

Averaged over oviposition periods, moth emergence date means consistently declined in each criterion with each successive emergence date (Table 8). The mean number of lesions produced by the F_{45} borers were low, ranging from 2.4 to 6.9 lesions/ plant and the average leaf feeding ratings were intermediate, ranging from 3.8 to 6.9. Averaged over moth
emergence dates, oviposition period means increased in each criterion with each successive oviposition period but the magnitude of the change was usually small.

Comparison of Borer Types Over Years

The data for each of the parameters are summarized for the 3 years in Tables 9, 10, and 11 for the wild, F₂, and the continuously reared F₃₄-F₄₅ colonies, respectively. The combined year analyses for these data are presented in Table A-4.

Within each borer type, the year X moth-emergence date interaction was significant for larval survival 7-8 and 21-30 days after egg hatch (with the exception of larval survival 7-8 days after egg hatch for the F₃₄-F₄₅ borers) and for leaf feeding ratings and lesion counts (Table A-4). The year X moth emergence date interaction is the appropriate error term for testing moth emergence dates for significance. Moth emergence dates combined over years were not different in either of the borer types for any of the criteria, with the exception of lesion counts for the wild borers. When combined over years, the differences within individual years for the moth emergence dates cancel one another.

Wild borers

Significant differences in larval survival 7 and 21 to 30 days after egg hatch and in lesion counts occurred between years. Leaf-feeding ratings for the wild borer did not differ from year to year (Table A-4).

Averaged over years, lesion counts were considerably lower for the 4th emergence date than for moth emergence dates I, II, and III (Table 9). In general, larval survival and plant damage increased in each successive year.

F₂ borers

Larval survival 21-30 days after egg hatch and lesion counts were significantly greater in 1967 than in 1965. Larval survival 7 days after egg hatch and leaf feeding ratings were not significantly different for the 2-year period (Tables A-4 and 10).

F₃₄ and F₄₅ borers

Larval survival 7 days after egg hatch and leaf feeding ratings were significantly greater in 1967 than in 1966; larval survival 21 days after egg hatch and lesion counts did not differ significantly between years (Tables A-4 and 11).

Rate of borer development in the field

The percentages of borer forms recovered 21 or 30 days after egg hatch were recorded each year by instar, oviposition period, moth emergence date, and borer type. As no differences were found among oviposition periods the data are summarized by season, borer type, and emergence dates in Table 12.

Of singular significance in the rate of borer development in the field was the consistency of development among the borer types. The F₂, F₃₄, and F₄₅ borers developed in the field environment at approximately the
Table 9. Summary of larval survival and damage per plant for wild borers. Ankeny, Iowa.

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<th>Year</th>
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<th>III</th>
<th>IV</th>
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<td></td>
<td></td>
<td>Average number of larvae at 7-8 day dissection</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>6.2</td>
<td>6.5</td>
<td>6.4</td>
<td>5.7</td>
</tr>
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<td>9.4</td>
<td>7.2</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>Average number of larvae at 21-30 day dissection</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>5.2</td>
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<td>3.9</td>
<td>4.9</td>
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<tr>
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<td>Average of leaf feeding ratings at 21-30 day dissection</td>
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</tr>
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</tr>
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Table 10. Summary of larval survival and damage per plant for F2 borers. Ankeny, Iowa.

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<td>7.2</td>
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Average number of larvae at 7-8 day dissection

<table>
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<th>III</th>
<th>IV</th>
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Average number of larvae at 21-30 day dissection

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<th>III</th>
<th>IV</th>
<th>Average</th>
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Average of leaf feeding ratings at 21-30 day dissection

<table>
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<th>IV</th>
<th>Average</th>
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Average number of lesions at 21-30 day dissection
Table 11. Summary of larval survival and damage per plant for F₃₄ and F₄₅ borers. Ankeny, Iowa.

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<th>Borer</th>
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<th>IV</th>
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<td>4.5</td>
<td>4.2</td>
<td>1.8</td>
<td>3.8</td>
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</table>
Table 12. Percentage of borers (by instar) recovered in the field 21-30 days after egg hatch. Ankeny, Iowa.

<table>
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<th>F₄/5</th>
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<td>Pupae</td>
<td>Pupae</td>
<td>Pupae</td>
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</tbody>
</table>
same rate as wild borers. In each season different rates of development appeared to occur among the moth emergence dates. For example, in 1967 the percentage of 5th instar larvae increased with successive moth emergence dates in all 3 borer types through date III and showed a slight decrease in date IV. In 1965, a similar response occurred in rate of pupation. The data indicates that the response to the micro and macro environment of the 4 types of borers was the same in rate of larval development.

Reciprocal mating of wild and F₅₄ moths (1968)

Based on the 4 criteria of larval survival 7 and 21 days after egg hatch, leaf feeding ratings, and lesions/plant, progeny from the wild ♀ X wild ♂ parent had a high level of larval establishment (Table 13) and progeny from the F₅₄ ♀ X F₅₄ ♂ parent had an extremely low level of larval establishment. The level of larval survival for progeny from crosses between these parental sources of moths was intermediate; however, progeny from the wild ♀ X F₅₄ ♂ cross had a higher level of survival than did progeny from the F₅₄ ♀ X wild ♂ cross, indicating a greater maternal than paternal influence on the progeny.

Viability of eggs

In 1967, egg masses were compared for viability. These egg masses, pinned to the composition boards, were placed in plastic bags with moist paper toweling on the same day comparable egg masses were placed on corn in the field. These eggs were incubated at 80°F until hatching occurred. The number of completely hatched, partially hatched, and sterile masses were recorded by moth-emergence date. The results are presented in Table 14. Averaged over moth-emergence dates, the F₄₅ colony had the highest incidence of sterile eggs (28.2%); 10.5% of the eggs from the F₂ colony were sterile; and 5.6% of the eggs from the wild borers were sterile.

Laboratory Tests

Under a controlled environment of 80°F and 80% RH, samples of larvae from each test unit taken to the field were individually isolated in 3-dram vials containing a meridic diet. Under these conditions, the more rapidly developing larvae started pupating in 12 to 13 days and the slower ones 30 to 35 days. The incidence of the disease Perezia pyraustae had some bearing on the extended development period but the degree of infection was not measured. Twenty-one days after egg hatch, borers that pupated at 12 days began to emerge as adult moths. Percentage pupation 21 days after egg hatch and final pupation were used to compare the rate of development and degree of larval mortality for the wild, F₂, F₃₄, and F₄₅ borers.

Since the data were summarized as percentages based on low numbers and the percentage values were usually above 80, the arcsin transformation for proportions was made for analysis of the date (LeClerg et al. 1962). The data are summarized in Tables 15, 16, and 17, and the analyses of variance or covariance are presented in Table A-5.
Table 13. Larval survival and damage per plant on WF9 from wild, F54, and wild X F54 borers. Ankeny, Iowa, 1968.a/

<table>
<thead>
<tr>
<th>Borer types</th>
<th>Wild ♀ X wild ♂</th>
<th>Wild ♀ X F54 ♂</th>
<th>F54 ♀ X wild ♂</th>
<th>F54 ♀ X F54 ♂</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Larvae at 7-day dissection</strong></td>
<td>9.8 a/b/</td>
<td>4.5 b</td>
<td>2.2 c</td>
<td>0.6 d</td>
</tr>
<tr>
<td>Standard error of the mean = 0.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Larvae at 21-day dissection</strong></td>
<td>5.5 a/b/</td>
<td>3.3 b</td>
<td>1.6 c</td>
<td>0.7 c</td>
</tr>
<tr>
<td>Standard error of the mean = 0.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Leaf feeding ratings at 21-day dissection</strong></td>
<td>8.5 a/b/</td>
<td>6.8 b</td>
<td>5.0 c</td>
<td>3.3 d</td>
</tr>
<tr>
<td>Standard error of the mean = 0.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lesions at 21-day dissection</strong></td>
<td>7.0 a/b/</td>
<td>5.2 b</td>
<td>3.0 c</td>
<td>1.9 c</td>
</tr>
<tr>
<td>Standard error of the mean = 0.41</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a/ Each average based on 10 reps/12 plants/rep

b/ Means followed by the same letter do not differ at the 1% level of probability.

<table>
<thead>
<tr>
<th>Borer type</th>
<th>Moth emergence date</th>
<th>Percentage Hatch</th>
<th>Partial hatch</th>
<th>Sterile</th>
<th>Number of egg masses observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wild</td>
<td>I</td>
<td>87.3</td>
<td>9.3</td>
<td>3.4</td>
<td>2,714</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>74.1</td>
<td>21.4</td>
<td>4.5</td>
<td>1,870</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>69.3</td>
<td>23.7</td>
<td>7.0</td>
<td>2,170</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>62.6</td>
<td>29.7</td>
<td>7.7</td>
<td>1,030</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>73.3</td>
<td>21.0</td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>( F_2 )</td>
<td>I</td>
<td>74.5</td>
<td>16.8</td>
<td>8.7</td>
<td>2,896</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>56.2</td>
<td>27.4</td>
<td>16.3</td>
<td>2,446</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>53.4</td>
<td>40.0</td>
<td>6.6</td>
<td>2,315</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>53.0</td>
<td>36.5</td>
<td>10.5</td>
<td>1,889</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>59.3</td>
<td>30.2</td>
<td>10.5</td>
<td></td>
</tr>
<tr>
<td>( F_{4/5} )</td>
<td>I</td>
<td>41.9</td>
<td>30.8</td>
<td>27.3</td>
<td>4,601</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>11.9</td>
<td>27.9</td>
<td>60.3( a^{/})</td>
<td>294</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>34.5</td>
<td>60.2</td>
<td>5.3</td>
<td>3,516</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>18.2</td>
<td>61.6</td>
<td>20.1( a^{/})</td>
<td>417</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>26.6</td>
<td>45.1</td>
<td>28.2</td>
<td></td>
</tr>
</tbody>
</table>

\( a^{/}\) Contained many masses left over from field infestations, therefore, were probably the poorer masses from the lot.
Table 15. Mean percentage pupation of wild and $F_2$ borers reared on an artificial diet. Ankeny, Iowa, 1965.a/

<table>
<thead>
<tr>
<th>Moth emergence</th>
<th>Wild borers</th>
<th></th>
<th></th>
<th></th>
<th>F$_2$ borers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oviposition period</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>Average</td>
</tr>
<tr>
<td>date</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage pupation 21 days after egg hatch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>84.4</td>
<td>73.9</td>
<td>57.2</td>
<td>71.3</td>
<td>77.4</td>
</tr>
<tr>
<td>II</td>
<td>74.4</td>
<td>76.2</td>
<td>76.3</td>
<td>75.6</td>
<td>66.2</td>
</tr>
<tr>
<td>III</td>
<td>85.2</td>
<td>80.2</td>
<td>72.7</td>
<td>79.4</td>
<td>31.3</td>
</tr>
<tr>
<td>IV</td>
<td>76.7</td>
<td>32.8</td>
<td>54.1</td>
<td>54.3</td>
<td>64.5</td>
</tr>
<tr>
<td>Average</td>
<td>80.1</td>
<td>65.8</td>
<td>65.1</td>
<td>70.3</td>
<td>59.8</td>
</tr>
</tbody>
</table>

Final percentage pupation

| I              | 87.2                | 77.0 | 68.9 | 77.7 | 78.4 | 80.9 | 75.1 | 78.1 |
| II             | 76.4                | 75.4 | 77.2 | 76.4 | 70.2 | 74.8 | 69.7 | 71.6 |
| III            | 88.6                | 86.6 | 75.6 | 83.6 | 83.3 | 72.0 | 73.2 | 76.2 |
| IV             | 79.9                | 82.3 | 77.6 | 79.9 | 72.9 | 70.8 | 72.1 | 71.9 |
| Average        | 83.0                | 80.3 | 74.8 | 79.4 | 76.2 | 74.6 | 72.5 | 74.4 |

a/ The percentages were based on 17 larvae each date, period, and borer type, replicated 10 times. These data are transformed by the arcsin transformation for proportions.
Table 16. Mean percentage pupation of wild and F₃₄ borers reared on an artificial diet. Ankeny, Iowa, 1966.¹

<table>
<thead>
<tr>
<th>Moth emergence</th>
<th>Wild borers</th>
<th>F₃₄ borers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oviposition period</td>
<td>Percentage pupation 21 days after egg hatch</td>
<td>Oviposition period</td>
</tr>
<tr>
<td>date</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I</td>
<td>76.2</td>
<td>76.4</td>
</tr>
<tr>
<td>II</td>
<td>81.3</td>
<td>78.5</td>
</tr>
<tr>
<td>III</td>
<td>80.3</td>
<td>58.8</td>
</tr>
<tr>
<td>IV</td>
<td>74.8</td>
<td>81.3</td>
</tr>
<tr>
<td>Average</td>
<td>78.1</td>
<td>73.7</td>
</tr>
</tbody>
</table>

Final percentage pupation

| I | 76.7 | 76.4 | 71.2 | 73.3 | 74.4 | 59.3 | 54.0 | 58.1 | 54.6 | 56.5 |
| II | 81.3 | 78.5 | 66.0 | 69.0 | 73.9 | 67.3 | 65.7 | 78.0 | 75.2 | 71.6 |
| III | 80.3 | 64.3 | 71.1 | 75.9 | 72.9 | 68.4 | 69.3 | 67.2 | 71.7 | 69.1 |
| IV | 74.8 | 82.3 | 79.1 | 80.2 | 79.1 | 43.2 | 60.0 | 67.6 | 74.2 | 61.3 |
| Average | 78.3 | 75.4 | 71.8 | 74.8 | 75.1 | 59.6 | 62.2 | 67.7 | 68.9 | 64.6 |

¹The percentages were based on 17 larvae each date, period, and borer type replicated 10 times.

These data are transformed by the arcsin transformation for proportions.
Table 17. Mean percentage pupation of wild, \( F_2 \), and \( F_{45} \) borers reared on an artificial diet.

Ankeny, Iowa, 1967. \(^a/\)

<table>
<thead>
<tr>
<th>Moth emergence</th>
<th>Wild borers Oviposition period</th>
<th>( F_2 ) borers Oviposition period</th>
<th>( F_{45} ) borers Oviposition period</th>
</tr>
</thead>
<tbody>
<tr>
<td>date</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>I</td>
<td>65.8</td>
<td>73.6</td>
<td>62.7</td>
</tr>
<tr>
<td>II</td>
<td>61.7</td>
<td>61.3</td>
<td>65.2</td>
</tr>
<tr>
<td>III</td>
<td>71.9</td>
<td>80.3</td>
<td>64.2</td>
</tr>
<tr>
<td>IV</td>
<td>80.1</td>
<td>69.4</td>
<td>75.4</td>
</tr>
<tr>
<td>Avg.</td>
<td>69.9</td>
<td>71.2</td>
<td>66.9</td>
</tr>
</tbody>
</table>

Percentage pupation 21 days after egg hatch

<table>
<thead>
<tr>
<th>Moth emergence</th>
<th>Wild borers Oviposition period</th>
<th>( F_2 ) borers Oviposition period</th>
<th>( F_{45} ) borers Oviposition period</th>
</tr>
</thead>
<tbody>
<tr>
<td>date</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>I</td>
<td>71.7</td>
<td>85.8</td>
<td>75.6</td>
</tr>
<tr>
<td>II</td>
<td>65.6</td>
<td>65.4</td>
<td>76.7</td>
</tr>
<tr>
<td>III</td>
<td>74.6</td>
<td>83.8</td>
<td>82.3</td>
</tr>
<tr>
<td>IV</td>
<td>80.7</td>
<td>76.1</td>
<td>82.3</td>
</tr>
<tr>
<td>Avg.</td>
<td>73.1</td>
<td>77.7</td>
<td>79.2</td>
</tr>
</tbody>
</table>

Final percentage pupation

<table>
<thead>
<tr>
<th>Moth emergence</th>
<th>Wild borers Oviposition period</th>
<th>( F_2 ) borers Oviposition period</th>
<th>( F_{45} ) borers Oviposition period</th>
</tr>
</thead>
<tbody>
<tr>
<td>date</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>I</td>
<td>71.7</td>
<td>85.8</td>
<td>75.6</td>
</tr>
<tr>
<td>II</td>
<td>65.6</td>
<td>65.4</td>
<td>76.7</td>
</tr>
<tr>
<td>III</td>
<td>74.6</td>
<td>83.8</td>
<td>82.3</td>
</tr>
<tr>
<td>IV</td>
<td>80.7</td>
<td>76.1</td>
<td>82.3</td>
</tr>
<tr>
<td>Avg.</td>
<td>73.1</td>
<td>77.7</td>
<td>79.2</td>
</tr>
</tbody>
</table>

\(^a/\) The percentages were based on 17 larvae each date, period and borer type replicated 10 times. These data are transformed by the arcsin transformation for proportions.
The borer type X moth-emergence date X oviposition period interaction was highly significant each year for percentage pupation 21 days after eclosion (Table A-5). This indicates that the borer types were responding differently in the different moth emergence dates and oviposition periods. The data in Tables 15-17 for the 2nd-order interactions show no consistent trends in 21 day or final pupation. The mean values for moth emergence dates averaged over oviposition periods in these tables are erratic and show no trends for either 21 day or final pupation. Averaged over moth emergence dates, the pupation for oviposition periods within borer type does not reveal consistent trends in either criterion.

