The crawfishes of Mississippi: with special reference to the biology and control of destructive species

Clay Lyle
Iowa State College

Follow this and additional works at: https://lib.dr.iastate.edu/rtd

Part of the Ecology and Evolutionary Biology Commons, Entomology Commons, Environmental Sciences Commons, and the Zoology Commons

Recommended Citation
https://lib.dr.iastate.edu/rtd/13075

This Dissertation is brought to you for free and open access by the Iowa State University Capstones, Theses and Dissertations at Iowa State University Digital Repository. It has been accepted for inclusion in Retrospective Theses and Dissertations by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.
NOTE TO USERS

This reproduction is the best copy available.

UMI
THE CRAWFISHES OF MISSISSIPPI, WITH SPECIAL REFERENCE
TO THE BIOLOGY AND CONTROL OF DESTRUCTIVE SPECIES

by

Clay Lyle

A Thesis Submitted to the Graduate Faculty
for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject Entomology

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

IOWA STATE COLLEGE

IOWA STATE COLLEGE LIBRARY
TABLE OF CONTENTS

I. INTRODUCTION
   A. Historical ................................................. 4
   B. Economic Importance .............................. 6
      1. As pests ........................................... 6
      2. As food ........................................... 8

II. GENERAL ANATOMY AND BIOLOGY ......................... 13
   A. Anatomy .............................................. 13
   B. Biology ................................................
      1. Life history ....................................... 18
      2. Food .............................................. 20
      3. Moulting .......................................... 20
      4. Enemies ........................................... 21

III. CLASSIFICATION ........................................... 23
   A. Characters used in classification .................... 23
   B. Subgenera of the genus Cambarus Erichson ... 27
   C. Key to Mississippi crawfishes ....................... 54
   D. Descriptions of Mississippi species .............. 38
      1. Cambarus (Girardiella) hagenianus Faxon ...... 38
      2. Cambarus (Girardiella) hagenianus evansi, 
         new subspecies .................................. 43
      3. Cambarus (Girardiella) hagenianus carri, 
         new subspecies .................................. 45
      4. Cambarus (Girardiella) hagenianus forestae, 
         new subspecies .................................. 47
      5. Cambarus (Ortmannicus) blainvillianus acutus 
         Girard ........................................... 48
      6. Cambarus (Ortmannicus) hayi Faxon ............. 50
      7. Cambarus (Ortmannicus) clarkii Girard ....... 51
      8. Cambarus (Ortmannicus) cookae, new 
         species ......................................... 54
      9. Cambarus (Ortmannicus) evictus, new species .... 57
     10. Cambarus (Ortmannicus) spiculifer LeConte .. 60
     11. Cambarus (Ortmannicus) vsatus Hagen ...... 61
     12. Cambarus (Paracambarus) harnedi, new 
         species ......................................... 63
     13. Cambarus (Cambariella) shufeldtii Faxon .. 66
     14. Cambarus (Faxonius) lancifer Hagen .......... 68
     15. Cambarus (Faxonius) mississippiensis 
         Faxon ............................................ 70

T5680
III. CLASSIFICATION (Continued)

16. Cambarus (Faxonius) creaseri, new species........72
17. Cambarus (Cambarus) diogenes Girard..................75
18. Cambarus (Cambarus) diogenes ludovicianus Faxon........78
19. Cambarus (Cambarus) latimanus LeConte.................80
20. Cambarus (Cambarus) ar. lillicola Faxon................82
21. Cambarus (Cambarus) lobdelli, new species............84
22. Cambarus (Faxonelle) clypeatus May......................86

IV. THE BIOLOGY AND CONTROL OF CAMBARUS HAGERIANUS FAXON AND ITS SUBSPECIES.................................90
A. Introduction....................................................90
1. Distribution....................................................90
2. Economic importance.........................................92
B. Biology..........................................................94
1. Methods of study..............................................94
2. General habits................................................95
   a. Burrows......................................................95
   b. Food and feeding habits..................................98
   c. Reaction to physical factors............................100
3. Life history...................................................102
   a. Mating.......................................................102
   b. Oviposition.................................................103
   c. Incubation................................................103
   d. Molting.....................................................104
   e. Sex ratio..................................................105
   f. Maturity and longevity....................................106
C. Control........................................................108
1. Early efforts.................................................108
2. Summary of poison tests....................................111
   a. Procedure................................................111
   b. Effective materials......................................113
   c. Ineffective materials....................................116
3. Methods of application.....................................117
4. Recommendations.............................................120

V. LITERATURE CITED..................................................126

VI. ACKNOWLEDGEMENTS.............................................132

VII. PLATES........................................................133
INTRODUCTION

This study of Mississippi crawfishes* had its origin in some economic problems which largely concerned only a few species. The work on biology and control was financed as a project of the Mississippi Agricultural Experiment Station and is, therefore, limited largely to the economic species. However, the prosecution of this work gave many opportunities for the collection of other species, and since the crawfish is one of the animal types generally studied by high school and college biology classes, this paper has been prepared with the hope that the information may be of value to the teachers and students of biology in Mississippi and neighboring states.

Historical

The earliest published record of any taxonomic work on crawfishes from Mississippi was by Charles Girard in 1852.

---

*The term "crawfish" is used in this paper since it is the common name for these animals throughout the South and in other rural sections of the United States. It was early given approval by Thomas Say (1817, p. 167) in a scientific publication on Crustacea, but the introduction of Huxley's book "The Crayfish" into the United States about 1880 caused the English term to become the standard designation in later zoology texts in this country.
He had received some specimens from D. C. Lloyd, collected from a branch of the Mobile River in Kemper County. Girard named this species *Cambarus acutus*, now synonymous with *C. blandingii acutus*. The next record was in Hagen's "Monograph of the Astacidae" in 1870, in which four species were listed from Mississippi. Two of these were later classed as the same, so only three species were actually known at that time. Faxon in 1885 in his "Revision of the Astacidae" reported seven species in Mississippi. In 1914 the same investigator recorded only three more. The catalog of the United States National Museum now lists 13 species for Mississippi, only 12 of which are known to be authentic. This paper increases the total to 23 species, of which 8 are new species and subspecies.

The earliest published report of the very serious crop damage caused by *C. hagenianus* Faxon was in 1911 by Dr. A. K. Fisher of the United States Bureau of Biological Survey, who had visited the Northeast Prairie section of Mississippi and conducted some control investigations on a small scale.