The 2nd-order interaction (borer type X moth emergence date X oviposition period) involving final percentage pupation was significant in 1966 and 1967, but not in 1965 (Table A-5). Borer types differed significantly in 21-day and final pupation for the 3-year period. Pupation 21 days after egg hatch and final percentage pupation of borers from different moth emergence dates differed significantly for the 3-year period. Pupation 21 days after egg hatch and final pupation of borers from different oviposition periods differed significantly in 1965 and 1967, but not in 1966. Averaged over moth-emergence dates and oviposition periods, final percentage pupation (transformed) in 1965 for the wild and F2 borer types was 79.4 and 74.4, respectively (Table 15). The magnitude of the difference, though significant, is quite low. In 1966 the final mean percentage pupation for wild and F34 borers was 75.1 and 64.6, respectively (Table 16). In 1967, the final average percentage pupation for the wild, F2, and F45 borer types was 77.9, 74.6, and 68.6, respectively (Table 17). When compared over years (averaged over moth-emergence dates and oviposition periods) final pupation for the wild borer was 79.4% in 1965, 75.1% in 1966, and 77.9% in 1967; final pupation for the F2 borer was 74.4% in 1965, and 74.6% in 1967, and final pupation for the continuously reared borer was 64.4% in 1966 and 68.6% in 1967. Since the borers under test were reared on wheat germ diet and the F34-45 had been continuously reared on corn leaf diet, some of the difference in rate of pupation of borer types may be attributable to the change in diet.

DISCUSSION

Borer Types

Colonies of borers 2 generations removed from the wild became established on the susceptible dent corn inbred, WF9, at a slightly lower rate than their wild counterparts; however, even though the difference was consistent, it was negligible. Leaf feeding and lesion damage incurred to the host plant by the F2 colonized borers was only slightly less than that produced by the wild borer. European corn borers that had been continuously reared on a meridic diet for 34, 45, and 54 generations did not become established or survive as well on WF9 as either the wild borer or the F2 colonized borer. Borers that have been reared continuously on a meridic diet should not be used in screening inbred lines of corn for resistant germ plasm or in studying the genetic basis of resistance because the leaf feeding ratings were too low for measuring differential resistance.
Differences in leaf-feeding ratings and in lesion counts between borer types were, for the most part, attributable to poor initial larval survival of the borers reared continuously on a meridic diet and a higher degree of egg sterility in these borers accounted for some of the difference, even though the best looking egg masses were used for field infestations. Representative plants showing the leaf feeding damage produced by the 3 borer types are illustrated in Figures 2, 3, 4.

Figure 2. Inbred WF9: Infested with F_{45} corn borer egg masses (leaf feeding rating = 3.3).

In manually infested field studies involving the European corn borer, a uniformly moderate to heavy infestation is desired. When egg masses are placed on the plants in the field, the borers' ability to survive becomes the critical issue. As Chiang and Hodson (1959) have pointed out, the 1st-instar larvae in the field suffer severe mortality even under the best conditions. This mortality is translated into the law of survival of the fittest. The weak individuals are constantly eliminated from the population and only those individuals able to withstand the rigors of the environment survive to perpetuate the species. Borer survival is highly responsive to the vagaries of the environment, particularly weather, and the year-to-year fluctuations may more appropriately be attributed to this cause rather than to inherent differences in the borer types. As the environment should act essentially the same on both borer types, a favorable atmosphere for the wild borer should be favorable to the colonized borer unless the latter has become adapted to an environment under laboratory culture conditions. When the wild borer is removed from the
Figure 3. Inbred WF9: Infested with F₂ corn borer egg masses (leaf feeding rating = 7.3).

Figure 4. Inbred WF9: Infested with egg masses derived from wild corn borer moths (leaf feeding rating = 7.6).
rigorous selection pressure of the wild environment and colonized in the laboratory under optimum conditions for growth and reproduction, weak individuals can survive and increase in the population.

Knipping (1960) has postulated that it might be possible to develop deficiencies in immature stages of insects for their own destruction. Deformed mouth parts in larvae is one example of a deficiency that might interfere with development of an insect in nature, but would not seriously affect their survival in the laboratory. The F_{34}, F_{45}, or F_{54} colonized borers were not examined for deficient mouth parts; however, if a weakness such as deformed mouth parts should occur in the laboratory cultures, a much lower level of larval survival would result on corn from artificial infestations.

Larvae reared continuously on a meridic diet for many generations may also become so acclimated to the diet that they no longer prefer corn as a host plant. Unintentional selection for this possibility might occur when the borers are reared continuously on the wheat germ diet currently in use at the European Corn Borer Research Laboratory.

Selection of progeny from the parental stock at Ankeny is not at random. Approximately 225 females and 225 males are used each generation to continue the culture. Therefore, only 450 larvae out of a possible total of 45,000 (assuming each female lays 200 eggs) are selected in each generation. The 450 larvae are selected from 1 day's egg production near the peak of egg laying, and from these the largest masses are always used. Under almost ideal conditions of food, temperature, and humidity in the laboratory, larval survival usually ranges from 95 to 99%. With this method of selection generation after generation, the evolution of a laboratory strain of corn borer different from a wild population is a distinct possibility.

Several approaches might be used to keep the continuously reared borer colonies closer to the wild type. If the colony is to be maintained in isolation, selection pressure in the form of fluctuating temperatures with some extremes might be injected into the developmental periods. Selection pressure using diseases might be applied on alternate generations using the microsporidian Perezia pyraustae Paillot. A larger sample of eggs should be used to perpetuate the colony. Frequent gene reinforcement from the natural population might be desirable if the colony is to be used for tests in which inferences about the wild population are to be made; the 1968 data of crosses between a wild population and the F_{54} colony indicate larval survival on corn plants can be improved with this method. However, if larvae reared on a meridic diet are used in resistance investigations, a new colony probably should be started each season from the wild population to be assured of comparability.

Moth Emergence Dates

When compared over years, the difference in moth emergence dates as a source of variation in larval establishment and damage were not significant. Within a particular year, the differences were significant; however, a method for predicting the responses was not developed in this study. In 1965, the 4th moth emergence date averaged for both borer types gave the greatest rate of survival and leaf feeding ratings,
In 1965 and 1966, larval survival, leaf feeding ratings, and lesion counts for the F2 and F34 borers increased during the middle of the oviposition period and declined at the end. In 1967, larval survival, leaf feeding ratings, and lesion counts increased with successive oviposition periods for the F2 and F45 colonized borers. The magnitude of change was small, but definite trends were recorded. The values obtained for oviposition periods of wild borer varied from year to year and by the different criteria within each year, and no consistent trends were obtained.


APPENDIX A

Appendix A-1. Analysis of variance of the borer types and moth emergence dates based on data reported in Tables 2 and 3 for 1965, Tables 4 and 5 for 1966, and Tables 6, 7, and 8 for 1967.

<table>
<thead>
<tr>
<th>Source</th>
<th>7-8 day dissection</th>
<th>21-30 day dissection</th>
<th>Leaf feeding ratings</th>
<th>Lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Larvae</td>
<td>Larvae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moth emergence date</td>
<td>** ** *</td>
<td>** ** **</td>
<td>** ** **</td>
<td>ns ** ** **</td>
</tr>
<tr>
<td>Borer type</td>
<td>ns ** **</td>
<td>ns ** **</td>
<td>ns ** **</td>
<td>** ** **</td>
</tr>
<tr>
<td>Moth emergence date X borer type</td>
<td>** ** **</td>
<td>** ns *</td>
<td>ns * **</td>
<td>ns ** *</td>
</tr>
</tbody>
</table>

* significant at the 5% level
** significant at the 1% level
ns nonsignificant
Appendix A-2. Analysis of variance of oviposition periods within emergence dates by borer type based on the data reported in Tables 2 and 3 for 1965, Tables 4 and 5 for 1966, and Tables 6, 7, and 8 for 1967.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Moth emergence date</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>*</td>
<td>*</td>
<td>ns</td>
</tr>
<tr>
<td>Oviposition period</td>
<td>**</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Moth emergence date X</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Oviposition period</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

* Significant at the 5% level
** Significant at the 1% level
ns nonsignificant
Appendix A-3. Analysis of variance of the data for leaf feeding ratings and lesions reported in Tables 2-8.

<table>
<thead>
<tr>
<th>Source</th>
<th>Leaf feeding ratings</th>
<th>Lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Borer type</td>
<td>Borer type</td>
</tr>
<tr>
<td>Wild F₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moth emergence date</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Oviposition period</td>
<td>ns</td>
<td>*</td>
</tr>
<tr>
<td>Moth emergence date X</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Oviposition period</td>
<td>**</td>
<td>*</td>
</tr>
</tbody>
</table>

* Significant at the 5% level
** Significant at the 1% level
ns nonsignificant
Appendix A-4. Analysis of variance for combined years based on data in Tables 9, 10, and 11.

<table>
<thead>
<tr>
<th>Source</th>
<th>7-8 day dissection</th>
<th>21-30 day dissection</th>
<th>21-30 day dissection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Larvae</td>
<td>Larvae</td>
<td>Leaf feeding ratings</td>
</tr>
<tr>
<td></td>
<td>Borer type</td>
<td>Borer type</td>
<td>Borer type</td>
</tr>
<tr>
<td>Wild</td>
<td>*</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>F₂</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>F₃₄-4₅</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

* Significant at the 5% level

** Significant at the 1% level

ns nonsignificant
Appendix A-5. Analysis of variance or covariance of percentage pupation of borer types reared on a meridic diet.\(^a\)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Borer type</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Moth emergence date</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>*</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>Borer type X moth emergence date</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>ns</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Oviposition period</td>
<td>*</td>
<td>ns</td>
<td>**</td>
<td>ns</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Borer type X oviposition period</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Moth emergence date X oviposition period</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>ns</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Borer type X moth emergence date X oviposition period</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>ns</td>
<td>**</td>
<td>*</td>
</tr>
</tbody>
</table>

* Significant at the 5% level
** Significant at the 1% level
ns nonsignificant

\(^a\) Based on transformed data in Tables 15, 16, and 17. Analyses of covariance were made on missing data.
MIGRATION EXPECTATIONS AND PERFORMANCES OF OPEN-COUNTRY YOUNG ADULTS: A LONGITUDINAL STUDY, 1948-1956*

Dean R. Yoeesting and Joe M. Bohlen**

ABSTRACT. This paper discusses the migration expectations of a sample of 152 respondents interviewed while high school seniors in 1948 and reinterviewed in 1956 concerning their migration performances. The research was designed to test the general hypothesis that a relationship exists between certain social and personal characteristics and the migration performances of the respondents. In addition, characteristics of those with migration performances congruent or incongruent with expectations are discussed. Analysis indicated that, when a decision was made concerning migration, a highly significant number of the respondents achieved their expectation. Of those undecided concerning their migration expectations, half were residing in and half had migrated from their home communities after 8 years. More females migrated than males, and more nonfarm males left than farm males. Males tended to support the hypotheses, but females gave limited support.

INTRODUCTION

Rural to urban migration is a major phenomenon that has been occurring in the United States for several decades. Changing technology with less demand for unskilled labor and a traditionally higher birth rate have been major factors in the increasing number of rural young people leaving their families and their home communities to seek occupational opportunities elsewhere.

Past research has indicated that the rural portion of the population has supplied the urban labor market with workers for many decades (4, 8,
In Iowa between 1950 and 1960, for example, the census count of the farm population showed a decrease of approximately 15% in the number of people residing on farms. In addition, with the increase in farm size and the rapid decline in the total number of farms, even larger numbers of rural residents will leave rural areas.

Sociologists have long been concerned with high mobility rates of young people from rural areas, and numerous studies have been conducted in recent decades to determine which youths will migrate from their rural home communities. The majority of the migration and occupational studies conducted have been concerned with the aspirations and expectations of high school youth, but there has been a gross lack of longitudinal studies to determine the actual performances of youth in relation to their aspirations and expectations. It is felt that this study will give insights into the relationship between migration expectations and the performance of rural youth a considerable length of time after graduation.

THEORETICAL FRAMEWORK

Previous research has discovered that migrants from rural areas differ from nonmigrants in a number of important characteristics (9, 10, 12, 13, 14, 17, 25, 26, 31). Those who migrate tend to be single, under 25 or 30 years of age, and generally move urbanward. Most studies indicated that when sex-residence aggregates were analyzed, farm males were the least mobile while farm females were the most mobile. Schwarzweller (29) found that the propensity to migrate was essentially the same for rural farm and rural nonfarm males.

A relationship seems to exist between spatial mobility and the types of occupations young people entered. Numerous studies found that farm males who remained at home were more likely to be employed in farming or in blue collar occupations (1, 8, 10). Past research indicated that males planning to farm have had few plans to continue their education beyond high school. If these males ever decide to discontinue farming and enter a nonfarm occupation, their chances of attaining a high status occupation would be limited because of their poor educational background. Because they fail to see the educational requirements for success in the nonfarm occupational world as relevant to themselves, these farm-reared males tend to isolate themselves from information concerning other types of occupations, know less about the occupational world, and are enrolled in fewer nonagricultural courses than males who do not plan to farm.

Males who have farm backgrounds but no plans to farm tend to have lower educational and occupational aspirations than rural nonfarm or urban youth. Upon entering the urban labor market, these youth encounter difficulty in adjusting to the urban way of life and generally find themselves employed in blue collar jobs, especially if no additional training beyond high school was obtained (3, 11, 22, 23). Rural nonfarm and village males were generally found in blue collar and white collar occupations with a greater proportion of the white collar occupations

\[1\] For a discussion of occupational choices of farm boys and a bibliography of related research see Haller and Sewell (15).
held by the village males. The proportion of females engaged in white collar occupations increased from farm through village residence.

When the distance individuals migrated from their home communities was considered, females tended to travel greater distances and at a younger age than males (26). In a Pennsylvania study, males were more likely than females to be classified as stay-at-homes (1). Females tended to be more mobile with a large proportion migrating from their parental homes but still residing within their home counties. Those persons with nonfarm backgrounds tended to leave the county more frequently than farm residents. In the Pennsylvania study, marriage seemed to be the major factor in the large proportion of females moving away from home.

In analyzing data for youth migrating from their parental home communities, Andrews and Sardo (2) found that among the males, going to school, job opportunities and greater avenues of success were the major factors given for leaving the home communities. In their study, females gave similar reasons for migrating, with marriage being of lesser importance than was indicated by Allen.

Past research has indicated that the more intelligent young people search for educational and occupational opportunities outside their home communities regardless of the opportunities that might have been available in the local communities (13, 28). Frequently, those who would have preferred to remain in their home communities had to leave because of the lack of local job opportunities. This drain from the communities of individuals with leadership potential occurs when there is this type of selective out-migration of youth.

Three other variables seem to be prevalent in the research as being related to migration from the home communities. In a series of studies in Indiana (9, 12, 25), high social status, a greater amount of knowledge concerning available jobs, and high educational attainments were found to be related to migration. While seniors in high school, it would seem that if these youth had a high socioeconomic background, discussed their future frequently with their parents and had aspirations to obtain additional training beyond high school, they would be more likely to migrate from their parental homes.

A large number of rural youth aspire to and eventually migrate from their home communities, but to date researchers have been unsuccessful in improving their ability to predict those who will definitely migrate. A longitudinal research design that analyzes data collected at two or more points in time, can provide insights to improve the predictability of those people who will migrate. By analyzing the congruency of migration performances with migration expectations and in analyzing factors related to migration performances, the present study may add to existing research in improving that predictability.

The literature reviewed indicates the following hypotheses to be pertinent: (1) rural youth with nonfarm background will be more likely to migrate from the home communities than those with farm backgrounds; (2) rural youth with high school socioeconomic backgrounds will be more likely to migrate from their home communities than youth with lower socioeconomic backgrounds: (3) rural youth who discussed their future plans with parents will be more likely to migrate from their home
communities than youth who infrequently discussed future plans with parents; (4) rural youth with aspirations to obtain additional training beyond high school will be more likely to migrate from their home communities than those with no aspirations for additional training; and (5) female rural youth will be more likely to migrate from their home communities than male rural youth.

THE DATA

This paper analyzes the personal and social factors related to migration of a sample of young adults interviewed in 1948 while seniors in high school. These same respondents were reinterviewed in 1956 concerning their migration actions and their occupational attainments of that time. Both the initial study (6) and the restudy were conducted by Bohlen (18). Bohlen and Wakeley (7) reported a follow-up of the students in 1949, one year after they graduated.

The data for this study were obtained prior to any migration actions of the respondents. Data were collected from all graduating senior males and females from the eight rural high schools in Hamilton County, Iowa, and the adjoining Story County community of Story City. Story City not only adjoins Hamilton County, but also is similar in regard to ethnic and other cultural factors. 2

Hamilton County and the northwestern portion of Story County are located in the north-central grain area of Iowa. The area, with the most of the economy based on the production of livestock and corn, is one of the richest agricultural counties in the Midwest. The county is basically rural, the largest city being Webster City with a 1950 population of 8520. 3

Hamilton County was one of the typical corn belt counties selected for study by the U.S.D.A., Bureau of Agricultural Economics, Division of Farm Population (19).

The nine high schools studied were located in towns of from 100 to 1800 population. The largest high school had 130 students enrolled, and the smallest high school had an enrollment of 53 students. A total of 157 students were interviewed in 1948. Of these, 152 were reinterviewed in 1956. 4

The data for the initial study were obtained by having the senior class assemble, with each student completing his own questionnaire. The same interviewer visited all schools and acted as a proctor in explaining the mechanics of the questionnaire. He read each question in order, allowing the students to complete that question before the next question was read. Data concerning intentions to migrate, vital statistics, socio-economic status of the families, questions concerning job experience, occupational and educational aspirations, parent-child relations and the respondents' attitudes toward farming were gathered and analyzed.

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2 Story City was chosen to increase the number of cases in the sample. Although it lies in Story County, it is the center of a Norwegian cultural area which includes the southeastern portion of Hamilton County.
3 Webster City was eliminated because the school was in an urban center and would require additional urban centers to increase the size of an urban sample.
4 Two persons were deceased and three were unavailable because of personal reasons.
A second phase of the study was conducted one year later to determine the actual migration patterns of the respondents. Migration performance in the second study was analyzed in the same framework as had the migration intentions.

The third phase of this project was completed in 1956, eight years after the original study. With this time span, it was felt that the respondents could achieve an occupational choice and geographic location of a more permanent nature. For this phase of the study, data were gathered by personal interview whenever possible; however, a special modification of the interview schedule was prepared for mailing when personal interviews were impossible. Only slight modifications were necessary to allow the completion of the questionnaire by the respondent as compared with use by the interviewer. Approximately 13 percent of the questionnaires completed were mailed. Statistical tests indicated no significant differences in responses from mailed questionnaires or personal interviews.

The operational definition of migration used by Bohlen (6) in the original study is used in this paper. Migration is defined as the permanent departure from the parental homes and home communities for any reason. Those respondents who lived in their home communities at the time of the 1956 study were considered to have stayed even though they may have moved out of their home between 1948 and 1956 and returned. This paper analyzes migration intention in 1948, migration action in 1949 and migration action in 1956.

Most discussion centers around the dependent variables of 1956 migration actions and the congruency of action with intentions stated in 1948. Congruency (21) refers to agreement between the migration pattern aspired to in 1948 and the attainment achieved in 1956. Incongruent refers to disagreement between these two variables. It was assumed that each graduating senior was a potential migrant and that his plan to leave the community was a migration intention. The 152 respondents interviewed at both periods of time are under study in this paper. There were 66 males and 86 females interviewed.

FINDINGS

Migration Congruency

Before analyzing factors related to those who migrated from their home communities and those who remained at home, it may be of interest to present a discussion of the amount or congruence or incongruence between the 1948 expectations of the seniors and their migration performance in 1949 and 1956.

In 1948 over one-third of the respondents were undecided concerning their migration intentions (see Table 1). Half of the respondents expected to leave and 13 percent planned to remain in their home communities upon completion of high school. One year after graduation, two-thirds of the respondents had migrated, but by 1956 fewer respondents were residing outside their home communities. The slight decrease from the number who lived outside their home communities in 1948 indicates that a number of respondents had left home but returned by the time of the restudy in 1956.
Table 1. Percentage Distribution of 1949 and 1956 Migration Performance by 1948 Migration Expectations.

<table>
<thead>
<tr>
<th>1948 Expectations</th>
<th>1949 Performance Leave</th>
<th>Stay</th>
<th>Total</th>
<th>1956 Performance Leave</th>
<th>Stay</th>
<th>Total</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leave</td>
<td>89.5</td>
<td>10.5</td>
<td>100.0</td>
<td>85.5</td>
<td>14.5</td>
<td>100.0</td>
<td>76</td>
</tr>
<tr>
<td>Stay</td>
<td>30.0</td>
<td>70.0</td>
<td>100.0</td>
<td>25.0</td>
<td>75.0</td>
<td>100.0</td>
<td>20</td>
</tr>
<tr>
<td>Undecided</td>
<td>48.2</td>
<td>51.8</td>
<td>100.0</td>
<td>44.6</td>
<td>55.5</td>
<td>100.0</td>
<td>56</td>
</tr>
<tr>
<td>Total</td>
<td>66.4</td>
<td>33.6</td>
<td>100.0</td>
<td>62.5</td>
<td>37.5</td>
<td>100.0</td>
<td>152</td>
</tr>
</tbody>
</table>

The data indicate that migration performances were more congruent one year following high school graduation than eight years following graduation. This trend was true for those who planned to migrate and for those who planned to remain in their home communities. The data do indicate, however, a greater degree of congruency among those who intended to migrate from their home communities. This is supported for migration performance in 1948 and 1956.

Of those who had made a decision concerning migration expectations, only a very small proportion were unable to achieve their expectations. The largest proportion of incongruency existed among those who had expectations to remain in their home communities. Among those who were undecided concerning migration expectations, nearly equal proportions remained in as migrated out of their home communities. This was true for both 1949 and 1956.

Although there were a limited number of cases of incongruencies among the respondents, the actions of the 11 respondents who planned to migrate from their home communities but actually remained yielded some insights. Three of the 11 were males who had been in the military service and returned home to farm in 2 cases and for a nonfarm job in the other case. The 8 females left home and later returned with their husbands who were farming or who had obtained jobs in the females' home communities. Of those who intended to stay but actually migrated, two were females who left when they married. Each of the three males indicated job opportunities as the major reason for leaving his home community.

Since there is a lack of longitudinal studies comparing migration expectations and performances, an analysis was conducted to test the relationship between certain socioeconomic variables and the degree of migration congruency. Chi-square tests were used to determine whether or not a relationship existed. See Table 2.

The data indicate that those persons with high socioeconomic status background, frequently discussed their future plans with their parents, and aspired to obtain additional training beyond high school, were more
Table 2. Relationship Between Specific Socio-Economic Variables and Migration Congruency

<table>
<thead>
<tr>
<th>Variable</th>
<th>D.f.</th>
<th>$X^2$</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>2</td>
<td>5.157</td>
<td>$&lt;.100$</td>
</tr>
<tr>
<td>Residential background</td>
<td>2</td>
<td>.410</td>
<td>N. S.</td>
</tr>
<tr>
<td>Socio-economic status</td>
<td>2</td>
<td>6.342</td>
<td>$&lt;.050$</td>
</tr>
<tr>
<td>Discussed with parents</td>
<td>2</td>
<td>12.999</td>
<td>$&lt;.010$</td>
</tr>
<tr>
<td>College aspirations</td>
<td>4</td>
<td>42.226</td>
<td>$&lt;.001$</td>
</tr>
</tbody>
</table>

likely to achieve their migration expectations than those who were incongruent or undecided concerning migration.\(^5\)

Characteristics of Migrants

What, then, are the characteristics of those persons who remained in their home communities as compared to those who migrated? In 1948 Bohlen found that the place of residence, either rural farm or rural nonfarm was not related at a statistically significant level to expressed intentions to migrate. There was, though, a highly significant relationship between intentions and sex. A larger proportion of the girls expressed intentions to migrate with a smaller proportion undecided concerning migration.

It was hypothesized that in 1956, graduates with nonfarm backgrounds will be more likely to migrate than those with farm backgrounds and more females will migrate than males.\(^6\) Data in Table 3 indicate the migration performance by sex and residence. The data support the residence hypothesis and using the difference of proportions test, a greater proportion of nonfarm residents migrated than remained, but there was no significant difference in the proportion of farm residents who migrated or remained. See Table 4 for the Z scores and probabilities for each of the difference of proportions tested in this paper. Further analysis indicated that a greater proportion of farm males remained in their home communities, but greater proportions of nonfarm males and farm and nonfarm females migrated from than remained in their home communities.

The hypothesis concerning the differences between sexes migrating from their parental homes was supported in the expected direction. A significantly greater proportion of females migrated than males. A Z score of -3.608 was obtained yielding a probability at the .001 level of significance.

\(^5\) The breakdown of these variables is discussed in the following section.
\(^6\) The hypotheses were tested in the null form using the differences of proportions test that $P_1 = P_2$. Blalock (5) stated that no assumption other than the hypothesis is required about a population and a Z score is the test statistic to use.
Table 3. Migration Actions of Rural High School Graduates by Sex and 1948 Residence.

<table>
<thead>
<tr>
<th>Residence</th>
<th>1956 Migration Performance</th>
<th>1948 Residence</th>
<th>Sex</th>
<th>Stay</th>
<th>Leave</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No.</td>
<td>No.</td>
<td>No.</td>
</tr>
<tr>
<td>Farm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>40</td>
<td>50</td>
<td></td>
<td>44.4</td>
<td>55.6</td>
<td>90</td>
</tr>
<tr>
<td>Female</td>
<td>28</td>
<td>11</td>
<td></td>
<td>71.8</td>
<td>28.2</td>
<td>39</td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>39</td>
<td></td>
<td>23.5</td>
<td>76.5</td>
<td>51</td>
</tr>
<tr>
<td>Female</td>
<td>17</td>
<td>45</td>
<td></td>
<td>27.4</td>
<td>72.6</td>
<td>62</td>
</tr>
<tr>
<td>Male</td>
<td>8</td>
<td>19</td>
<td></td>
<td>29.6</td>
<td>70.4</td>
<td>27</td>
</tr>
<tr>
<td>Female</td>
<td>9</td>
<td>26</td>
<td></td>
<td>25.7</td>
<td>74.3</td>
<td>35</td>
</tr>
<tr>
<td>Total</td>
<td>57</td>
<td>95</td>
<td></td>
<td>37.5</td>
<td>63.5</td>
<td>152</td>
</tr>
</tbody>
</table>

Another background characteristic found to be related to migration performance is the socioeconomic background of the youth. It is hypothesized that rural youth with high socioeconomic backgrounds will be more likely to migrate than youth with lower socioeconomic backgrounds. Data give no support to the hypothesis. Using the socioeconomic status scale developed by Sewell (29) and dichotomizing the respondents into high and low socioeconomic status, a greater proportion of those with a low socioeconomic status migrated than those with a high socioeconomic status.

To determine if there were any sex differences in socioeconomic status, difference of proportions tests were performed. Results of the analysis indicated no significant differences between migration performance and socioeconomic status for males, but the results were in the expected direction. For the females, results indicated that a higher proportion of those with low and high socioeconomic status migrated than remained in their home communities. Therefore, the hypothesis is supported by the males but not by the females.

The hypothesis that rural youth who discussed their future plans with parents will be more likely to migrate from their home communities than youth who don't discuss or infrequently discussed their plans with parents was not supported. Data indicated that a higher proportion of respondents migrated who frequently discussed their future plans with parents, and a higher proportion of those who did not discuss or infrequently discussed their plans did not migrate, but the associated value of Z for no discussion was not significant at the .05 level.

Again, it was the females who were inconsistent with the hypothesis. Greater proportions of females migrated than remained among those who frequently discussed or did not discuss their future plans. The data from the males is in the expected direction.
Table 4. Summary of Difference in Proportions Total Migration Performances for Specific Social and Economic Characteristics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1956 Migration Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stay</td>
</tr>
<tr>
<td>Farm background</td>
<td>44.4</td>
</tr>
<tr>
<td>Nonfarm background</td>
<td>27.4</td>
</tr>
<tr>
<td>Male farm</td>
<td>71.8</td>
</tr>
<tr>
<td>Male nonfarm</td>
<td>29.6</td>
</tr>
<tr>
<td>Female farm</td>
<td>23.5</td>
</tr>
<tr>
<td>Female nonfarm</td>
<td>25.7</td>
</tr>
<tr>
<td>High Socio-economic Status</td>
<td>43.6</td>
</tr>
<tr>
<td>Low Socio-economic Status</td>
<td>31.5</td>
</tr>
<tr>
<td>Male Low S.E.S.</td>
<td>51.9</td>
</tr>
<tr>
<td>Male High S.E.S.</td>
<td>57.9</td>
</tr>
<tr>
<td>Female Low S.E.S.</td>
<td>19.6</td>
</tr>
<tr>
<td>Female High S.E.S.</td>
<td>30.0</td>
</tr>
<tr>
<td>Frequently discussed with parents</td>
<td>29.0</td>
</tr>
<tr>
<td>No discussion with parents</td>
<td>52.6</td>
</tr>
<tr>
<td>Males frequently discussed with parents</td>
<td>38.7</td>
</tr>
<tr>
<td>Males no discussion with parents</td>
<td>68.6</td>
</tr>
<tr>
<td>Females frequently discussed with parents</td>
<td>24.2</td>
</tr>
<tr>
<td>Females no discussion with parents</td>
<td>25.0</td>
</tr>
<tr>
<td>College aspirations</td>
<td>13.7</td>
</tr>
<tr>
<td>No college aspirations</td>
<td>55.3</td>
</tr>
</tbody>
</table>
A Chi-square test was used to determine the relationship between college aspirations and migration performance, and a relationship at the .001 level of significance was found. Since a relationship was found, two sets of comparisons in proportion to migration performances were then made: one was between having aspirations to attend college and those having no aspirations; the second was between the proportion making a decision concerning college aspirations and those who were undecided concerning college aspirations.

The results of this analysis indicated differences in the predicted direction for those who made a decision, but when comparing those who had made a decision with those who were undecided, larger proportions of both groups migrated from then remained in their home communities. From these results, the hypothesis that rural youth with aspiration to obtain additional training beyond high school will be more likely to migrate from their home communities than those with no college aspirations for additional training was supported.

Previous studies have indicated that migration from rural areas takes place shortly after graduation from high school. Data from the present study strongly support these findings. It was found that a larger percentage of females than males left their home communities sooner after high school graduation. Over 81 percent of the females had migrated within one year of graduation, 16 percent of whom returned to their home communities by 1956 and were considered to have remained in their home communities for analysis in this paper. Only 12 percent of the females never left their home communities between 1948 and 1956.

The males as compared to the females, did not have the mass migration tendencies during the first year after graduation. Only 47 percent had migrated the first year. Fourteen percent of the males never left their home communities between 1948 and 1956. Approximately 41 percent of the males migrated some time between 1948 and 1956 but returned and resided in their home communities by 1956 and were considered to have remained in their home communities for the analysis of this paper.

What was the geographic distribution of the sample in 1956? Table 5 indicates the 1956 residence of the respondents by sex. Only one-fourth of the females lived in their home communities while over 50 percent of the males lived in their home communities. It also is seen that 78 percent of the females and 85 percent of the males lived within the state of Iowa, while 22 percent of the females and 15 percent of the males left Iowa. From these data, it is clear that the females migrated greater distances from their home communities than the males. After eight years, over one-third of the respondents were residing in their home communities.

SUMMARY AND CONCLUSIONS

The present paper is concerned with the migration expectations and performances which existed among the 1948 graduates in the eight rural high schools in Hamilton County, Iowa, and Story City High School in Story County, Iowa. The respondents were interviewed as seniors in 1948 and reinterviewed in 1956 concerning their migration performance
Table 5. 1956 Residence of 1948 Graduates of Hamilton County and Story City Rural High Schools.

<table>
<thead>
<tr>
<th>Residence</th>
<th>Female</th>
<th>Male</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>Home Community</td>
<td>21</td>
<td>24.5</td>
<td>36</td>
</tr>
<tr>
<td>Home County</td>
<td>13</td>
<td>15.1</td>
<td>4</td>
</tr>
<tr>
<td>Contiguous County</td>
<td>15</td>
<td>17.4</td>
<td>3</td>
</tr>
<tr>
<td>Other Counties in Iowa</td>
<td>18</td>
<td>20.9</td>
<td>13</td>
</tr>
<tr>
<td>Contiguous States</td>
<td>11</td>
<td>12.8</td>
<td>5</td>
</tr>
<tr>
<td>Other States</td>
<td>7</td>
<td>8.1</td>
<td>5</td>
</tr>
<tr>
<td>Foreign</td>
<td>1</td>
<td>1.2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>86</td>
<td>100.0</td>
<td>66</td>
</tr>
</tbody>
</table>

at that time. In 1948 the respondents were asked whether or not they intended to leave their home communities and in 1956 it was determined where they resided. Analysis indicated that in 1948, 63 percent of the sample had made a decision concerning migration intentions, and it further was found that over 83 percent of those who had made a decision achieved their goal in 1956. Of those who were undecided in 1948 concerning migration intentions, nearly half migrated from their home communities and half remained in their home communities.