Recent collections have been made in many parts of the state by the writer and others. Also the collection of the Zoology and Entomology Department of Mississippi State College, largely unidentified until the inception of this study and for
the most part gathered by Professor R. W. Lobdell several years ago, has been available. Comparison of specimens with types in the United States National Museum and in the Harvard Museum of Comparative Zoology aided greatly in the identifications. It is believed that most of the common species of the state are included in this study, although there are several species reported from adjacent states which have not been collected in Mississippi, but may possibly occur here.

Types of all the new species and subspecies described in this paper are being retained for the present in the collection of the Zoology and Entomology Department of Mississippi State College. However, it is planned ultimately to deposit these types in the National Museum and the Harvard Museum of Comparative Zoology.

Economic Importance

As pests

The statement by Newcombe (1929) that crawfish probably are of no economic importance, either positively or negatively, does not apply in some parts of Mississippi and other southern states. Mississippi is almost unique in possessing the only crawfish in the United States which frequently causes wholesale destruction of major farm crops.
Other species may sometimes cause some damage in low, poorly drained areas commonly classed as "crawfish land," but *Cambarus hagenianus* Faxon and its subspecies, which are discussed in detail later, often ruin entire crops of cotton and corn in a single night in the black prairie soils of northeast Mississippi. The same species also extends into Alabama with the same soil types, but much the larger part of the heavy infestation lies in Mississippi, comprising an area of several hundred thousand acres. (fig. 4) Besides the destruction of cultivated crops, the burrow-mounds built by these crawfish in meadows are serious obstacles to mowing machines. Also, the large amount of subsoil piled out of these burrows is believed by some planters to cause increased erosion since the unweathered, gummy clay brought up several feet from the bottom of the burrows is more impervious to water than the natural topsoil and results in increased run-off as the crawfish population grows. Separate chapters are devoted to the biology and control of this important species, hence no detailed account of its habits and damage will be given here.

Another type of damage which causes numerous complaints every year is the construction of burrows in dams and levees. Farmers who have built ponds for watering livestock, for irrigation, or for fish production often see their efforts largely nullified by the hundreds of crawfish burrows which
permit the water to escape. This form of damage becomes of special importance along the Mississippi River where the breaking of a levee might result in the loss of much life and property. A crawfish burrow in a levee, under the pressure of high water, as in figure 1, may develop into a "sand boil" which requires prompt attention to prevent a levee break. (fig. 2). The chief species concerned in this type of damage is *O. blandingii acutus* Girard.

As food

In many sections of Louisiana crawfish are esteemed highly as food and the dish "crawfish bisque" is nationally known among epicures. Aside from the experimental frying of crawfish "tails" by small boys, which is probably almost universal, there is no consumption of these animals for food in Mississippi except in the Gulf Coast towns where many citizens of New Orleans reside for part of the year. The species offered for sale in this section is the one so generally eaten in Louisiana, *Cambarus clarkii* Girard.

Though of only minor importance for human food, crawfish form a considerable part of the regular diet of several wild animals and are also eaten by many of our valuable game fish. Seton (1929), Howell (1931), and many others have reported that the raccoon is especially fond of crawfish.
Dearborn (1932), in an examination of 500 raccoon feces in Michigan, found that crawfish constituted 58.08% of the volume. The mink is also a voracious feeder on crawfish. Dearborn, in the work already cited, found crawfish composing 68.72% of the summer food of the mink, and occurring to a much less extent in the winter diet. The same investigator found crawfish supplying 3.52% of the volume of the opossum's food. Bailey (1936) reports that crawfish constitute an important part of the food of the Olympic black bear in some localities in Oregon.

Alligators were found by Kellogg (1929) to take 47.03% of their food in crabs, crawfish, and shrimp. He estimated that crawfishes supplied about 30% of the total food of the alligator. McIlhenny (1935) states that this is chiefly true of specimens less than three feet in length as the older specimens seek larger prey. Dimich and Mote (1934) found crustaceans second only to insects in numbers in the food of Oregon trout, and in the stomach of the eastern brook trout this class provided 51.9% of the contents. Two or three species of crawfish of the genus Astacus formed a large part of this important source of food. Pearse (1918, 1921), Turner (1926) and others have reported that crawfish form an important part of the diet of such popular game fish as large-mouthed black bass, small-mouthed black bass, crappie, bluegill, yellow perch, yellow bass, channel cat
Figure 1. Crawfish burrows in a river levee under flood pressure as in this case might cause dangerous "sand boils". (Photo, R. N. Lobdell).
Figure. A "cone boil" discovered and ringed with bags of soil to prevent a break in the levee.
(Photo, R. N. Lobdell).
and others. Reichard (1915) states that the crawfish is the chief food of the small-mouthed black bass in Douglas Lake, Michigan, in midsummer.

Wading birds undoubtedly make crawfish a staple and important part of their food. A study of the yellow-crowned night heron in Louisiana revealed crawfish in 104 of 105 stomachs, and constituting the entire contents in 99 specimens (Cottam, 1936). Crawfish also provide a small part of the food of several important ducks, according to McAtee (1918) who found 4 to 6 specimens in a few mallard stomachs and also some in the southern black duck. The same investigator (1921) also found some specimens in the shoveller, while Mabbott (1920) reported that they were of only slight importance in the food of seven other species of shoal-water ducks. Pirnie (1935) found crawfish in the stomachs of the black duck, American golden-eye, white-winged scoter, and hooded merganser, the last named securing a large part of its food from this source.
GENERAL ANATOMY AND BIOLOGY

Anatomy

The anatomy of the crawfish is treated in so many zoological texts it seems unnecessary to give details here. However, in order that the student endeavoring to identify specimens by the aid of this paper may have no difficulty in understanding what parts of the body are referred to in the descriptions of the species, a brief discussion of the external anatomy is given here. The principal parts used in classification are illustrated in figure 3.