Further analysis yielded results indicating that those who were congruent with their intentions were more likely to have frequently discussed future plans with their parents, had a higher socioeconomic background and aspired to obtain additional training beyond high school.

Concerning differences between those who remained in and those who migrated from their home communities, it was found that more females migrated than males and more nonfarm males migrated than farm males. Nearly half the males and four-fifths of the females left their home communities within one year after graduation. Data from the males gave more support to the hypotheses than did data from the females. The males who migrated had a higher socioeconomic background, more frequently discussed their future plans with their parents and more aspired to obtain additional training beyond high school than those males who remained in their home communities. For these variables, no differences existed between females who migrated or remained in their home communities.

Data from this study give little support to studies which have indicated that little differences exist in the decision making process of males and females. In practically every case, males conformed to expectations,
but females did not. Other intervening variables appear to be involved in the females not performing as they expected at the time of graduation. Further research is needed to determine which factors are involved.

REFERENCES


MARK AND RECOVERY ESTIMATES OF FISH POPULATIONS
IN CLEAR LAKE, IOWA 1958 AND 1959

James A. McCann and Kenneth D. Carlander

ABSTRACT. Standing crops of fish in 3643-acre Clear Lake, Iowa were estimated by mark and recapture tech-
niques in 1958 and 1959. The lake was divided into
seven sampling regions and fish captured in each re-
gion were either tagged or finclipped. Equal sampling
was conducted in each region in 1959. An 150-volt
electric shocker was the best sampling gear in water
less than 5 feet and an 18-foot trawl was more efficient
in deeper water.

Recruitment bias was eliminated by increasing the
minimum size limit to compensate for growth. Differ-
ential mortality and vulnerability were not considered
serious. Placement of strap tags over both upper jaw
bones on walleyes and largemouth was more satisfac-
tory than placing tags only over the premaxillary bone.
Regeneration of correctly cut fins was slow and incom-
plete for all species.

Chi-square tests for random distribution indicated
that crappies, black bullheads and walleyes dispersed
over the entire lake after marking, but largemouth bass
and bluegill dispersed only in the shallow areas. Yel-
low bass did not disperse and were not sampled in pro-
portion to the population present.

Petersen, Schnabel and Schumacher-Eschmeyer esti-
mates were similar for both years for walleyes and
largemouth bass. The 1958 sampling was inadequate
for bullheads and crappies. Estimates indicated a de-
crease in the bluegill population between 1958 and 1959.

The best estimates for standing crop in pounds per

1 Journal Paper No. J-6294 of the Iowa Agriculture and Home Economics
Experiment Station, Ames, Iowa, Project 1374. Iowa Cooperative Fish-
ery Unit, sponsored by the Iowa State Conservation Commission, and
Iowa State University of Science and Technology and the Bureau of Sport
Fisheries and Wildlife, U.S. Dept. of Interior. This project also re-
ceived support from the Sport Fishing Institute, Inc., Washington, D.C.
This paper is from a portion of J. McCann's Ph.D. dissertation, 1960,
on file in the Iowa State University Library, entitled "Estimates of the
fish populations of Clear Lake, Iowa."

2 Now Leader, Massachusetts Cooperative Fishery Unit, University of
Massachusetts, Amherst, Mass.

3 Professor, Department of Zoology and Entomology, Iowa State Univer-
sity of Science and Technology, Ames, Iowa.
 acre were: walleyes 9.3, largemouth bass 0.6, bullhead 43.4, bluegill 0.8, black crappie 0.8, white crappie 0.6, and yellow bass 11.0. The yellow bass estimate is probably low. Sampling was not adequate to estimate populations of northern pike, yellow perch, white bass, channel catfish, smallmouth bass and white sucker; but observations were made on their distribution.

INTRODUCTION

Since 1941 the Iowa Cooperative Fisheries Research Unit has conducted research on Clear Lake, Iowa with emphasis on the life histories of the principal fishes, changes in relative abundance, success of year classes, effects of stocking, and measurement of some environmental factors of the lake. Although considerable data are available to indicate changes of fish populations in Clear Lake, very little has been done towards determining the standing crops of the various species. The present study was initiated in 1958 to estimate the numbers of fish of each species by mark and recovery techniques.

In estimating populations by these techniques, marks are placed on a known number (M) of fish in the lake and then after allowing sufficient time for the marked fish to become distributed in the population, the population (P) can be estimated from the numbers of marked fish recaptured (R) in a given catch (C).

$$P = \frac{CM}{R}$$

Even though the concept is simple, sampling problems make it difficult to determine the accuracy of the population estimate and may require modification of the formula (some of these are reviewed by Schaefer 1951; Bailey 1952; Chapman 1952; and Ricker 1958). When the fish are marked prior to the sample, we refer to the estimate as of the Petersen-type. In most instances in our study, marking continued throughout the sampling period, and estimates were made using multiple-sample techniques. One of these, the Schnabel type (Schnabel 1938) weights the samples according to the maximum likelihood theory while the Schumacher and Eschmeyer (1943) method is based upon the theory of least squares. Both methods were used although the estimates were usually similar, as reported by Fessler (1950), Crowe (1953), Chapman (1954) and Hundley (1954). The Schumacher-Eschmeyer estimate is less likely than the Schnabel estimate to be biased by nonrandom distribution of the marked fish (Schaefer 1951).

Description of Clear Lake and Sampling Areas

Clear Lake, Cerro Gordo County, Iowa is eutrophic and has an area of 3,643 acres (Fig. 1) and a maximum depth of 20 feet (Pearcy 1953). During 1958 and 1959, the water level was approximately 2.5 feet below outlet level decreasing the lake area by about 300 acres. No surface
water entered the lake in the summer of 1958 except during the early spring thaw and occasional rainy periods. During the summer of 1959, a small continuous flow of water entered the lake from Ventura Marsh. A carp trap prevented any movement of fish into or out of the lake at this inlet. Except for the lower water level and an increase in the number of cottages around the lake, the limnology of the lake apparently had not changed much since it was described by Pearcy (1953).

The lake was divided into seven major sampling regions to provide information on the movement of the fish and the presence of subpopulations of fish in the lake. For ease of reference the regions will be referred to as West End, Black Rushes, Hatchery, South Bay, Clausen’s Cove, East Center and West Center. Since the main sampling gear, a 150-volt alternating current shocker, was not effective in over 5 feet of water, the shore regions included the area from the shore line to the 5-foot contour, leaving two deeper lake regions, East and West Center.

### Methods of Capturing Fish

**Experimental Gill Nets**

Experimental gill nets have been used in Clear Lake since the summer of 1947 (Carlander 1954) to obtain samples for age and growth studies and to determine changes in the fish population. The experimental gill nets used in 1958 and 1959 consisted of 25-foot sections of 0.75, 1.0, 1.25, 1.5, and 2.0 inch (bar measure) nylon net. A 24-hour gill net set (four nets during the day and two nets at night) was made in each of the seven regions during each summer, and a second set was made each summer in the South Bay and Black Rushes regions. These additional sets were made to coincide with the number and location of

![Figure 1. Map of Clear Lake, Iowa, with seven sampling regions indicated.](image-url)
sets made in previous years, thus allowing direct comparisons of catches from year to year. The nets were checked every two hours and the fish measured, weighed and marked before being released in the same region clear of the nets. Since the gill nets frequently injure the fish, only fish in good condition were marked to reduce any differential mortality of the marked fish. Moyle (1950) and Buck and Cross (1952) indicated that gill nets were very selective for the size and species of fish caught. Whitney (1958) found that when gill nets alone were used for mark and recovery, population estimates had to be computed separately for different size groups to overcome selective bias. Since the use of several types of gear minimized the gear size-selection, all estimates in the study were computed for combined size and age groups.

Otter Trawl

An otter trawl, with a mouth 18 feet wide and 4 feet deep, was used in 1959 to sample fish in water over 5 feet in depth. The general sampling route followed each day was usually picked so that the hauls would not overlap or come too close to the previous hauls or to release points of the previous day. The fish caught were marked and released at the end of each run. The trawl proved very effective in taking bullheads, carp, walleye, crappie, white bass and yellow bass, in sizes ranging from fingerling to adult.

Seines

Twice each year the Iowa State Conservation Commission lake survey crew made three to four seine hauls with a 500-foot, 1/4 inch bar mesh seine at different locations. Because of the short length of seine and the limited places available for seining, the catch of these nets provided very little data for the population estimates. Some data on adult fish were also secured during shore sampling for young-of-the-year fish with a 50-foot bag seine (Ridenhour 1960a, b).

Before the fishing season opened in the spring of 1958, the Iowa State Conservation Commission rough fish crew made four seine hauls with a 2,000-foot (1/2-inch mesh) seine on the east side of McIntosh State Park and in the West End. Primarily, this work was done to remove carp, buffalo, and bullheads, but 5,335 game and pan fish were marked and released. In October 1958 the rough fish crew sampled various parts of the western half of the lake with a 3,400-foot (1-inch mesh) seine and made one haul on the east short of the island. All game and pan fish were checked for tags, marked and released.

In August of both years the rough fish crew made a demonstration haul with a 2,000-foot, 1/2-inch mesh seine for Governor's day. The 1958 site was the east side of the island where 303 fish were taken, nearly half of which were bullheads. In 1959 the demonstration haul was off Garner Beach, but only 117 fish were taken.

In the fall of 1959 (September 22 to November 2) the rough fish crew returned with a 3,400-foot seine to remove as many rough fish as possible from the lake. Since the net consisted of 2-inch bar mesh, only adult game fish such as northern pike, walleye, and largemouth were taken. During most of the first two weeks of operation J. McCann
supervised checking of all game and pan fish for marks. After this period only the ratio of tagged to untagged fish was recorded by the crew foreman. The crew was not asked to check for finclips. Snags, docks, boat tieups, heavy mud and other obstructions on the lake bottom prevented the use of the seines in many locations of Clear Lake. Because the unequal distribution of sampling effort may give biased estimates if the marked fish did not randomly distribute throughout the population after marking, the usefulness of large seines was limited in Clear Lake.

Rotenone

During the late summer and early fall of 1959, spot poisoning by the Iowa Conservation Commission indicated that large populations of young carp, yellow bass, and bullheads were present in the West End. On September 8, the entire West End, with the exception of the deep channel area, was treated with 5% rotenone. Most of the dead fish were examined for tags and finclips. Since all marking was completed before this period, Petersen estimates could be made.

Electric Shocker

The major sampling device for areas with a water depth of less than 5 feet was an electric shocker described by McCann (1966). Around the docks and through heavy vegetation, one of the crew, wearing waders, pushed the boat at a slow, walking pace, giving maximum maneuverability. In deeper water or near areas of poor footing a 10-HP outboard motor was used to propel the boat.

For night operation photographic reflectors containing 50-watt bulbs were attached to 3-foot uprights, and their beams were directed towards each electrode. This arrangement of lights allowed easy netting of fish without casting shadows over the sampling area. Another smaller light was attached to the rear gunnel beside the outboard motor, enabling the operator to see and pick up fish that came up behind the boat. In contrast to the work done by Loeb (1957) in New York, the electric shocker proved more efficient in Clear Lake during the day than at night. Twelve night-sampling periods (from 8 to 12 p.m.) were completed during the summers of 1958 and 1959. Only yellow bass and a few walleyes were taken in the evening even in locations that normally yielded good catches during the day. The greater transparency of the water in the New York waters probably explains the differences in success. Moen (1954) stated that alternating shockers worked best in the daytime in lakes having Secchi disc readings between 1 and 3 feet, and at night in lakes having readings of more than 3 feet. Clear lake had no Secchi disc reading exceeding 2 feet throughout the 1958 and 1959 sampling periods. The correlation between turbidity and the best sampling time probably resulted from the fish in clear water seeing the approaching gear and avoiding the electric field; whereas, at night or in turbid water, the fish do not sense the approaching gear until they are in the electric field. At night, even with the lights, it is more difficult than in the daytime to see the fish in the turbid water.
Walleyes and northern pike over 12 inches and largemouth bass over 10 inches were marked with a size 3 Monel metal strap tag (9.16 inch long and 1/8 inch wide when clenched) on the upper jaw. White bass and smaller walleyes were marked with a size 1 Monel metal tag (3/8 inch long and 1/16 inch wide when clenched).

On northern pike the tag was placed only over the premaxilla, but so few recaptures were taken that it was not possible to determine the permanency of these tags. Whitney (1958) in his work at Clear Lake in 1952 and 1953 marked walleye with tags placed only over the premaxillae. From later recapture data, he estimated that nearly 40% of these tags were lost in the first year. Early in the summer of 1958, tags were applied over the premaxillary bone or over both the premaxillary and maxillary bones of the walleye and largemouth bass. Recaptures showed that tags placed over only the premaxillary bone left large sores and, in several cases, the tag had almost eroded through the bone. Only one of the recaptures carrying a tag placed over both bones indicated poor healing. Because of these observations, all subsequent tags were placed over both bones. No recaptured walleyes showed any indication of having shed tags placed over both bones. No tag loss correction factor was considered in later population estimates.

In early July, 1959, one adult 17-inch largemouth was captured in the Black Rushes and transferred to the hatchery for exhibition to summer visitors. When the fish arrived at the hatchery, it was found to be a tagged fish with well-healed maxillary and premaxillary bones. This largemouth remained in the aquarium for almost two months before it was returned to the lake in good condition. During the time the fish was in the hatchery, it was fed live minnows and 4-inch bluegills. The tag did not interfere with the feeding.

One white bass recovered 60 days after tagging showed a slight redness around the tag but otherwise was in good condition. Two white bass tagged in October 1958 and recaptured in June 1959 showed complete healing around the tags.

Black bullheads, bluegills, yellow bass, black crappie and white crappie which had been over 6 inches in total length at the beginning of each season were finclipped with distinctive marks for each region of capture (Table 1). Bullheads and bluegills less than 6 inches were almost entirely missing. The presence of smaller yellow bass and crappies made it necessary to increase the lower size limit (Table 2) for these species so that only fish 6 inches or larger at the beginning of the study were included in the estimate.

Fins were clipped close enough to the base to draw some blood. Although the regeneration of the clipped fin started almost immediately, the relative age of the finclip could normally be determined up to one year after marking. By the spring of 1959 the soft rays of most fish showed some regeneration. However, it was possible until the latter part of August 1959 to separate fish marked in 1958 from fish marked in 1959 except for black and white crappie. All finclip recaptures were examined independently by two men in the crew and, with the exception of the crappies, one yellow bass and one bullhead taken near the end of
Table 1. Combinations of fins clipped for the different sampling regions of Clear Lake, Iowa, in 1958 and 1959.

<table>
<thead>
<tr>
<th>Region</th>
<th>Fins clipped</th>
</tr>
</thead>
<tbody>
<tr>
<td>West shore prior to 1958 season</td>
<td>Left pelvic</td>
</tr>
<tr>
<td>West End</td>
<td>Left pectoral</td>
</tr>
<tr>
<td>Black Rushes</td>
<td>Right pelvic</td>
</tr>
<tr>
<td>Clausen's Cove, other species</td>
<td>Left pectoral</td>
</tr>
<tr>
<td>Hatchery</td>
<td>Right pectoral and right pelvic</td>
</tr>
<tr>
<td>South Bay</td>
<td>Left pectoral and left pelvic</td>
</tr>
<tr>
<td>West Center</td>
<td>Left pectoral and right pelvic</td>
</tr>
<tr>
<td>East Center</td>
<td>Both pelvics</td>
</tr>
</tbody>
</table>

Table 2. Minimum size limits used to remove recruitment bias due to growth of the fish while estimating the population of fish in Clear Lake, Iowa, 1958 and 1959.

<table>
<thead>
<tr>
<th>Species</th>
<th>Minimum size limit in inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>June</td>
</tr>
<tr>
<td>Walleye</td>
<td>12.0</td>
</tr>
<tr>
<td>Yellow bass</td>
<td>6.0</td>
</tr>
<tr>
<td>Black crappie</td>
<td>6.0</td>
</tr>
<tr>
<td>White crappie</td>
<td>6.0</td>
</tr>
</tbody>
</table>
the summer in 1959, their conclusions were identical. Although there was a possibility that both men were incorrect, bias due to errors in determining the year in which the fish was clipped was not considered large. Cauterization of cut fins (Herman 1946) was not thought necessary since the regeneration of fins in this study was minimal.

A few naturally-missing fins were encountered during this study, but not enough to affect any estimates. Two bullheads missing right pelvic fins and one missing both pelvic fins were taken. Two yellow bass, one missing the right pelvic fin and the other missing both pelvic fins, were also taken. All five of these fish were examined under a dissecting scope. There was no evidence of any supporting bones in the area of these missing fins such as would be found if a clipped fin had healed over after being clipped.

Ten of the 20 yellow bass placed in the aquaria at the hatchery were clipped with the same combinations as those used in the lake. The remainder were used as controls. All fish sank to the bottom of the tank for several minutes, but arose to swim around after becoming accustomed to the aquaria. The marked fish generally took several minutes longer to become accustomed to the aquaria, probably because each of these fish had been handled individually while being marked. A slight awkwardness of the marked fish was noticed during the first day after marking, but after this period, little difference was noticed between marked and unmarked fish in swimming or feeding behavior. Ricker (1945) found that marked fish resumed normal behavior within two days.

Yellow perch, smallmouth bass, channel catfish and white suckers were fin clipped or tagged when captured but there were too few returns to be considered in any population estimate.

Basic Assumptions for Population Estimation

Mark and recovery estimates may be biased if basic assumptions are not fulfilled. Six major basic assumptions outlined by Ricker (1958) are discussed below in reference to their effect on the population estimates.

1. The population must be fixed in size.

Since Clear Lake is an isolated lake, there was no chance of fish movement into or out of the lake. Minimum size limits were changed during the summer according to observed growth to avoid bias due to recruitment. The magnitude and effect of the natural and fishing mortality on the population estimates at Clear Lake are poorly known, but available information is discussed in reference to each species. Mortality, if the same for marked and unmarked fish, does not affect Petersen estimates but does the multiple sample type.

2. Mortality rate of marked and unmarked fish must be equal.

Under normal field conditions this assumption is difficult to prove and frequently little evidence of its validity can be found. Increased mortality of fish due to marking or handling can be a serious source of bias. To minimize this mortality only fish in good physical condition were marked.
Mark and unmarked fish must be equally vulnerable to sampling gear.

Loeb (1957) recommended the use of an electric shocker for mark and recovery studies since this type of equipment is an aggressive sampling device and probably not affected as much by the behavior of the fish as are passive gear such as gillnets and traps.

In our study, the electric shocker was supplemented by several other types of sampling equipment. Use of several methods of capturing fish reduces differences in vulnerability of marked and unmarked fish (Fredin 1950). The various species of fish are not equally vulnerable to capture, but these species vulnerability differences do not seriously affect the population estimates since the population size of each of these species was estimated independently. Latta (1959) found differences in vulnerability of different sizes of fish in estimating populations by size group. Most of the species in Clear Lake for which estimates were made covered rather short size ranges above a minimum size limit (Table 3).

Table 3. Length frequency of eight species of fish in Clear Lake, Iowa, 1959, of sizes included in population estimates

<table>
<thead>
<tr>
<th>Total length in inches</th>
<th>Numbers in each size class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wall-eye</td>
</tr>
<tr>
<td>6-6.9</td>
<td>596</td>
</tr>
<tr>
<td>7-7.9</td>
<td>227</td>
</tr>
<tr>
<td>8-8.9</td>
<td>2</td>
</tr>
<tr>
<td>9-9.9</td>
<td>1</td>
</tr>
<tr>
<td>10-10.9</td>
<td>6</td>
</tr>
<tr>
<td>11-11.9</td>
<td>5</td>
</tr>
<tr>
<td>12-13.9</td>
<td>54</td>
</tr>
<tr>
<td>14-15.9</td>
<td>54</td>
</tr>
<tr>
<td>16-17.9</td>
<td>88</td>
</tr>
<tr>
<td>18-19.9</td>
<td>188</td>
</tr>
<tr>
<td>20-21.9</td>
<td>129</td>
</tr>
<tr>
<td>22-23.9</td>
<td>74</td>
</tr>
<tr>
<td>24-25.9</td>
<td>44</td>
</tr>
<tr>
<td>26-27.9</td>
<td>7</td>
</tr>
<tr>
<td>28-29.9</td>
<td>1</td>
</tr>
</tbody>
</table>
4. Loss of marks must be insignificant.

The loss of tags or the regeneration of fin clips preventing the identification of recaptured fish will bias the population estimate upwards. As mentioned in the section on marking, loss of marks was believed to be insignificant.

5. The capture of all marked fish must be recorded.

Closely related to the loss of marks is the incomplete reporting of marked fish. Since all fish which were used for population estimates in this study were examined for tags or clipped fins by a permanent crew of two (Marvin Buchholz and J. McCann), the error due to incomplete reporting of marked fish is considered negligible.

6. The marked fish must randomly distribute or sampling must be in proportion to the population.

Nonrandom distribution of marked fish and the existence of subpopulations of fish were considered the largest sources of possible error in this study. Except for the largemouth bass and bluegill, Lepomis macrochirus, which were restricted to the littoral regions, all population estimates in subsequent sections were based on the assumption of a uniform ratio of marked to unmarked fish throughout the lake. Tests of this uniformity were made for each species. Any tendency for the marked fish to concentrate in certain areas or to remain in the location where marked may cause serious bias in the population. If the fish are not randomly distributed, unbiased estimates may still be secured if sampling is proportional to the population in the various areas (Ricker 1958; Lagler and Ricker 1942; Cooper and Lagler 1956).

Population Estimates

Walleye (*Stizostedion vitreum*)

The walleye is the most sought after fish in Clear Lake and is considered by most sportsmen to be the best game fish in the lake (Di Ciotanzo and Ridenhour 1957). Since few walleyes less than 12 inches total length are taken by anglers, the population estimates were confined to fish over this size.

One of the basic assumptions in estimating populations of fish in a body of water by the mark and recovery method is that after marking, the fish randomly disperse throughout the unmarked population. The amount of dispersal can be shown by relating the region in which the fish were recaptured to the region in which the fish were marked (Table 4).

In the summer of 1958, 46 walleyes tagged in 1958 were recaptured. Since four of these fish were recaptured within 7 days after tagging, they were not used in estimating the walleye population. Three of the four were taken in the same region as tagged, while the fourth was taken in an adjacent region. The widespread distribution of recaptures of fish which were tagged at the Hatchery is misleading because these fish were originally taken from various regions of the lake for the spawning operations of the Hatchery. The distribution of the recaptured fish, therefore, may only indicate the returning of fish to the place where originally taken.

The relatively low chi square, 2.6 with 3 d.f., indicates that the
number of recaptures from fish tagged in each area was about as expected from the number tagged in each area. On the other hand, the number recaptured in each area was not as expected on the basis of the total catch (chi square was 20.4 with 3 d.f.). However, the major discrepancy was the small number of recaptures at the Hatchery. Since the catch at the Hatchery was mostly early in the study when few fish had yet been tagged, this test does not indicate any serious nonrandomness in recaptures.

Of walleyes tagged in 1958 and recaptured in 1959 (Table 5), 46% were recaptured at the tagging location although most of the fish had probably moved to spawning areas and dispersed again in the interval. The number of recaptures in each region did not differ significantly from that expected on the basis of total catch (chi square was 6.7 with 4 d.f.). The recaptures from the tagging regions were not as expected, however (chi square was 44.8 with 2 d.f.). The percentage return was high from the Clausen's Cove fish and low from the fish tagged at the Hatchery.

During the 1959 season, 93 walleyes tagged earlier in the season were recaptured. Since 19 of these were recaptured within 7 days of tagging, they were not used in estimating the population. Recapture data for the remaining 74 indicated a fair dispersion (Table 6) with 45% recaptured at their tagging locations. Recaptures were not as expected with random sampling either on the basis of total catch per region or numbers tagged per region.

Detailed analysis of the data, however, indicated that the West End data made the largest contribution to the significant chi square. A further analysis of the recaptures taken in the West End showed that 15 of the 20 recaptures reported from that region were taken after the poisoning of the West End in early September. Two of the walleyes that had moved into the West End after the poisoning came from the Hatchery region, four from the Clausen's Cove region and five from the Black Rushes region. Since four of the fish were local recaptures, they must have left the West End before the poisoning and returned afterward.

Elimination of the tag returns in the West End after September 1, reduced the chi square comparing the recaptures to the numbers expected on the basis of total catch in each region to 8.7 with 4 d.f., which is barely nonsignificant at the 95% confidence level, but did not improve the goodness of fit to the numbers expected on the basis of number tagged in each region.

The largest component of the latter chi square test is caused by the larger than expected number of Clausen's Cove marked fish being recaptured in the Black Rushes.

Sport fishermen during the summers of 1958 and 1959 took 7.3 to 8.8% of the walleye population according to the tags returned (Table 7). These 1958 and 1959 estimates are low since most of the tagging in these years was done during the fishing season, while the tagging of walleye in previous years was done before the fishing season opened. Fish tagged later in the season do not have the same chance to be caught by anglers as fish tagged before the season begins. The percentages were 14.2 and 11.4 when computed using only the walleyes tagged before the fishing season in 1958 and 1959 and recaptured in the same season as tagged.
<table>
<thead>
<tr>
<th>Region recovered (1958)</th>
<th>Region tagged</th>
<th>West End</th>
<th>Clausen's Cove</th>
<th>West Center</th>
<th>Black Rushes</th>
<th>Hatchery</th>
<th>South Bay</th>
<th>East Center</th>
<th>Combined</th>
<th>Expected</th>
<th>Total Catch</th>
</tr>
</thead>
<tbody>
<tr>
<td>West End</td>
<td></td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>0.6</td>
<td>15</td>
</tr>
<tr>
<td>Clausen's Cove</td>
<td></td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>4</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>6.8</td>
<td>166</td>
</tr>
<tr>
<td>West Center</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>0.4</td>
<td>11</td>
</tr>
<tr>
<td>Black Rushes</td>
<td></td>
<td>2</td>
<td>4</td>
<td>-</td>
<td>16</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>17.3</td>
<td>424</td>
</tr>
<tr>
<td>Hatchery</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>15.9</td>
<td>389</td>
</tr>
<tr>
<td>South Bay</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>0.6</td>
<td>15</td>
</tr>
<tr>
<td>East Center</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0.3</td>
<td>7</td>
</tr>
<tr>
<td>Total recaptured</td>
<td></td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>20</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td></td>
<td>0.5</td>
<td>4.1</td>
<td>0.5</td>
<td>18.5</td>
<td>17.9</td>
<td>0.5</td>
<td>0.5</td>
<td>3.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number tagged (1958)</td>
<td></td>
<td>11</td>
<td>87</td>
<td>9</td>
<td>391</td>
<td>378</td>
<td>11</td>
<td>1</td>
<td>42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Not including 4 walleyes recaptured 7 days or less after tagging, nor including 126 walleyes caught in the fall of 1958.

If those classes where the expected frequencies are less than 1.0 are combined, the chi square is 20.4 with 3 d.f. for the recaptures within the regions compared to total catch in the regions, and is 2.6 with 3 d.f. for the recaptures of fish tagged in each region compared to the total tagged.
Table 5. Numbers of 1958-tagged walleyes recaptured in the various regions of Clear Lake, summer of 1959.

<table>
<thead>
<tr>
<th>Region recovered (1959)</th>
<th>West End</th>
<th>Clausen's Cove</th>
<th>Black Rushes</th>
<th>Hatchery</th>
<th>South Bay</th>
<th>East &amp; West Center</th>
<th>Combined</th>
<th>Expected</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>West End</td>
<td>2</td>
<td>13</td>
<td>6</td>
<td>3</td>
<td>12</td>
<td>2</td>
<td>40</td>
<td>2.1</td>
<td>40</td>
</tr>
<tr>
<td>Clausen's Cove</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.4</td>
<td>307</td>
</tr>
<tr>
<td>West Center</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td>2.1</td>
<td>40</td>
</tr>
<tr>
<td>Black Rushes</td>
<td>2</td>
<td>3</td>
<td>19</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
<td>30.3</td>
<td>568</td>
</tr>
<tr>
<td>Hatchery</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
<td>9.9</td>
<td>185</td>
</tr>
<tr>
<td>East Center</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td>2.8</td>
<td>53</td>
</tr>
<tr>
<td>South Bay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td>7.0</td>
<td>131</td>
</tr>
</tbody>
</table>

Combined       2  23  40  12  2  0  79

Expected Number tagged
1958 1.0 7.8 34.8 33.7 1.0 0.9

If those classes where expected frequencies are less than 5.0 are combined, the chi square is 6.7 with 4 d.f. for recaptures within regions compared to total catch in regions, and is 44.8 with 2 d.f. for recaptures of fish tagged in each region compared to the total tagged in the region.
Table 6. Distribution of walleyes tagged in 1959 and recovered in the various regions of Clear Lake, 1959.

<table>
<thead>
<tr>
<th>Region recovered (1959)</th>
<th>Region tagged (1959)</th>
<th>West</th>
<th>Clausen's Cove</th>
<th>Black Rushes</th>
<th>West Center</th>
<th>Hatchery</th>
<th>South Bay</th>
<th>East Center</th>
<th>Combined</th>
<th>Total</th>
<th>Catch</th>
<th>Expected</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>(West end up to Sept. 1)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>106</td>
<td></td>
<td></td>
<td>5.6</td>
<td></td>
</tr>
<tr>
<td>West End</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>20</td>
<td>194</td>
<td>9.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clausen's Cove</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>307</td>
<td>15.4</td>
<td>16.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Rushes</td>
<td>2</td>
<td>10</td>
<td>17</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>33</td>
<td>568</td>
<td>28.4</td>
<td>30.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Center</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>40</td>
<td>2.0</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>Hatchery</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>185</td>
<td>9.3</td>
<td>9.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Bay</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>131</td>
<td>6.6</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Center</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>53</td>
<td>2.7</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total recapture</td>
<td>10</td>
<td>22</td>
<td>28</td>
<td>0</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>74</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>10.6</td>
<td>13.8</td>
<td>25.6</td>
<td>2.6</td>
<td>11.7</td>
<td>6.9</td>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number tagged</td>
<td>152</td>
<td>198</td>
<td>372</td>
<td>38</td>
<td>168</td>
<td>99</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Not including 73 taken by 3,400-foot seine, September 22 to November 2, 1959.*

If those classes where expected frequencies are less than 5.0 are combined, the chi square is 18.7 with 4 d.f. for recaptures within regions compared to total catch in regions, or 8.7 with d.f. if the West End data after September is eliminated; and is 11.3 with 4 d.f. for recaptures of fish tagged in each region compared to total tagged in the region.
Table 7. A summary of the walleye tag returns from anglers for the years 1952 through 1959 in Clear Lake, Iowa

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>144</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1953</td>
<td>16</td>
<td>105</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1954</td>
<td>6</td>
<td>40</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1955</td>
<td>1</td>
<td>10</td>
<td>6</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1956</td>
<td>6</td>
<td>5</td>
<td>9</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1957</td>
<td>2</td>
<td>8</td>
<td>13</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1958</td>
<td>9</td>
<td>1</td>
<td>7</td>
<td>25</td>
<td></td>
<td></td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>1959</td>
<td>1</td>
<td></td>
<td>3</td>
<td>7</td>
<td></td>
<td></td>
<td>52</td>
<td>64</td>
</tr>
</tbody>
</table>

Number marked: 781 1424 167 265 525 995 1062
Per cent returned 1st year: 18.4 7.4 9.6 8.3 7.5 7.3 8.8
All tags turned in by fishermen or taken from a few dead fish found along the shore were subtracted from the number of tagged fish in the lake as the summer progressed, for the multiple sample estimates.

With a single-census or Petersen estimate, the captured tagged fish should not be subtracted from the number of tags in the lake because the estimate refers back to the time when fish were tagged. With multiple sample estimates the population estimated is an average during the time of tagging. If the tagged fish are not subtracted as the fish are removed, the number of tagged fish in the lake continually increases while the number of untagged fish decreases. Correction for mortality and recruitment is complicated in a Schnabel estimate (Ricker 1958 p. 104). We have assumed that recruitment and mortality were relatively small during the sampling period, but recognize that the estimates are somewhat in error because of this assumption.

Estimates of the walleye population were obtained by the Schnabel, and Schumacher-Eschmeyer methods (Table 8). Although the percentage of marked walleyes in the population was less than 5% in 1958 and over 5% in 1959, the Schumacher-Eschmeyer estimates were considered the best estimates for both years, since some sampling periods in both years contained no recaptures and since the Schumacher-Eschmeyer estimate is not affected as seriously if the marked fish do not randomly distribute. Since the 1959 confidence limits included the 1958 estimates, the walleye population of the lake did not differ significantly during the study.