The body of the crawfish is covered with a horny, calcareous shell or exoskeleton. The anterior part is known as the carapace and is divided by a cervical groove into the head and thorax. The head is projected forward into a rostrum which assumes different forms in the various species and is therefore important in classification. Although the carapace is not externally segmented, there are eight pairs of appendages on the head and five pairs on the thorax, indicating the number of segments or metameres in this part of the body. The abdomen or posterior part of the body has six external segments and a flat terminal plate or telson.
Abdomen
Acumen
Antenna
Antennules
Areola
Antennal scale
Location of annulus ventralis in female
Bearded hand
Branchiostegian spine
Carpus
Carapace
Cervical groove
Claw, chela or hand
Epistoma
Hook on walking leg
Interrupted cervical groove
Immovable finger
Lateral thoracic spine
Third maxillipeds
Necros
Movable finger
Palm
Postcarapace
Postorbital ridge
Procarapace
Prosternal
Sex organs or 1st abdominal legs
Suborbital angle
Swimmerets
Telson
Spines on proximal segment of telson
Uropod spines
Walking legs
The body appendages are of great importance in the life of the crawfish and will be described here in some detail. The most noticeable appendages are the first walking legs, chelipeds or claws, as they are variously known. These heavy claws are formidable weapons of offense and defense. They are used for catching prey and carrying food, and also serve as a hod or basket for bringing mud to the surface in constructing chimneys over the burrows. The terminal segment of the cheliped is known as the chela, hand, or claw. In many species this segment is much longer and more slender in the male than in the female. Posterior to the first walking legs are four other pairs of walking legs, but without the marked development of the terminal segment as in the first pair. The second, third, and fourth pairs are important in identification because of the hooks which are found in various combinations on these legs in first form males. The external openings of the reproductive organs of the female and male are found in the basal segment of the third and fifth walking legs respectively. Between the bases of the fourth and fifth walking legs of the female is located the annulus ventralis, or receptacle for storing the male sperm until oviposition occurs. This is another structure important in classification.

Posterior to the walking legs are the five pairs of abdominal legs, of which the first two pairs in the male are
specialized for copulation. The first pair lies in a groove between the bases of the last two pairs of walking legs and serves to transfer the sperm from the male ducts to the annulus ventralis of the female. The first abdominal legs, or gonopods as they are also called, are different in form for most species but are very constant within the species. The second abdominal legs of the male have a peculiar flat blade a short distance from the tip. The exact function of these legs is not known although the author has carefully watched several copulating pairs in an effort to discover the purpose of the special form. The other abdominal appendages, or swimmerets, are alike in both sexes. The eggs are attached to them in the female.

The head appendages and the gills have been so well described by Turner (1926) that the following is quoted from his excellent paper:

"The appendages of the head are eight in number and are packed into a very small space. The third pair of maxillipeds is just anterior to the chelipeds. It consists of a short basal piece, to which are attached two pieces, a slender external one and a heavier, longer one near the mid line. The first segment of the larger branch bears a row of teeth on its inner surface. A similar arrangement is present on the other member of this pair of appendages and when the toothed surfaces are brought together they make a very efficient apparatus for cutting and masticating food. The terminal segments of this same branch function also as antennal cleaners. The second pair of maxillipeds is just anterior to the first. In form it is much like the third, but both branches are reduced in size and it
possesses no masticating surfaces. Its chief function is to pass forward toward the mouth the food which the third pair maxillipeds have partially masticated. The first pair of maxillipeds is still further reduced in size but has the basal segment modified to form blade-like processes which aid in mastication. Anterior to the maxillipeds are two pairs of small leaf-like appendages called maxillae. They aid to some extent in mastication but their function must be limited to mincing the food already masticated. The mandibles are best developed for the purpose of chewing. The basal joint and one of the branches are fused, heavily reinforced with chitin, and equipped with a strong cutting edge. A short branch with three segments is also a part of the appendage. The mandibles are worked by masses of cone-shaped muscles which are attached directly to the dorsal side of the carapace on the one hand and to the mandibles on the other. The remaining two pairs of appendages are quite conspicuous as compared to those of the mouth parts. They are often referred to as the "feelers," and, indeed, feeling is one of their chief functions. The appendage with the single, long, jointed filament is the antenna. It is made up of a heavy basal piece which bears a small pore (the opening of the excretory organ), on the ventral side. The two branches which are attached to this basal piece are very unlike. The external branch is in the form of a flat blade with one straight margin terminating in a spine and a curved margin covered by bristles. This branch is called the antennal scale. The internal branch is composed of two short, heavy segments, and a long, jointed terminal filament. Aside from being a tactile or feeling organ, the antenna also has the ability through some groups of cells near its base, to "taste" or to "smell." Chemical substances which are in solution in the water, especially soluble food substances, affect these minute organs which are in contact with nerve endings. A chemical sensation, which may be described as the sense of either taste or smell is then conveyed over the nerve-ending and the nerve fibers to the central nervous system. The antennules are located just anterior to the antennae. Each member of the pair has three segments in its basal portion and a bifurcated, terminal filament. The antennules function in part in the same way as the antennae but they contain in addition organs of
equilibrium, called statocysts. A statocyst consists of a chamber, located in the basal segment, which is lined internally with short bristles. Grains of sand forced through the opening of the chamber by the animals, lie within the chamber, stimulating the bristles of the floor, and apparently producing in the animal the familiar sensation which he has when in a normal position.

The gills are white, plume-like organs located just beneath the carapace on either side. They should be properly considered as external organs since they are outside of the body cavity and are extensions of the epidermal layer. They are arranged in two rows, extending from the second maxilliped backward to the last walking leg, and are attached to the basal segments of the legs and to the sides of the body wall. There is one group of gills for each body segment. Each gill contains a central stem with numerous branching filaments which serve to extend the gill surface. The hollow canal of each filament is connected with the canal of the central stem. The blood circulates through the canals of the entire gill system and oxygen is taken from the water through the gill walls. To insure a fresh supply of water a paddle-shaped appendage attached to one of the maxillipeds plays back and forth in the anterior part of the gill chamber, causing a current of water to flow over the gills. The maxillipeds are almost constantly in motion, even when the crayfish is at rest, as are the walking legs to a less extent. The result is, of course, to keep the attached gills moving about in the water of the gill chamber.

Biology

Life history

As related elsewhere in this paper, the writer has learned many important details in the life of *Cambarus hagenianus*, although some points such as the time and place of mating have not been definitely settled.
Andrews (1907), Turner (1936), Hay (1903), and others have reported their observations on various other species, some of which occur in Mississippi.