During the seining done by the rough fish crew in the fall of 1958 all walleyes taken were checked for marks and were tagged if not previously marked. Of the 152 walleyes taken during this period, 12 were recaptures. Since 1,029 had been marked previously in that year, the Petersen estimate is 13,034 with 95% binomial confidence limits of 8,320 and 23,827. Since the fish were tagged over a period of 3 months during which there was recruitment and fishing and natural mortality, this estimate applies to the average population during that period and has errors due to mortality and recruitment. There were 73 tags known to have been removed from the lake by fishermen before this time. If we were to accept these 73 tags as the total mortality or loss of tags during the

<table>
<thead>
<tr>
<th></th>
<th>1958</th>
<th>1959</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of recaptures</td>
<td>42</td>
<td>74</td>
</tr>
<tr>
<td>Total number marked</td>
<td>995</td>
<td>1,062</td>
</tr>
<tr>
<td>Schnabel</td>
<td>12,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Schumacher-Eschmeyer</td>
<td>11,600</td>
<td>12,300</td>
</tr>
<tr>
<td>96% confidence limit</td>
<td>8,600-14,600</td>
<td>9,500-15,000</td>
</tr>
</tbody>
</table>
period, there would have been 956 tagged fish in the lake when the sampling was done. The Petersen estimate would then be 12,109 with confidence limits of 7,648 to 21,819. This estimate would apply to the population in the fall and can be assumed to be too high because certainly more than 73 tags had been removed by that time.

Whitney (1958) stated that his most accurate estimate was 30,822 for the walleyes over 12 inches, indicating that the walleye population in Clear Lake in 1952 and 1953 was much larger than it was during the 1958 and 1959 seasons. The ratio of the 1952-3 population estimate to the 1958-9 population estimate 30,800 to 12,300 or 2.5 to 1.0 is about the same as the ratio, 2.58 to 1.0, of the mean catch per gill net day in these two periods (Table 9). The drop in water level from 1955 probably caused low survival and a decrease in adult walleyes by 1958 and 1959 (Carlander et al. 1960).

Table 9. Catch of walleye per 24-hour period of 125-foot experimental gill nets along the North Shore of Clear Lake, Iowa - June through August for the years 1952-1953 and 1958-1959

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of net days</th>
<th>Mean catch of walleyes per net day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952a</td>
<td>28.1</td>
<td>14.8</td>
</tr>
<tr>
<td>1953a</td>
<td>11.8</td>
<td>12.3</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>13.55</td>
</tr>
<tr>
<td>1958a</td>
<td>6.0</td>
<td>5.4</td>
</tr>
<tr>
<td>1959</td>
<td>6.0</td>
<td>5.1</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>5.25</td>
</tr>
</tbody>
</table>

*Taken from Carlander et al. (1960).

Anglers caught an estimated 3,870 walleyes from April 17 to September 1955 (Di Costanzo and Ridenhour 1957) which would mean a 31% removal if the population were the same as estimated for 1958-1959. Since this percentage is high compared with the tag returns (Table 7) the walleye population was probably higher in 1955 than in 1958-1959.

An estimate of 12,300 walleyes over 12 inches corresponds to 3.4 walleyes per surface acre of Clear Lake. In Clear Lake the average weight of the walleyes over 12 inches, as determined from the weights of 201 walleyes taken by the gill nets and anglers in 1959, was 2.75 pounds, giving a standing crop of 9.3 pounds per acre. This is similar to standing crops reported for Storm and Spirit Lakes (Rose 1949a, b and 1955), and for Minnesota lakes (Carlander 1955).

During the summers of 1958 and 1959, the heaviest concentrations of walleyes were located in the rush areas of the lake, especially in the
Black Rushes. In the Black Rushes region, two small gravel areas were found, separated by a large patch of rushes that extended toward the center of the lake. Depending upon the wind direction, one area was exposed to the full force of the wind while the other area was partly sheltered by the point of rushes. On extremely windy days when the wind was blowing from a southerly direction, the area that received the full force of the wind attracted no walleye, while the sheltered area attracted a large concentration of walleyes. On quiet days walleyes were found in both areas. Rose (1955) found walleyes preferred rocky reefs and points in Spirit Lake, Iowa. He frequently took walleyes by seining along sandy, boulder-strewn beach areas away from vegetation. In Clear Lake the smaller walleyes preferred the dock areas while the larger walleyes were taken near the rush areas or near the reefs.

Carlander and Cleary (1949), Sieh and Parsons (1950), and Rawson (1957) found that walleyes are more active during the dawn and dusk periods, moving into shallower water at night to feed. In our study shocking at night also indicated that walleyes move into shallower water. Gill netting at night showed that some adult walleyes inhabited the deeper parts of the lake usually near the surface. However, during the day the otter trawl took 21 walleyes from the bottom of the lake, indicating that some walleyes spend part of the daylight hours in deep water near the bottom.

Largemouth bass (Micropterus salmoides)

Largemouth bass are considered major game fish in many lakes, but because of the small numbers in Clear Lake, only a few ardent fishermen seek them out (Di Costanzo and Ridenhour 1957).

All largemouth bass (101 in 1958 and 233 in 1959) in our study were taken either by the seine of the rough fish crew or by the electric shocker. All the largemouth were taken near rushes except for several which were taken by the electric shocker from rock piles in the South Bay region and in the center of the West End parallel to the road. In the last two locations the water was only 10 inches deep and the bottom was muddy. Bass were taken every time these locations were sampled with the electric shocker. On seven different occasions in 1959, a largemouth bass was taken from one isolated boulder (24 inches in diameter) in the center of the West End. A different largemouth was taken each time, which might indicate that the shocker drove the fish out of the location. In South Bay two small rock piles, probably the remains of old fish shelters placed in the lake many years ago, yielded two to four largemouth each time sampled with the electric shocker. Several times concentrations of largemouth were found in the rushes near gravel beds along the east side of the Sand Bar and in the rushes off Lone Tree Point. In these concentrations 6 to 11 largemouth of different ages and sizes were taken in an area of approximately 10 square yards.

During the 1958 season, 7 of the 98 marked largemouth bass were recaptured. All were local recoveries, indicating the bass did not become randomly distributed. Cooper (1952) and Hasler and Wisby (1958) found that when bass were released in the area in which they were caught, they would remain in this area of the lake throughout the summer. Rodeheffer (1941) indicated that largemouth bass released in an area other than the
one in which they were caught wandered more than largemouth bass released where caught.

In 1959, 5 of the 8 recaptures of 1958 marked bass were still at the location first caught. Two fish from Black Rushes had wandered to East Sand Bar and Lone Tree and one from Farmer's Beach was recaptured at East Sand Bar. The 1959 tagged fish showed considerable dispersion, although 14 of 25 recaptures indicated no movement (Table 10). Three

Table 10. The dispersion of the tagged largemouth bass in Clear Lake, Iowa, during 1959.

<table>
<thead>
<tr>
<th>Region recovered (1959)</th>
<th>West End</th>
<th>Clausen's Cove</th>
<th>Black Rushes</th>
<th>Hatchery</th>
<th>South Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>West End</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Clausen's Cove</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Black Rushes</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hatchery</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>South Bay</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>

| Number caught | 66        | 33         | 90         | 28       | 16       |
| Number marked  | 24        | 28         | 73         | 25       | 7        |

bass that traveled farthest were tagged in June at the Boy Scout Camp, Black Rushes and Farmer's Beach and were recaptured in South Bay in less than 7 weeks, distances of 3.5, 2.25 and 3.25 miles, respectively. Distances along shore, the likely routes, would be longer. Decreasing water levels in 1959 may have caused the largemouth bass to seek new territories more than in 1958. Largemouth bass occasionally have been found to move considerable distances in other lakes (Hancock 1956; Hulse and Miller 1958).

Population estimates were computed from the 1958 data only for the west half of the lake since only two bass were tagged and none were recovered elsewhere (Table 11). In 1959, the estimate was considered to

Table 11. Comparison of the population estimates of largemouth bass in Clear Lake, Iowa, for 1958 and 1959.

<table>
<thead>
<tr>
<th></th>
<th>1958&lt;sup&gt;a&lt;/sup&gt;</th>
<th>1959&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of recaptures</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>Total number marked</td>
<td>98</td>
<td>157</td>
</tr>
<tr>
<td>Schnabel</td>
<td>727</td>
<td>808</td>
</tr>
<tr>
<td>Schumacher-Eschmeyer</td>
<td>693</td>
<td>820</td>
</tr>
<tr>
<td>95% Confidence limits</td>
<td>335-1049</td>
<td>448-1152</td>
</tr>
</tbody>
</table>

<sup>a</sup> Estimates only for Clausen's Cove, Black Rushes and West End regions.

<sup>b</sup> Estimates for entire lake.
represent the entire lake since there had been dispersion. The population estimates for the two years are quite similar and the part of the lake not included in the 1958 estimate probably had few bass. The Schnabel estimate in 1959 was considered the best since less than 5% of the bass were marked.

The mean weight of 40 largemouth bass taken in 1959 was 2.7 pounds and thus the population of 808 represents 2,180 pounds. If only shore regions are considered, the standing crop is 0.8 bass or 2.2 pounds per acre, a low figure compared with many other waters (Carlander 1955).

Black bullhead (Ictalurus melas)

Electric shocker and a 2,000 foot seine took 3,573 bullheads in 1958. Experimental gill nets, the only deep water gear used, took only 163 bullheads in East and West Center areas, over 75% of the lake. In 1959, a trawl was used in the deeper waters, beginning in mid-June. Trawl catches were low in June but averaged about 90 bullheads per 10-minute haul in July. Since the electric shocker in shallow water caught more bullheads in June than July, there was probably a movement from shallow to deep water at this time. In the first two weeks of August the trawl averaged 54 bullheads per haul, but the catch then increased with a maximum of 451 bullheads taken in 10 minutes in the East Center region off Oakwood on August 24.

On several occasions in 1959 large schools of adult bullheads (1,000 to 2,000) were observed in the West Center region swimming with their mouths breaking the surface of the water. Two attempts, once with the shocker and once with the trawl, failed to take these fish. The school dispersed as the boat approached.

The size distribution of the bullheads suggested that there was an abundant year class with poor recruitment for the last 3 or 4 years. Most of the bullheads were 7 to 9 inches long. Only 29 bullheads over 9 inches and only 30 bullheads smaller than 6.9 inches were taken even though the sampling gear should not have been particularly size selective. Some young of the year (not included in the 30 mentioned above) were taken, but these were not abundant even though there was much bullhead spawning activity in the rush areas in June 1959.

Only 18 marked bullheads were recaptured in 1958, and the population estimate is probably not very accurate. In 1959, 64 of the bullheads marked in 1958 were recaptured (Table 12). The numbers of recaptures were not as expected with random distribution in relation either to catch or to region of marking. Elimination of the large group of bullheads marked in April did not improve randomness of recapture. The 1959 recaptures of bullheads marked in 1959 were about as expected on the basis of total catch, but not on the basis of region marked (Table 13). Forney (1955) found that in Clear Lake the bullhead population of the West End was separate and distinguishable from the bullhead population of the remainder of the lake at least during the summer period. His conclusions were based on the difference in growth rate and length-weight relationship that existed between the bullheads in the east and west ends of the lake. The recapture of so many bullheads in regions different from where they tagged does not suggest separate populations in 1959.
Table 12. Distribution of bullheads marked in 1958 and recaptured in various regions of Clear Lake, 1959

<table>
<thead>
<tr>
<th>Region recaptured</th>
<th>West End &amp; East McIntosh April 1958</th>
<th>West End &amp; Clausen's Cove</th>
<th>Black Rushes</th>
<th>West Center</th>
<th>Hatchery</th>
<th>East Center</th>
<th>South Bay</th>
<th>Combined</th>
<th>Total</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>West End</td>
<td>12</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>23</td>
<td>2870</td>
<td>13.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clausen's Cove</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>415</td>
<td>1.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Rushes</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Center</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>16</td>
<td>19.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hatchery</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Center</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>11</td>
<td>24.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Bay</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total recapture</td>
<td>27</td>
<td>17</td>
<td>12</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>56</td>
<td>64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number marked</td>
<td>2290</td>
<td>343</td>
<td>300</td>
<td>66</td>
<td>117</td>
<td>97</td>
<td>262</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>42.2</td>
<td>6.3</td>
<td>5.5</td>
<td>1.2</td>
<td>2.1</td>
<td>1.8</td>
<td>4.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If those classes where expected frequencies are less than 5.0 are combined, the chi square is 21.9 with 2 d.f. for recaptures within regions compared to total catch in regions and is 31.7 with 3 d.f. for recaptures of fish tagged in a region compared to total tagged in region.
Table 13. Distribution of bullheads marked in 1959 and recaptured in various regions of Clear Lake, 1959

<table>
<thead>
<tr>
<th>Region recaptured</th>
<th>West End &amp; Clausen's Cove</th>
<th>Black Rushes</th>
<th>West Center</th>
<th>Hatchery</th>
<th>East Center</th>
<th>South Bay</th>
<th>Combined</th>
<th>Total Catch</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>West End</td>
<td>10</td>
<td>4</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>16</td>
<td>2870</td>
<td>26.5</td>
</tr>
<tr>
<td>Clausen's Cove</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>415</td>
<td>3.7</td>
</tr>
<tr>
<td>Black Rushes</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>867</td>
<td>7.7</td>
</tr>
<tr>
<td>West Center</td>
<td>3</td>
<td>2</td>
<td>18</td>
<td>2</td>
<td>9</td>
<td>2</td>
<td>36</td>
<td>4196</td>
<td>37.5</td>
</tr>
<tr>
<td>Hatchery</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>166</td>
<td>1.5</td>
</tr>
<tr>
<td>East Center</td>
<td>6</td>
<td>5</td>
<td>14</td>
<td>6</td>
<td>23</td>
<td>-</td>
<td>54</td>
<td>5198</td>
<td>46.4</td>
</tr>
<tr>
<td>South Bay</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>56</td>
<td>0.5</td>
</tr>
<tr>
<td>Total recapture</td>
<td>26</td>
<td>15</td>
<td>33</td>
<td>10</td>
<td>34</td>
<td>5</td>
<td>123</td>
<td>13768</td>
<td></td>
</tr>
<tr>
<td>Numbers marked</td>
<td>1599</td>
<td>847</td>
<td>4131</td>
<td>161</td>
<td>5133</td>
<td>52</td>
<td>11923</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected</td>
<td>16.5</td>
<td>8.7</td>
<td>42.6</td>
<td>1.7</td>
<td>53.0</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If those classes where expected frequencies are less than 5.0 are combined, the chi square is 6.6 with 3 d.f. for recaptures within regions compared to total catch in regions and is 17.8 with 2 d.f. for recaptures of fish tagged in a region compared to total tagged in region.
Table 14. Comparison of the population estimates of bullheads by the different methods for 1958 and 1959 in Clear Lake, Iowa

<table>
<thead>
<tr>
<th>Method</th>
<th>1958</th>
<th>1959</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper</td>
<td>Point</td>
</tr>
<tr>
<td></td>
<td>limit</td>
<td>estimate</td>
</tr>
<tr>
<td>Schnabel</td>
<td>260,491</td>
<td></td>
</tr>
<tr>
<td>Schumacher-Eschmeyer</td>
<td>435,361a</td>
<td>257,382</td>
</tr>
<tr>
<td>Petersen Ic</td>
<td>779,000b</td>
<td>617,600</td>
</tr>
<tr>
<td>Petersen Iic</td>
<td>1,042,200b</td>
<td>526,000</td>
</tr>
</tbody>
</table>

a 95% Confidence limits.
b 95% Poisson confidence limits.
c Petersen I was based upon 1958 marked fish caught in the 1959 sampling. Petersen II was based upon 1958 marked fish in a sample of 1620 bullhead taken from the carp trap on June 24, 1959.

The estimate of about a quarter million bullheads based upon the 1958 recaptures is probably inaccurate (Table 14). Two Petersen estimates could be made of the 1958 population and these indicate twice as large a population, a figure which compares favorably with the 1959 estimates. The length distributions of the bullheads indicated that no significant recruitment took place in 1958 or 1959 and thus the 1958 population of bullheads over 6.0 inches could not be less than the 1959 population. One-half million corresponds to about 140 bullheads per acre. The average weight of 235 bullheads in 1959 was 0.31 pounds, giving a standing crop of about 43 pounds per acre.

An additional estimate of the bullhead population was attempted. Although the trawl was classified as an 18-foot trawl, the sampling width probably was somewhat smaller than this due to the drag of the water. A set-up of the trawl on dry land indicated that the actual fishing width probably varied between 14 and 18 feet. When 16 feet was used as the mean width and 1,700 feet as the length of a haul, the computed area covered for each 10-minute haul was 0.624 acres. Since the mean number of bullheads taken before August 1, 1959 was 90 per haul, an estimate of 144 bullheads per acre was obtained, which is close to the mark and recapture estimates.

The angler catch of bullheads was estimated at 229,600 from April 17 to September 5, 1955 (DiCostanzo and Ridenhour 1957). The average gill net catch was 2.24 bullheads per hour in 1955 compared with 0.92 and 1.12 in 1958 and 1959. If the bullhead population in 1955 was twice that estimated for 1958 and 1959, the fishing mortality of catchable-sized bullheads would be 25%. This value is believed to be high but the sources of error are not known. The average size of bullheads in 1958 and 1959
was much less than in 1954 (Forney 1955). The 1951, 1952, 1953 and 1954 year classes of bullheads were abundant (Forney 1955) but the 1955 to 1958 year classes were not very abundant.