Egg-laying occurs with most species in the spring, although egg-bearing females of *C. hagenianus* and *C. shufeldtii* have been found in Mississippi only during October. *C. blandinii acutus* and *C. diogenes* have been observed by other investigators to carry eggs and young at nearly all times of the year. No egg-bearing females of *C. blandinii acutus* have been found in Mississippi during this investigation and the only records of eggs in *C. diogenes* have been during the spring. This is also true of *C. mississippiensis*. No egg-bearing females of other species have been found in Mississippi. The number of eggs varies from a very small number, probably 8 or 10 as the maximum in *C. shufeldtii*, to more than two hundred in *C. mississippiensis*. *C. hagenianus* has usually not more than 25 or 30 eggs, while *C. diogenes* has a very large number, or about as many as *C. mississippiensis*.

The incubation period varies with different species and is probably also affected by temperature. Turner (1936) reports hatching occurring during the third week while Hegner (1936) states that incubation requires 5 to 8 weeks. Turner also states what is reported in many
zoology texts - that the young remain with the parent only about a month and become sexually mature in the fall of the same year in which they are hatched. This is not the case with the young of *G. hagenianus* which spend about 15 months or longer in the burrow with the mother and apparently do not become fully grown under 6 or 7 years.

**Food**

Crawfishes will eat a wide variety of foods, including both animal and vegetable material. Most species inhabiting streams and ponds probably feed largely on animal life while *G. hagenianus*, a burrowing species, shows a special fondness for vegetation although it also feeds on earthworms and other animal life offered it. When confined they are cannibalistic and often eat any weak or small specimens in the container.

**Moulting**

Since it is covered by a hard exoskeleton, a crawfish can grow only by moulting. After hatching it remains attached to the shell until after the second moult. Several moult(s) occur the first year in most species, although the number in *G. hagenianus*, which develops slowly, is probably less than in many other species. The number in the same species may vary for some unexplained
reason, as the writer had some young specimens one season which moulted frequently and the next year had another group of the same age which did not moult at all for several months. For a day or so after moulting the carapace is very soft and newly-moulted specimens are often eaten by their companions in captivity. The color is often changed somewhat during the moult of _P. hagenianus_.

Regeneration of lost parts and changes in the form of the male also occur during moulting. The sexually-functional form of the male is known as Form I while the form in which the sexual appendages are not fitted for copulation is known as Form II. Turner (1926) states that these changes occur at certain seasons, but the writer has found both forms of the male in many collections made at various times of the year.

**Enemies**

Reference is made elsewhere in this paper to the importance of crawfish in the diet of fish, birds, and other animals. They also have numerous parasites both internal and external. Nearly all species taken in Mississippi are infested with worms of the genus _Xironodrilus_ (_Bdelloдрilus_). Stafford (1932) has reported the following trematodes in Mississippi crawfish:
*Microphallus opacus* in the liver
*Crepidostomum cornutum* in gills
*Cephalogonimus* sp. in the tail muscles, and
*Maritrema* sp. in the gills.
CLASSIFICATION

Characters Used in Classification

Because of irregular regeneration of lost appendages and modifications of the carapace in molting it is rather difficult to classify crawfishes on the basis of structural characters such as are used in the identification of insects. There are also morphological variations between the sexes, between the first and second form males, and between immature and adult specimens of both sexes. The following discussion of characters useful in classification and the illustration of parts in figure 3 may be helpful to anyone beginning this study.

First Abdominal Legs of Male. The structure of the first abdominal legs of the first form males, which are peculiarly modified for sexual purposes, is one of the most constant and, therefore, most important characters used in classification. The second abdominal legs are also modified, but do not show such marked and constant differences among the species as the first legs.

Annulus Ventralis. The annulus ventralis of the female, another sexual character, is also rather typical
for each species, but shows more variation in individuals and less among the different species than the male organs. Several species have annuli so much alike it is impossible to separate them on the basis of this character alone.

Hooks on Male Legs. The hooks on certain walking legs of the first form males are of much value in determining the larger divisions or so-called subgenera. In some species hooks on the second form males are barely large enough to be counted as such.

Rostrum. Although the rostrum often loses its typical shape through injuries or in molting, it is sufficiently stable to be of much value in classification. It may be rounded or acute, plane or deeply hollowed out, with or without spines on its margins. Its sides may be convex, concave, parallel, or uniformly convergent toward the tip.

Areola. The form of the areola is rather constant in adult specimens. It may be of moderate or excessive width, or so narrow as to be obliterated. It should always be considered in classification.

Claws. With a large number of specimens for examination, the claws serve very well as a minor identifying character. However, regenerated claws often do not have the typical shape. Also in some species, even when the claws are the same size and there is no evidence of regeneration, they
will have quite different shapes. Furthermore, several species have claws so much alike it is almost impossible to find any constant differences.

**Spines.** The presence or absence of spines on various parts of the body, and the number of such spines when present, are important aids in classification. Some species have a single spine on each side of the carapace just back of the cervical groove, others have two, and some have none. Spines may be present or missing on each side of the rostrum, back of the eyes (postorbital), and on the anterior margin of the carapace (branchiostegian). They occur in varying numbers, according to the species, on each side of the next to the last segment of the telson. This number is fairly constant in most species, but varies in a few. Some species have long strong spines on the uropods, or lateral divisions of the telson, while in others they are short or insignificant.

**Antennal Scales.** The form of the antennal scale is often of much value in identification. However, just as with some other characters, the scales of several species are so nearly alike it is difficult to detect any differences.

**Suborbital Angle.** The anterior margin of the carapace may be more or less angulated just below the eye. This is
usually constant within the species and readily serves as a distinguishing character where there is a marked difference in the degree of angulation. In some groups of related species the angles are practically the same and are of little or no value for identification within the group.

Carapace Measurements. The ratio of the length of the posterior part of the carapace to the length of the part in front of the cervical groove is of considerable value in separating some of the members of the *blandingii* group. Comparative measurements of chelae, fingers, antennae, rostrum, abdomen, and other parts may be of help with some species.

Epistoma. Hagen, especially, placed much emphasis on the shape of the epistoma, but the writer has found that there is often much variation of this structure within a species and does not consider it of much importance in the classification of the *Mississippi* species. Its shape is undoubtedly altered frequently by injuries or in molting.

Bristles. In some species certain parts of the body are much more heavily adorned with bristles or hairs than in other species. Except in a few cases, however, this character is not greatly used for classification. It will be discussed in detail in the descriptions of the species that may be partially identified by means of this character.
Color. Color may be of some value in identifying living specimens but since most studies are conducted with preserved material from which the color has faded, it is not of great importance. Several species have about the same color patterns, although colors may vary according to the nature of the habitat. The writer has found no case of constant color differences between the sexes, Faxon's reference (1914) to such a condition in *G. hagenianus* being based on too few specimens. Both sexes of this species show all variations of the colors characteristic of this species.

Subgenera of the Genus *Gambarus*, Erichson

The crawfishes of the world are grouped in two families, Parastacidae and Astacidae (or Potamobiidae, as some taxonomists prefer). In the Parastacidae are included all the crawfishes of Australia, Tasmania, New Zealand, New Guinea, Madagascar, and South America. The family Astacidae includes all those occurring in Europe, Asia and North America. There are no crawfishes known on the mainland of Africa and in Central and Southern Asia. The family Astacidae is divided into several genera but all the freshwater species may be
grouped in the following: *Astacus* which includes the species of Europe, Asia (except Japan and Korea), and the western part of the United States; *Cambaroides*, those in Japan and Korea; and *Cambarus* which includes the species of Mexico, the West Indies, and the United States east of the Rocky Mountains.

The earliest students of crawfishes saw the necessity for dividing the genus *Cambarus* into smaller groups. Girard (1852) set up three groups based on the form of the rostrum and the first abdominal legs of the males. Hagen (1870) also recognized three groups based on the number of hooked legs in the male and the form of the rostrum. These two systems did not produce the same results in classification, so Faxon (1885) suggested the division of the genus into five subordinate groups on the basis of the hooked thoracic legs and the first abdominal legs of the male, but did not name the groups. Ortmann (1905), largely using the first abdominal legs, named four subgenera, *Cambarus*, *Cambarellus*, *Faxonius*, and *Bartonius*. The next year (1906b) he added two more subgenera, *Procambarus* and *Paracambarus*, to include some species from Mexico, Central America and Cuba. Ortmann restricted the name *Cambarus* to the group of which *C. blandini* is the type, but Fowler (1913), finding that Faxon (1898) had designated *C. bartoni* as the type of the genus, transferred the name *Cambarus* to the *Bartonius* group.
of Ortmann and gave the blandingii group a new subgeneric name, Ortmannicus. In 1914, Faxon, with many new species to be grouped, recognized seven divisions on the same basis he suggested in 1885. The species known at that time would now be divided into eight groups, for the first abdominal legs of the male of *C. clypeatus*, which had not been found in 1914, do not fit into any of the divisions made at that time. It is remarkable that seven of these eight groups apparently are represented in Mississippi, if *C. harneyi*, a new species, is considered as belonging in the genus *Paracambarus* Ortmann. Faxon's Group I, which occurs in Mexico, Central America, and the West Indies, apparently is the only one not present in this state. To avoid the confusion arising from the designation of groups by numbers, as used by Faxon, the writer is adopting in this paper, with one exception, the subgeneric classification of Ortmann as revised by Fowler, and is suggesting a new subgenus, Girardiella, to comprise Faxon's Group 2 which Ortmann did not separate from Faxon's Group 3. An eighth division, of which *C. clypeatus* is the only known representative, should also be added. Oreaster (1933) has given the name *Faxonella* to this subgenus.
These subgenera with the chief characters separating them, are listed here, with their type species and with the representatives of each group which have been found in Mississippi:

Subgenus *Procambarus* Ortmann. Hooks on third segment of third pair of male legs. First abdominal legs of male stout, inner and outer parts closely appressed, laterally compressed, with a horny (Form I) spine at the tip; anterior margin with a prominent shoulder near the distal end. Type species, *C. digueti* Bouvier. (Faxon's Group 1).

Not represented in Mississippi or United States. Occurs in Mexico, Central America, and West Indies.

Subgenus *Cirardiella*, new subgenus. Hooks on third segment of third pair of male legs. First abdominal legs of male truncate, outer part closely applied to inner, the tip with from one to three horny, recurved teeth; inner part ending in a sharp spine generally directed outward. Type species, *C. advena* LeConte (Faxon, 1885, p. 17.) (Faxon's Group 2.)

Mississippi species:

1. *Cambarus hagenianus* Faxon
2. *Cambarus hagenianus evansi*, new subspecies
3. *Cambarus hagenianus carri*, new subspecies
4. *Cambarus hagenianus forestae*, new subspecies
Subgenus Ortmannicus Fowler. Hooks on third segment of third and fourth pairs of male legs. First abdominal legs of male truncate, outer part closely applied to inner, the tip with from one to three horned recurved teeth; inner part ending in a sharp spine which is often directed outward. Type species, Astacus blandingii Harlan. (Faxon's Group 3).

Mississippi species:
5. Cambarus blandingii acutus Girard
6. Cambarus boyi Faxon
7. Cambarus clarkii Girard
8. Cambarus evictus, new species
9. Cambarus spiculifer LeConte
10. Cambarus versutus Hagen
11. Cambarus cookae, new species.

Subgenus Paracambarus Ortmann. Hooks on third segment of fourth pair of male legs. First abdominal legs of male long, slender, truncate, outer part closely applied to the inner and ending in slightly recurved, horned teeth; the inner part ending in a sharp spine directed outward. (This does not entirely coincide with Ortmann's subgenus Paracambarus, but the species below seems nearer it than in any other.) Type species, C. paradoxus Ortmann. (Faxon's Group 4).
Mississippi species:


Subgenus *Cambarellus* Ortmann. Hooks on third segment of second and third pairs of male legs. First abdominal legs of male not truncate, inner and outer parts separate and spreading for some distance from the tip; outer branch cleft into two slender teeth at the end; inner branch either acute or spatulate at the tip. Type species, *C. montezumae* Saussure. (Faxon's Group 5).

Mississippi species:

13. *Cambarus shufeldtii* Faxon

Subgenus *Faxonius* Ortmann. Hooks on third segment of third pair of male legs. First abdominal legs of male split into two branches, straight or somewhat recurved, and acute at the tips. Type species, *Astacus limosus* Rafinesque. (Faxon's Group 6).

Mississippi species:

14. *Cambarus lancifer* Hagen
15. *Cambarus mississippiensis* Faxon
16. *Cambarus creasci*, new species

Subgenus *Cambarus* Fowler. Hooks on third segment of third pair of male legs. First abdominal legs of male short and thick, terminating in two large recurved teeth, usually at right angles to the leg, the larger formed by the outer
part, the smaller by the inner part. Type species, Astacus bartoni Fabricus. (Faxon's Group 7).