Bluegill (Lepomis macrochirus)

Although Bailey and Harrison (1945) considered the bluegill one of the most abundant species in Clear Lake, Di Costanzo (1957) indicated that the relative size of the population of bluegill had declined. Di Costanzo and Ridenhour (1957) reported that bluegill made up only 3.3% of the anglers' catch in 1953, but increased to 12.7 and 16.0% in 1954 and 1955 respectively. This increase was caused by successful 1951 and 1952 year classes. Gill net records indicate that the bluegill population declined after 1955 possibly because of mortality among the 1951 and 1952 year classes with little replacement. In 1958 and 1959 most of the bluegill ranged from 6.5 to 7.8 inches long. No bluegills over 8 inches were taken and only 40 of 1,678 were from 4 to 6.5 inches long. Therefore, recruitment during study was considered negligible. Most of the bluegill were taken with the electric shocker from the rush areas, in water less than 3 feet deep. Although Snow et al. (1960) reported that bluegills often swim in close schools, this behaviour was not evident in Clear Lake.

A few bluegill moved from one region to the next, but most remained in the same region in which they were marked, even with an intervening winter period (Table 15). Although the bluegill did not randomly disperse, it is believed that the efficiency of sampling was the same in each region due to the similarity of bluegill habitat in each region, and thus the population was sampled in proportion to the number of fish present.

Another basic assumption that must be satisfied if the population estimates are to be unbiased is that the different marks do not cause a differential mortality. A comparison of the number of bluegill marked in each region and differently marked with the total number of recaptures indicated that finclipping had no differential mortality effect as far as could be determined (Table 16).

The population estimates obtained by the different methods indicated that the bluegill population dropped between the summers of 1958 and 1959 (Table 17). The gill net catch per hour also dropped from 0.107 in 1958 to 0.029 in 1959.

Even though the percentage of marked bluegill was below 5% of the estimated total population, the Schumacher-Eshmeyer estimate for both years was believed to be the best estimate since the nonrandom distribution of the bluegills and the lack of recaptures in some sampling periods would bias this estimate the least.

The mean individual weight of 200 bluegills in 1959 was 0.26 pound. Since bluegills were restricted to the rush areas of the lake, the standing crop per acre was based only on the shore regions which were considered suitable habitat for bluegills. When this was done, standing crops of 5.3 and 3.3 pounds per acre were obtained for 1958 and 1959 respectively. The population of bluegills in Clear Lake was lower than average (Carlander 1955).

The angler catch of bluegills was estimated at 110,800 from April 17 to September 5, 1955 (DiCostanzo and Ridenhour 1957) about ten times
Table 15. The 1958 and 1959 recapture data by regions for the bluegills marked in 1958 and 1959 in Clear Lake, Iowa

<table>
<thead>
<tr>
<th>Region recovered (1958)</th>
<th>Region marked - 1958</th>
<th>Region marked - 1959</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Special clip</td>
<td>West End</td>
</tr>
<tr>
<td>West End</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Clausen's Cove</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Black Rushes</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Hatchery</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>South Bay</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total marked</strong></td>
<td>215</td>
<td>34</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region recovered (1959)</th>
<th>Region marked - 1958</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>West End</td>
</tr>
<tr>
<td>West End</td>
<td>-</td>
</tr>
<tr>
<td>Clausen's Cove</td>
<td>-</td>
</tr>
<tr>
<td>Black Rushes</td>
<td>-</td>
</tr>
<tr>
<td>Hatchery</td>
<td>-</td>
</tr>
<tr>
<td>South Bay</td>
<td>-</td>
</tr>
<tr>
<td><strong>Region recovered (1959)</strong></td>
<td><strong>Region marked- 1959</strong></td>
</tr>
<tr>
<td>West End</td>
<td>-</td>
</tr>
<tr>
<td>Clausen's Cove</td>
<td>-</td>
</tr>
<tr>
<td>Black Rushes</td>
<td>-</td>
</tr>
<tr>
<td>Hatchery</td>
<td>-</td>
</tr>
<tr>
<td>South</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total marked</strong></td>
<td>-</td>
</tr>
</tbody>
</table>

<sup>a</sup>Left pelvic clip given to 215 bluegills in April, 1958 at McIntosh State Park.
Table 16. Comparison of the number of bluegill marked in a region with the number of recaptures originally marked in that region, but caught over the entire area of Clear Lake, Iowa, for 1958 and 1959.

<table>
<thead>
<tr>
<th>Region marked (1958 and 1959)</th>
<th>Special clip</th>
<th>West End</th>
<th>Clausen's Cove</th>
<th>Black Rushes</th>
<th>Hatchery</th>
<th>South Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number caught</td>
<td>215</td>
<td>117</td>
<td>369</td>
<td>659</td>
<td>153</td>
<td>159</td>
</tr>
<tr>
<td>Number recovered over entire lake</td>
<td>5</td>
<td>9</td>
<td>24</td>
<td>28</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Chi square = 7.9, not significant at 95% level of significance.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

the population estimated for 1959. The 1951 and 1952 year classes of bluegills were abundant and provided good bluegill angling in 1955 and 1956 (DiCostanzo 1957). There was not an abundant year class from 1952 until after 1958.

Yellow Bass (Morone mississippiensis)

The yellow bass probably were introduced into Clear Lake with mixed stocking of fish obtained from salvage operations along the Mississippi River and first appeared in the anglers' catch in 1932 (Bailey and Harrison 1945). During the first few years after the species became established, yellow bass weighing over one pound provided excellent fishing in the lake. Lewis and Carlander (1948) indicated that by 1947 the growth rate of the yellow bass had decreased and the fish were generally in poorer condition. Carlander et al. (1952) found the yellow bass population increasing and the fish showing even slower growth by 1950. From 1955 to 1958 many yellow bass did not grow at all after reaching 3 to 5 years of age (Buchholz and Carlander 1963). DiCostanzo and Ridenhour (1957) reported a large mortality of yellow bass in the fall of 1955; and because of this, the anglers' catch of yellow bass in 1956 was only one-tenth of what it had been during the previous year. Since 1955 the yellow bass fishing in the lake has been poor, probably due to the small average size of the fish.

During the sampling in 1958 and 1959 the catch included only one yellow bass over 9 inches and very few over 7.9 inches total length. The average total length of 500 randomly picked yellow bass was 6.9 inches in 1959. Although the lower size limit of the yellow bass included in the study was set at 6 inches, the limit had to be increased as the summer progressed. Since it was possible to separate the younger age groups by size alone, the lower limit could be moved as the fish grew during the summer. No attempt was made to carry the size limit over the winter of 1958-1959, and the size limit was again placed at 6 inches in the spring of 1959. For this reason the 1959 population include another year class recruited.

In 1958 only one of the 26 recaptures was taken outside the region marked, which indicates nonrandom distribution (Table 18). Even in
Table 17. Comparison of the population estimates for bluegills in Clear Lake, Iowa, for 1958 and 1959.

<table>
<thead>
<tr>
<th>Method</th>
<th>Upper limit</th>
<th>Point estimate</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Point estimate</th>
<th>Lower limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schnabel</td>
<td>13,984</td>
<td></td>
<td></td>
<td>10,856</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schumacher-Eschmeyer</td>
<td>21,762&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14,473</td>
<td>7,183</td>
<td>14,238&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10,880</td>
<td>7,522</td>
</tr>
<tr>
<td>Petersen</td>
<td>20,000&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13,700</td>
<td>9,700</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> 95% Confidence limits.

<sup>b</sup> 95% Poisson confidence limits, estimates made in 1959 on basis of 1958 tags.

Table 18. Number of yellow bass captured and marked in all regions of Clear Lake, Iowa, in 1958 and 1959.

<table>
<thead>
<tr>
<th></th>
<th>West End</th>
<th>Black Rushes</th>
<th>Clausen's Cove</th>
<th>West Center</th>
<th>Hatchery</th>
<th>East Center</th>
<th>South Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number caught</td>
<td>277&lt;sup&gt;a&lt;/sup&gt;</td>
<td>644</td>
<td>750</td>
<td>253</td>
<td>315</td>
<td>602</td>
<td>566</td>
</tr>
<tr>
<td>Number marked</td>
<td>158</td>
<td>384</td>
<td>505</td>
<td>140</td>
<td>214</td>
<td>206</td>
<td>329</td>
</tr>
<tr>
<td>1959</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number caught</td>
<td>1,072</td>
<td>828</td>
<td>544</td>
<td>429</td>
<td>381</td>
<td>418</td>
<td>856</td>
</tr>
<tr>
<td>Number marked</td>
<td>786</td>
<td>703</td>
<td>467</td>
<td>204</td>
<td>314</td>
<td>218</td>
<td>583</td>
</tr>
</tbody>
</table>

<sup>a</sup> 1,977 Yellow bass marked in April, 1958, not included.
1959, 22 of the 26 recaptures of the 1958 marked fish were taken in the region marked. Only 2 of 35 recaptures of 1959 marked yellow bass were taken from outside the region marked. Carter (1958) found that yellow bass in lakes tended to move little but those in rivers averaged 16.4 miles before recapture. A nocturnal inshore movement of yellow bass was reported from gill net studies at Clear Lake (Carlander and Cleary 1949).

The low recapture rate of the yellow bass (1.2%) may be related to mortality of yellow bass after marking. The population estimates would then be too high. Although there was little direct evidence of such mortality, yellow bass are more difficult to handle or transport without mortality than most species of fish. Only a small percentage of the yellow bass taken in gill nets or trawl were considered in satisfactory condition for marking and releasing. For this reason few yellow bass taken from the center of the lake were marked, and, since yellow bass do not seem to move around much, the yellow bass in the center of the lake may be adequately represented in the estimates.

The yellow bass population estimates (Table 19) are probably subject to more error than those of the other species. The 1958 estimates are much higher than those for the 1959 population. The average gill net catches, 2.49 yellow bass per hour in 1958 and 2.47 in 1959, do not suggest a population drop. However, about 60% of the gill net catch in 1959 consisted of yellow bass under 6 inches long compared with 42% in 1958. The gill net catches of yellow bass over 6 inches was thus about 1.44 per hour in 1958 and 0.99 in 1959. Furthermore only 4,428 yellow bass over 6 inches were taken in 1959 compared with 5,384 in 1958, even though much more effort went into sampling in 1959.

The mean individual weights of 74 yellow bass over 6 inches long in 1959 was 0.16 pounds and using the 1959 Schumacher-Eschmeyer estimate, the standing crop is estimated at 11.0 pounds per acre. The 1958 estimate would be about 36 pounds per acre. The summer angler harvest of yellow bass was estimated at 114,000 to 186,000 per year for 1953 to 1955 (DiCostanzo and Ridenhour 1957). There was little evidence that the fishing was seriously reducing the population. On the basis of 0.43 pounds per fish, which was the average reported for 1953, this harvest represents 13.5 to 22.0 pounds per acre. In 1955, the spring angler harvest was also measured and the April 17 to September 5 catch of yellow bass was 269,500, which corresponds to 31.8 pounds per acre. The average gill net catches in 1953 and 1955 were 0.65, 1.59 and 1.75 compared to 2.49 and 2.47 for 1958 and 1959 indicating that the numbers of yellow bass in 1953-1955 were probably not as high, but because of the larger average size the standing crop may have been higher.

Species for which population estimates could not be made

Black crappie (Pomoxis nigromaculatus). The black crappie was considered by Bailey and Harrison (1945) to be one of the four most abundant species of fish in Clear Lake, providing sport for anglers in the spring. Black crappies outnumbered white crappies in Clear Lake until 1957 but from then until at least 1961 white crappies were the more abundant species (Neal 1963). In 1958 and 1959, respectively, 164 and 528 black
**Table 19.** A comparison of the population estimates of the yellow bass in Clear Lake, Iowa, in 1958 and 1959.

<table>
<thead>
<tr>
<th>Method</th>
<th>1958</th>
<th>1959</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper limit</td>
<td>Point estimate</td>
</tr>
<tr>
<td>Schnabel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schumacher-Eschmeyer</td>
<td>1,426,420</td>
<td>820,280</td>
</tr>
<tr>
<td>Petersen</td>
<td>1,006,900</td>
<td>668,000b</td>
</tr>
</tbody>
</table>

a 95% Confidence limits. Poisson limits for the Petersen estimates.
b Based on fish marked in 1958, recovered in 1959.
c Based on rotenone sample, 1959, in which 5 recaptures were found among 687 yellow bass.

crappies were taken by various sampling methods. Only one was recaptured in 1959, and 17 were recaptured in 1959 with 13 of the 18 recaptured in the region marked.

The regeneration of clipped fins of this species was so slow and incomplete that it was impossible in 1959 to distinguish the year in which a fish was marked. An accurate population estimate could not be obtained. The sampling for black crappies during both summers indicated that the sub-adults, as well as the adults, prefer weedy areas. Most of the black crappies were taken from the rush areas of Clear Lake although the gill nets did sample some from the center of the lake.

**White crappie (Pomoxis annularis)**

Bailey and Harrison (1945) did not believe that white crappies spawned successfully in Clear Lake, but this species did become quite abundant in 1957, probably associated with increased turbidity of the water (Neal 1963). The number of white crappies taken in 1958 and 1959 was just slightly larger than the number of black crappies, 803 compared with 792.

The slow and incomplete growth of clipped fins was similar to that of black crappies, making it difficult to separate 1958 from 1959 marks in 1959. Fins were clipped from 161 white crappies in 1958 and 391 in 1959. There were 6 recaptures in 1958 and 14 in 1959. Of 20 recaptures, 12 were taken in the region where first marked. Hancock (1954) indicated that white crappies tended to move around the lake in large schools. This tendency was noticed in Clear Lake. White crappies in Clear Lake preferred the rush areas, but Roach (1942) pointed out that in Buckeye Lake, Ohio, the white crappies normally inhabited open water, while the black crappies always remained near abundant vegetation. Hall et al. (1954) stated that white crappies were able to do well in either clear or turbid water, while black crappies usually grow well only in clear water.

**Smallmouth bass (Micropterus dolomieui)**

Clear Lake is not well suited for smallmouth bass since these fish prefer cool, clear water, but a small population maintains itself. Only one smallmouth in 1958 and four in 1959 were taken by sampling equip-
ment. These fish were taken from the rocky beaches located on the east shore of the lake. One of the tagged 14-inch bass was caught by an angler and reported to the Chamber of Commerce.

White bass (Morone chrysops)

White bass established themselves after they were introduced with fish from the Mississippi River (Bailey and Harrison 1945). The population has fluctuated (Lewis 1950) but in recent years white bass have not been abundant. In the 1958 and 1959 sampling seasons, 63 and 103 white bass were taken. The mean length and weight of those over 6 inches in length (based on measurements of 50 fish) was 10.3 inches and 0.55 pound. The largest white bass was 14 inches in length. No tagged white bass were recaptured in 1958 but 6 were recaptured in 1959.

Yellow perch (Perca flavescens)

Although Meek (1892), Bailey and Harrison (1945) and Parsons (1950) found a large population of yellow perch in Clear Lake, many of the present anglers do not realize that there are any yellow perch in the lake. Parsons (1950) found that the growth rate of yellow perch declined from 1941 to 1949.

During the summer of 1958, only 258 yellow perch over 5 inches long were taken. A more intensive effort to take yellow perch in 1959 yielded only 66. One local recapture was taken in 1959. During both seasons the maximum size of the yellow perch sampled was 6.5 inches total length. The sampling indicated that the yellow perch population was restricted to the rush areas of the lake. Mraz (1952) in his study in Lake Michigan found that yellow perch that had been marked by finclipping did not disperse as well as yellow perch that had been tagged. He felt that the loss of a fin made it difficult for the fish to swim.

Northern pike (Esox lucius).

The northern pike is the largest predatory species of fish in Clear Lake and for this reason is an important factor in predator-prey relationships of the lake (Ridenhour 1957). Bailey and Harrison (1945) stated that the natural reproduction was sufficient for this species to maintain itself.

Although DiCostanzo and Ridenhour (1957) reported good catches of northerns from 1951 to 1956, the catches have dropped steadily. The catch per gill net hour of northerns also indicated a decrease in population since 1953. Ridenhour (1957) estimated that 7,372 and 1,015 northern pike were caught by anglers in Clear Lake during 1954 and 1955, respectively, following the stocking of 15,000 fingerlings in 1953. Only 19 and 9 northerns were reported as taken by anglers to the Chamber of Commerce in 1958 and 1959 respectively. Because most northerns which are taken are large and of interest to many people, it is believed that most of the northerns caught were reported. The largest northern taken during these two years weighed 12.75 pounds.