Mississippi species:

17. Cambarus diogenes Girard
18. Cambarus diogenes ludovicianus Faxon
19. Cambarus latimanus LeConte
20. Cambarus arvallicola Faxon

Subgenus Faxonella Creaser. Hooks on third segment of third pair of male legs. First abdominal legs of male long, slender, outer parts horny, curving inward, with tip of one appendage crossing and resting on the tip of the other; inner part short, not over one-third the length of the appendage. Type species, C. clypeatus Hay.

Mississippi species:

22. Cambarus clypeatus Hay.
Key To Mississippi Crawfishes

This key is based almost entirely on the characters of the first form males. In a few cases where they aid greatly in identification, certain female characters are included. It is realized that any key which requires first form males for identification will be criticized, but the author feels that it is better to have specimens unclassified than to have them wrongly labeled as the result of using a key which includes variable or doubtful characters. In making local collections biology students and instructors will usually be able to secure first form males and where they are lacking an additional incentive is provided for further collecting.
1 Hooks on third walking legs only................................. 2
   Hooks on walking legs not confined to third pair........... 14

2 First abdominal legs split into two branches, one or both long and slender................................. 3
   First abdominal legs not split deeply into long branches......................................................... 6

3 Branches of first abdominal legs of nearly equal length................................................................. 4
   Outer branch of first abdominal leg long and slender, with tips crossing; inner branch blunt, one-third as long as outer.....C. clypeatus Hay

4 Rostrum with lateral spines.......................................................... 5
   Rostrum without lateral spines.............................................C. mississippiensis Faxon

5 Rostrum medium length; simple hooks on third walking legs..............................C. creaserei, n. sp.
   Rostrum long, with very long sharp acumen; double pointed hooks on third walking legs.............
   .......................................................C. lancifer Hagen

6 First abdominal legs short and thick, tips recurved at almost right angles................................. 7
   First abdominal legs truncate, with two rounded horny teeth on the outer part, inner part ending in sharp spine........................................ 11

7 Anterior margin of carapace angulated................................. 8
   Anterior margin of carapace not angulated................................. 10
8 Areola narrow or linear............... *C. diogenes* Girard
Areola obliterated........................................ 9

9 Carapace full, rounded, sides of rostrum almost parallel................... *C. latimamus* Le Conte
Carapace converging sharply anteriorly, with vertical sides, margins of rostrum often concave between the eyes...... *C. diogenes ludovicianus* Faxon

10 Rostrum long, spine on under side of first joint of antennules at mid-length... *C. argillicola* Faxon
Rostrum short, no spine on antennules..................... ........................................ *C. lobdelli* n. sp.

11 Hand of male bearded on inner margin.............. 12
Hand of male not bearded.............. *C. hagenianus* Faxon

12 Beard on third maxillipeds sparse and stiff;
proximal segment of telson often trispinose;
uropod spines rather short and blunt.................. ........................................ *C. hagenianus evansi*, n.sp.
Beard on third maxillipeds soft and profuse;
telson not trispinose; uropod spines long and sharp pointed................................. 13

13 Telson bispinose; female hand often noticeably bearded............... *C. hagenianus carri*, n.sp.
Telson uni- or bispinose; female hand not noticeably bearded........ *C. hagenianus forestae*, n.sp.

14 Third and fourth walking legs with hooks.............. 15
Third or fourth walking legs without hooks............ 21
15 Tip of rostrum rounded, without lateral spines............. C. cookei, n.sp.

Tip of rostrum acute, with rudimentary or prominent lateral spines............................. 16

16 Single spine on each side of thorax....................... 17

Two spines on each side of thorax......................... 20

17 First abdominal legs with deep depression just back of terminal teeth..................... C. hayi Faxon

First abdominal legs without depression back of terminal teeth........................................ 18

18 First abdominal legs with two large round plates on outside, one horny, the other soft with horny margin, and barely noticeable horny tooth between; inner part prolonged as a spine.........

.................................................. C. clarkii Girard

First abdominal legs with three horny teeth on outer part; inner part prolonged as spine........ 19

19 Proximal segment of telson with 3 or 4 spines on each side; from cervical groove to tip of rostrum 2½ to 3 times distance from cervical groove to abdomen.................................................. C. evictus, n.sp.

Proximal segment of telson bispinose; from cervical groove to tip of rostrum 2 to 2½ times distance from cervical groove to abdomen...........................................

.................................................. C. blandinii acutus Girard

20 Telson with two strong spines on each side of proximal segment......................... C. spiculifer LeConte

Telson with 3 or 4 spines on each side of proximal segment................................. C. versutus Hagen
Second and third walking legs with hooks; very small species. ..............C. shufeldtii Faxon

Fourth walking legs only with hooks..................
.................................C. harnedi, n. sp.

Descriptions of Mississippi Species

CAMBARUS (GIRARDIELLA) HAGENIANUS Faxon

Plate I, fig. 1; Plate II, fig. 1; Plate III, fig. 1; Plate IV, fig. 1.


Zool. 2, No. 3: 87.


Zool., 40, No. 8: 366.

Distinguishing characters: Since C. hagenianus and its subspecies or varieties are the only known representatives of Faxon's Group II (C. gracilis, C. advena, C. simulans, etc.) in Mississippi, it is not difficult to distinguish them from other common species. The rostrum is deeply excavated, with tip depressed, and without lateral spines. Areola obliterated. Antennal scale small, almost rectangular, widest near the outer end. No thoracic or postorbital spines. Branchiostegan spine very short and blunt. No suborbital angle. Telson bispinose, with spines extending beyond the
margins of the inner branches of the uropods. Hooks on third walking legs. Hand broad, palm inflated, movable finger excised at base with several tubercles on cutting edge, and one prominent tubercle about the middle of the cutting edge of the opposing finger. First abdominal legs of male with truncate tip, the outer part consisting of two rounded, horny teeth, the inner part prolonged into a sharp spine usually curving slightly outward and extending a little beyond the horny tips of the other branch. In the second form males the parts are soft and the inner branch is not prolonged into a spine.

The annulus ventralis of the female shows some individual variation but has the same general form in this species and its varieties. Typically, the anterior well is deeply cleft, with a prominent tubercle on each side, which may be with or without tiny teeth; the fissure curves to one side or the other, then back toward the opposite side and out through a depression in the posterior wall.

This is one of the most beautiful species the writer has ever seen. Instead of the drab shades of several common species it is brilliantly colored with red, blue and all intermediate tints. Each sex may show all variations in color and individuals often change greatly in molting. Generally an individual will have a predominance of either red or blue, but both colors are usually present and often so evenly balanced as to make it impossible to group the specimens under either color.
Historical: This species was first known from the type specimen in the Museum of Comparative Zoology at Harvard, a first form male sent by Professor L. P. Gibbes of Charleston, S. C. (No. 232). Hagen in 1870 classified this specimen as *Cambarus carolinus* Erickson. Faxon, in 1884, separated it from *carolinus* and listed it as a new species, *C. hagenianus*. In 1914, having then secured other forms from State College and Vuldin, Mississippi, Faxon gave a more detailed description including illustrations in color of both sexes collected at Vuldin, mentioning the peculiarity of the Vuldin males in having a beard along the inner border of the hand. On account of this character and other constant differences, the writer is separating the Vuldin form and naming it *Cambarus hagenianus evansi*. Two other subspecies are also described in this paper.

Economic importance: So far as published records show, this is the only crawfish in the United States of great importance as a crop destroyer. In the prairie sections of northeast Mississippi and western Alabama crops of cotton and corn on several hundred thousand acres are threatened each spring with severe damage, which frequently amounts to total destruction if the season is very rainy. The value of farm lands has been greatly
reduced in many communities on account of its ravages. This subject is discussed in more detail later in this paper.

**Biology:** The writer has accumulated considerable information about the biology of this species which is presented later in more detail. Briefly, it is wholly a burrowing species, never inhabiting streams or ponds at any stage of its life. It lives in prairie soils underlaid with limestone which serves to keep the water table fairly high. The burrows may be in valleys, on slopes, or frequently on hilltops, and in summer may extend to a depth of fifteen feet or more. Only one individual lives in a burrow, except when the young are with the mother. The writer has never observed mating, but it probably occurs on the surface of the ground at night during warm spring rains. Females bearing eggs or young have been collected in October, November, and December, always in their burrows, never on the surface of the ground. The average number of young is about 5 or 6, although the writer has found 20 in one burrow. The young usually remain with the mother about 12 to 18 months, or until the second spring after hatching, when they start burrows of their own. They apparently become full grown in about 6 or 7 years and undoubtedly live 10 years and probably much longer.
Food: This species is almost wholly vegetarian except for such earthworms and insects as may reach its burrow by chance, or be captured on the surface. The writer has kept specimens in the laboratory for several years on a diet of grass and clover. It is very fond of cotton seed and will peel the hull off in a few moments.

Distribution: This species and its varieties are present in the prairie sections of Alabama and Mississippi (fig. 4). The type specimen was reported to have come from Charleston, South Carolina, but the writer seriously doubts that this species occurs in that state. Correspondence with the Zoology and Entomology Department of Clemson College and with the Curator of the Charleston Museum indicates that no other specimens have been found since the type. The fact that this is a very destructive crop pest would almost certainly have brought it to the attention of zoologists or museum authorities if it occurred there. Also, the soil type in the vicinity of Charleston is not at all like that in which this species lives in Alabama and Mississippi. There are other instances in which Professor Gilbes either wrongly labeled specimens as to locality, or incorrectly identified specimens after very superficial examination, (Faxon 1885b, p.10) and, therefore, until other specimens are collected in South Carolina, the writer is inclined to doubt that state as the origin.
of the type.

*Cambarus hagenianus* proper occurs in Oktibbeha, Lowndes, Noxubee, and Kemper Counties in Mississippi and its area of infestation swings across Alabama toward Montgomery. Tibbee Creek, a tributary of the Tombigbee, flowing east along the line between Oktibbeha and Clay Counties, is the northern boundary of this species. North of Tibbee Creek, *C. hagenianus evansi* occupies the lime soils in Clay, Monroe, and eastern Chickasaw Counties. In the flatwoods soil at Houston the subspecies *C. hagenianus carrri* is present, while the other subspecies, *C. hagenianus forestae* is confined to Scott, Rankin, and perhaps other counties of the central prairie region.

**Cambarus (Girardiella) Hagenianus Evansi**, new subspecies

Plate IV, Fig. 2.


**Distinguishing characters:** In most respects this subspecies fits the description of *C. hagenianus*, but differs in the following points. In addition to the beard on the inner margin of the hands of the male, there is a tendency to more hairiness on the hands of the female than in *C. hagenianus*. The third maxillipeds are covered
with coarse hairs, much stiffer than in the other subspecies. The proximal segment of the telson often has three spines on each side but some specimens have only two. The spines on the border of the uropods are much shorter than in the subspecies found at Houston and Forest, which are described next.

The coloration of this subspecies is not so striking as in _C. hagenianus_, the blues and reds being usually paler than in the other form. The colored illustrations accompanying Faxon's paper are typical of many specimens, but there are no constant color differences between the sexes.

Faxon in 1916 called attention to the chief character which distinguishes this subspecies from _C. hagenianus_, the bearded hands of the male, but having only a few specimens and not knowing that it was a constant difference, he did not suggest another name for it. This is the most destructive of the four subspecies of _C. hagenianus_, and since Dr. J. E. Evans of Huldon, Mississippi, one of the most progressive planters of the Northeast prairie section, has given much time to the development of a practical control measure, the writer is suggesting the name in his honor.

**Biology:** This crawfish lives in burrows under similar conditions as _C. hagenianus_ and apparently has about the same habits and life history. The writer attempted to cross this crawfish with _C. hagenianus_ but was unable to
get either species to mate in captivity. The males and females of this subspecies occur in almost equal numbers (527 females and 473 males in a catch of 1000), while the adult females of *C. hagenianus* greatly outnumber the adult males in all collections at State College (351 to 6 in one case).

**Distribution:** This species is known only in Mississippi and is apparently limited to the prairie soil area lying north of Tibbee Creek and west of the Tombigbee River, comprising parts of Clay, Monroe, and Chickasaw Counties especially. No specimens have been taken south of Tibbee Creek and no complaints of crawfish damage to crops have been received from north of Okolona.

**Mississippi records:** Egypt, Muldon, West Point.

*Cambarus (Girardiella) hagenianus garricki*, new subspecies

Plate IV, fig. 3.