Only 10 northerns in 1958 and 34 in 1959 were taken by the sampling equipment. In addition, 21 northerns brought from the Mississippi River were tagged and released into the lake. No tagged northern pike were recaptured. Of the 34 northerns taken during the summer of 1959 all but
seven were taken near the rush areas. Ridenhour (1957) pointed out that although the northern pike population was concentrated in the emergent vegetation, some northerns were distributed over the lake. Carlander and Ridenhour (1955) found that tagged northerns released as late fall young of the year dispersed over the entire lake.

Channel catfish (Ictalurus punctatus)

Five channel catfish were marked in 1958 and 73 in 1959. Only one recapture was recorded. The Clear Lake Chamber of Commerce recorded 26 and 19 channel catfish caught by anglers in 1958 and 1959. The largest weighed 16 pounds. Probably more channel catfish would be caught if more people fished specifically for them. A few anglers took catfish fairly consistently.

Flathead catfish (Pylodictus olivaris)

Bailey and Harrison (1945) recorded one 33-pound flathead catfish found dead on the north shore of Clear Lake. In 1959, a 45-pound flathead was taken off Garner Beach with a 500-foot survey seine. The fish was displayed at the state fair and returned to the lake. These two fish probably do not represent an established population but were introduced at some time.

Yellow bullhead (Ictalurus natalis)

Only two adult yellow bullheads, each over 10 inches long, were seen among the thousands of adult bullheads in 1958 and 1959. Young of the year yellow bullheads have been taken in the lake by seining indicating natural reproduction.

White sucker (Catostomus commersoni)

There were 3 recaptures from 46 suckers marked in 1958 and 4 from 19 marked in 1959. It was assumed that the population is quite small.

Minnows (Cyprinidae) and suckers (Catostomidae)

Minnows made up only 4.7 and 8.5% of the forage size fish in Clear Lake in 1956 and 1957 (McCann 1959). Since all carp (Cyprinus carpio) taken in 1958 and 1959 were destroyed and not returned to the lake, it was impossible to estimate the size of the carp population.

The rough fish removal figures provided by the Iowa Conservation Commission (personal communication from Mr. K.M. Madden, Superintendent of Fisheries, January 29, 1969) give some indication of the magnitude of the carp population (Table 20).

Table 20. Pounds per acre of carp and buffalo removed from Clear Lake by the Iowa State Conservation Commission

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carp</td>
<td>3.07</td>
<td>5.04</td>
<td>2.41</td>
<td>6.60</td>
<td>12.25</td>
<td>7.47</td>
<td>3.62</td>
</tr>
<tr>
<td>Buffalo</td>
<td>0.09</td>
<td>1.59</td>
<td>0.19</td>
<td>1.02</td>
<td>0.17</td>
<td>0.23</td>
<td>0</td>
</tr>
</tbody>
</table>
The buffalo (*Ictiobus cyprinellus*) population was probably less than one-tenth that of the carp. Quillback (*Carpiodes cyprinus*) and redhorse (*Moxostoma aureolum*) were taken only occasionally. Madtom (*Noturus gyrinus*), green sunfish (*Lepomis cyanellus*) and pumpkinseed (*L. gibbosus*), were also present in small numbers, although the pumpkinseed became more abundant than bluegills by 1963 (Kudrna 1967).

### The Standing Crop

The standing crops of the populations estimated in 1959 total about 65 pounds per acre:

<table>
<thead>
<tr>
<th>Fish</th>
<th>Weight (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walleye</td>
<td>9.3</td>
</tr>
<tr>
<td>Largemouth bass</td>
<td>0.5</td>
</tr>
<tr>
<td>Black bullhead</td>
<td>43.0</td>
</tr>
<tr>
<td>Yellow bass</td>
<td>11.0</td>
</tr>
<tr>
<td>Bluegill</td>
<td>0.8</td>
</tr>
</tbody>
</table>

| Total           | 65.6             |

Yellow bass under 6 inches long were probably abundant enough so that their total weight equaled or exceeded the weight of those over 6 inches. In the other estimated species the numbers of small fish were relatively low and the addition which they would make to the standing crop is small. Of the species for which population estimates were not made it is unlikely that any except the carp would exceed 2 pounds per acre. The total standing crop, except carp, is thus estimated at about 80 pounds per acre. The standing crop figures for Clear Lake were computed on the full lake acreage of 3,643 acres. In 1959 with the water level about 2.5 feet below outlet level, the area of the lake was about 300 acres less. The estimates per acre should thus be increased about 10%. Even 90 pounds per acre seems low for a eutrophic lake such as Clear Lake. Tabulation of standing crops of fish in lakes (Carlander 1955) indicated 125 to 150 pounds per acre for average warm water lakes, with a total range of 19 to 370 pounds per acre.

The carp standing crop probably was 30 or more pounds per acre. If the yellow bass estimate for 1958 is taken instead of that for 1959, another 25 pounds per acre would be added bringing the estimate to 145 pounds per acre.

### Acknowledgments

Thanks are expressed to the members of the fishery management classes for their aid in tagging walleyes during the spring of 1958 and 1959, to Robert Cooper, Superintendent of the Clear Lake Fish Hatchery, to the Iowa State Conservation rough fish crew, headed by Charles O'Farrell, to the survey crew, headed by Tom Moen, and to Larry Small, Dee Keeton, and especially Marvin Buchholz who collaborated in the field work.

We are also indebted to Dr. T.A. Bancroft, Director of the Statistical Laboratory, and to Dr. D.V. Huntsberger, Professor of Statistics, for assistance with statistical problems. Joanne McCann typed the first drafts of this paper.
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ABUNDANCE ESTIMATES OF SELECTED ZOOPLANKTON SPECIES IN CLEAR LAKE, IOWA, BY TWO SAMPLING METHODS

Ross V. Bulkley and John A. Scheider

Iowa State University of Science and Technology
Ames, Iowa

ABSTRACT. Abundance estimates of Bosmina, Cyclops, and Diaptomus sampled at the inlet pipe of the Clear Lake Water Treatment Plant were not statistically different from estimates obtained by sampling in the center of the lake. In addition, trends in seasonal abundance of Daphnia from the two sampling sites were similar. Treatment plant samples have the advantage of coming from a constant depth and location and being readily obtainable in all seasons.

Introduction

Fluctuations in abundance of zooplankton have a profound effect on growth and survival of fish in Clear Lake, Iowa. Most of the approximately 23 species of fish in the lake feed on zooplankton during some period of their lives (Ridenhour 1960; Welker 1963). Monitoring zooplankton abundance by sampling at various locations on the lake is hazardous during periods of unsafe ice cover in late autumn and early spring. Unfavorable wind conditions frequently preclude sampling on selected days during other times of the year. This study was conducted from April 1967 to April 1968 to determine the feasibility of estimating abundance of net zooplankton in the lake from samples collected at the intake pipe of the Clear Lake City Water Treatment Plant.

Clear Lake is a shallow 1474-hectare eutrophic lake of glacial origin located in western Cerro Gordo County, Iowa. Maximum depth is about 5 m.

Methods

Plankton were collected at approximately weekly intervals during the spring and usually once monthly during the rest of the year. Samples of 3 liters each were collected around midday at the water surface, 1-, 2-,
and 3-m depths from the east center of the lake. Depth at the sampling site was 4-5 m. After straining through Number 20 silk bolting cloth, samples from different depths were combined and preserved in 3% formalin.

Usually within 1 hr after collection of the lake sample, a 3-liter water sample was obtained from the intake pipe at the Clear Lake Water Treatment Plant located 2.5 km east of the lake sampling site. Water for the plant is withdrawn from a depth of 3 m at a point in the lake where maximum depth is about 4 m. The treatment plant sample was strained and preserved similarly to the lake sample.

For plankton enumeration, each sample was placed in a museum jar, and the volume adjusted to 229 ml. The jar was inverted several times. A 3.3-ml aliquot was then extracted from the center and placed in a circular counting chamber. Four 3.3-ml aliquots totaling 5.76% of the sample were counted. In selected samples, body length was measured of the first 30 Daphnia pulex observed. Measurements to the nearest 0.033 mm were made from the top of the head to the base of the spine. Zooplankton commonly utilized by yellow bass were identified to species (Small 1961). Other zooplankton were identified to major taxonomic groups.

Seasonal Abundance

Daphnia pulex, Bosmina longirostrus, and other cladocerans showed a typical spring pulse in abundance (Fig. 1). Daphnia were most abundant in samples collected June 1, when estimates of 193 Daphnia per liter were obtained from the lake, and 179 Daphnia per liter from the treatment plant intake. Summer and late fall pulses of low magnitude also were evident. Lowest Daphnia counts were recorded in November (9 and 17 organisms per liter) and in January (3 and 11 organisms per liter). Bosmina had the most distinct cyclic trend in abundance and were very numerous in late May, when they averaged over 300 per liter. Occurrence of abundance pulses agreed with those of Daphnia. A very low level of abundance in July agreed with observations on this species by Small (1961).

Cyclops bicuspidatus did not show a distinct seasonal trend. Numbers appeared high during April and low during May, followed by a relatively high abundance during the summer. Ricker (1938a) found spring and fall pulses of Cyclops in Cultus Lake, British Columbia. Diaptomus were abundant in early spring, early autumn, and midwinter. Rotifers were consistently the most abundant net plankters observed in samples. A spring peak in abundance was evident, but levels exceeding 200 rotifers per liter were maintained for most of the year. Combining all species of rotifers into a single group might have masked seasonal trends in species abundance because rotifer species may exhibit unimodal, bimodal, or even more complex seasonal distributions (Ricker 1938a).

Comparison Between Samples

Differences in the estimated number of organisms per liter by the two sampling methods were obvious, although for certain organisms, a similar trend was evident. Correlation coefficients were significant at the
Figure 1. Estimated mean number per liter of selected zooplankton species based on samples obtained from Clear Lake and from the Clear Lake water-treatment plant, April 1967 to April 1968.
0.01% level of probability for Daphnia (r = 0.69), Bosmina (r = 0.70), and Diaptomus (r = 0.63). Samples of the other organisms fluctuated independently and were not significantly correlated.

Analysis of variance of estimates taken from the lake and treatment plant samples suggested no significant differences by the two sampling methods for Bosmina, Cyclops, and Diaptomus (Table 1). Abundance estimates of Daphnia, other cladocerans, and rotifers obtained by the two methods were not similar.

Table 1. Values of F from analysis of variance of lake and treatment plant estimates of net plankton abundance, April 1967 to April 1968

<table>
<thead>
<tr>
<th>Plankton</th>
<th>F-value</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daphnia</td>
<td>36.248</td>
<td>0.01</td>
</tr>
<tr>
<td>Bosmina</td>
<td>0.012</td>
<td>ns</td>
</tr>
<tr>
<td>Other cladocera</td>
<td>8.773</td>
<td>0.05</td>
</tr>
<tr>
<td>Cyclops</td>
<td>0.004</td>
<td>ns</td>
</tr>
<tr>
<td>Diaptomus</td>
<td>0.491</td>
<td>ns</td>
</tr>
<tr>
<td>Rotifers</td>
<td>17.142</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Daphnia, one of the most important fish food organisms in Clear Lake, was consistently more abundant in the lake samples (Fig. 1). The greatest difference in estimates occurred in samples collected Aug. 3. Body length of Daphnia collected on that date was measured to examine the possibility that the large difference in abundance estimates was related to a difference in size frequency of organisms in the sample. We suspected that recruitment of a large number of small Daphnia might have occurred in the center of the lake or that larger Daphnia might be screened out or fragmented by passing through the treatment plant pump. Measurements of 30 Daphnia each from the lake and from the treatment plant samples were compared by chi square. Organisms were separated into eight 0.15-mm length groups for comparison. A chi-square value of 10.4 was obtained, which was not significant at the 0.10% level. Thus, a difference in size of Daphnia in the two samples was not evident. Mean length of Daphnia in both samples was 0.96 mm. The reason for the consistently higher number of Daphnia in the lake samples was not determined. If the August comparison was representative, however, the abundance difference was not due to a difference in size of Daphnia captured. It is possible that Daphnia avoided the current produced by the intake pump in a manner characteristic of copepods and other active zooplankters as reported by Welch (1948). A rheotactic response by Daphnia
was unlikely, however, because no such response was evident in the copepods Cyclops and Diaptomus. The simplest explanation was that Daphnia probably tended to concentrate at depths shallower than the 3-m location of the intake pipe. Samples from different depths in the lake were combined before organisms were counted so that this explanation could not be verified.

Discussion

Plankton counts were surprisingly similar for the two sampling sites when one considers the tendency toward uneven distribution within plankton populations and the difference in method of collection. Superdispersion or patchiness in abundance is a common occurrence with zooplankton (Tonolli and Tonolli 1958; Ricker 1938b). A difference among samples as large as 10 to 20% is meaningless in estimating plankton abundance (Ruttner 1953). Because the purpose of the study was to determine how well the pumped sample represented the actual population of zooplankters in the lake, the treatment plant sample was drawn from a constant depth of 3 m, whereas the lake sample was a composite of samples collected at 1-m intervals in the vertical water column. Nevertheless, abundance estimates of Bosmina, Cyclops, and Diaptomus obtained from the plant intake and from midlake were not statistically different. General trends in Daphnia abundance also agreed in samples from both sites. The seemingly erratic distribution of rotifers evidently precludes estimating trends in abundance of these organisms without extensive sampling and enumeration by species.

Samples from the treatment plant are not expected to vary in accuracy according to time of day because Small (1961) failed to detect any distinct diurnal vertical migration of zooplankton species in Clear Lake, presumably because of its shallow nature. But, the possibility of diurnal variations in treatment plant samples should be explored.

The use of pumping devices to obtain plankton samples is not a new technique but has frequently produced biased samples due to avoidance reactions by certain species (Welch 1948). Aron (1958) evaluated a 400 gal/min centrifugal pump as a collecting device and recommended further use of large-capacity pumps for studying plankton distribution. The large capacity of the Clear Lake treatment plant pump, which supplies water for a city of approximately 6,300 people, should overcome some of the biases observed in using small pumping devices for plankton sampling.

Findings in this study suggest that, if collections are made sufficiently often to bring sampling error within reasonable bounds, samples obtained from the water plant intake pipe are adequate for monitoring abundance of zooplankton species commonly used for food by Clear Lake fishes. Treatment plant samples have the advantage of coming from a constant depth and location and being readily obtainable in all seasons.
We express thanks to Drs. Roger Backmann, Kenneth Carlander, and Robert Muncy for criticizing the manuscript and to Mr. Lloyd Kennedy for providing access to water samples from the Clear Lake Water Treatment Plant.

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AN ESTIMATE OF THE LARGEMOUTH BASS POPULATION IN CLEAR LAKE, IOWA, 1964

J. Douglas Thompson and Kenneth D. Carlander

ABSTRACT. The largemouth bass, Micropterus salmoides, population was estimated at 431, on the basis of mark and recapture data.

Largemouth bass, Micropterus salmoides, are not abundant in Clear Lake, Iowa (McCann and Carlander 1970). They are limited to a few shallow areas with moderate amounts of aquatic vegetation or other cover. In the summer of 1964, an electric shocker was used to collect fish in many areas of Clear Lake (Kudrna 1967), and 97 largemouth bass from 4.2 to 19.6 inches total length were captured, tagged and released. Only 14 of these were over 9.0 inches, and most of the fish were probably yearlings.

The population was estimated at 431 bass, by the Schnabel method (see McCann and Carlander). Although the number of recaptures, 9, was small (Table 1), the sampling was fairly well distributed, and the estimate is believed of the right magnitude. It was below the 727 estimate for 1958 and 808 for 1959 but within the 95% confidence limits of the 1958 estimates and just outside the limits for the 1959 estimate (McCann and Carlander 1970).

Only one of the recaptures was not at the location of the original capture and this fish had traveled about 800 yards in the 7 days between the two captures. Several of the other fish were released 125 to 674 yards from the point of capture but were recaptured at the original site 2 to 28 days later.

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J. D. Thompson was in the Undergraduate Science Education Program sponsored by the National Science Foundation (NSF-GE2606).
Table 1. Numbers of largemouth bass captured, marked, and recaptured at weekly intervals, Clear Lake, Iowa, 1964.

<table>
<thead>
<tr>
<th>Date</th>
<th>Number caught</th>
<th>Total marked</th>
<th>Recaptures</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 22-28</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>June 29-July 5</td>
<td>14</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>July 6-12</td>
<td>6</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>July 13-19</td>
<td>5</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>July 20-26</td>
<td>16</td>
<td>37</td>
<td>1</td>
</tr>
<tr>
<td>July 27-Aug. 2</td>
<td>7</td>
<td>52</td>
<td>1</td>
</tr>
<tr>
<td>Aug. 3-9</td>
<td>8</td>
<td>58</td>
<td>0</td>
</tr>
<tr>
<td>Aug. 10-16</td>
<td>6</td>
<td>66</td>
<td>1</td>
</tr>
<tr>
<td>Aug. 17-23</td>
<td>22</td>
<td>71</td>
<td>5</td>
</tr>
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