**Distinguishing characters:** This subspecies would be most readily mistaken for *C. hagenianus evansi*, but differs in the following respects: The male claws are more heavily bearded than in evansi, even the movable finger being bearded part of its length in most specimens. The third maxillipeds are also much more densely bearded in both sexes than in evansi, and the hairs are not stiff and coarse as in
evansi. The female hand has a short beard in nearly all specimens, though in some cases the length is almost equal to that of the males and is distinctly noticeable on living specimens in water. In no other species known to the writer does the female hand have a noticeable beard. The epistoma is shorter and more triangular than in evansi. The antennal scale is much like that of evansi but is not so wide at the distal end and has a longer spine at the tip. The proximal segment of the telson is bispinose. The spines on the uropods are of a pink or reddish color and longer and sharper than in evansi. No constant differences have been observed in the sexual characters.

The color of the specimens collected thus far is distinctly reddish with rich henna or brown tints. The size is apparently smaller on the average than the other subspecies of this group.

Biology: Like its relatives, this is a burrowing species and comes to the surface only at night, especially rainy nights. The burrows are noticeably smaller than those made by C. hagenianus and C. hagenianus evansi. Nothing is known of its food habits but it is undoubtedly largely a vegetarian species, since its burrows were not found in close proximity to bodies of water.

Distribution: Known only from specimens collected at Houston, Mississippi, April 11, 1936, by the writer and
Mr. Carlyle Carr of the United States Biological Survey.

Burrows were rather numerous in a level Flatwoods soil type just west of Houston and on a sandy, grassy slope east of the town. More collecting is needed to outline the range.

CAIIBARUS (GIRARDIELLA) HAGENIANUS FORESTAE, new subspecies

Plate IV, fig. 4.

Distinguishing characters: This crawfish is at once recognized as belonging to the hagenianus group. In most of the important points of classification it is identical with C. hagenianus evansi, but differs as follows: The tip of the rostrum is slightly more depressed. The antennal scale is widest near the base or at midlength instead of nearer the tip as in evansi, and peculiarly, some of the scales bear spines on the rounded inner margin while one or two specimens examined had spines on the outer margin. The beard is softer and more dense on the third maxillipeds of both sexes and also more profuse on the inner margin of the male hand, often extending on the movable finger. The proximal segment of the telson bears one or two spines on each side instead of the usual three in evansi, while the spines on the margin of the uropods are long and sharp-pointed in contrast to the short, often blunt spines of evansi. No differences have been observed between the
sexual characters.

The color is rather variable but blue apparently predominates in the only collection of any size made by the author.

**Biology:** Typical of the *hagenianus* group this is a burrowing species and is apparently dependent on a plant diet except for such insects and earthworms as may be caught. A very heavy infestation was observed in a lawn of white clover and grass. Specimens were dug out during daylight at the water level about 18 inches below the surface. About 48 hours after a good rain they were fairly numerous at night crawling around in the grass.

**Distribution:** Known only in Mississippi, specimens being collected at Forest in Scott County and Leesburg in Rankin County. Probably occurs elsewhere in the Central Prairie soil belt of Mississippi.

**CAMBARUS (ORTMANNICUS) BLANDINGII ACUTUS Girard**
Plate I, fig. 2; Plate II, fig. 2; Plate III, fig. 2; Plate IV, fig. 2.


1852 *Cambarus acutissimus*, Girard, loc. Cit.

**Distinguishing characters:** Rostrum with acute point and lateral spines. Areola linear. Antennal scale varies in different localities, but usually broadest near middle. Single spine on each side of carapace. Proximal segment of telson bispinose. Chelae slender, subcylindrical, the fingers curving typical of the entire *blandingii* group. Hooks on third and fourth walking legs of male. First abdominal legs of first form male with three curved horny teeth on the outside and with inner part prolonged into a pointed spur curving outward; brush of setae just back of horny teeth. Annulus of mature females usually with overshadowing prominence on one side, but lacking in young females. From cervical groove to tip of rostrum usually twice the distance from cervical groove to the abdomen.

Color of large specimens is usually red but young are often light olive or yellowish. Varies greatly.

**Biology:** Although this is the most common crawfish in Mississippi no females bearing eggs or young have been taken. Turner (1926) records such females in Ohio and Indiana in March, July, and September, indicating that reproduction may occur at almost any time. Young specimens
not attached have been collected throughout the year.

This species is usually found in stagnant ponds, roadside barrow pits, and sluggish streams. It is the most common species in Delta waters and is apparently an important source of fish food. As ponds become dry it constructs burrows, also building them around the banks and edges of the water at all times.

Distribution: This species is known from Alabama, Arkansas, Florida, Illinois, Indiana, Iowa, Kansas, Louisiana, Maryland, Michigan, Mississippi, Missouri, Ohio, Oklahoma, Tennessee, Texas, and Wisconsin. Creaser and Ortenburger (1933) report its presence in the State of Vera Cruz, Mexico.

Mississippi records: Probably occurs throughout the state as specimens have been taken in all sections and in all surrounding states.

CAMBARUS (ORTHANNICUS) HAYI Faxon

Plate I, fig. 3; Plate II, fig. 3; Plate III, fig. 3. 1884 Cambarus hayi Faxon, Proc. Amer. Acad. Arts and Sci., 20:108.

Distinguishing characters: This species is almost identical in appearance with C. blandingii acutus. The only
differences observed by the writer are in the first abdominal legs of the male, the annulus of the female, and the shape of the rostrum. There is a deep depression near the tips of the legs, just back of the beardlike brush of cilia, while in *blandingii acutus* the same area is smooth and rounded. The annulus has the same general shape as in *blandingii acutus* but does not have the overhanging lateral prominence often found in the latter. The swelling or tubercle in the middle is also more marked in *hayi*. The sides of the rostrum are more rounded than in *blandingii acutus*. In other respects this species conforms almost exactly to the description of *C. blandingii acutus*. The color varies from red to olive-green, with dark areas on the abdominal segments.

**Biology:** This species lives in pools and ponds, or about the same habitat as *C. blandingii acutus*. The writer has no records of egg-bearing females but presumably its reproductive habits are similar to its close relative.

**Distribution:** *C. hayi* has been reported only from a limited area in Mississippi in the Tombigbee watershed. Presumably it occurs in the same drainage system in Alabama but no records have been obtained there.

**Mississippi records:** Artesia, Yacon, State College,
Ripley. The last record is from a jar of young specimens in the Mississippi State College collection which contains a note stating that they were caught in a "muddy run one mile east of Ripley." This location is just north of the headwaters of the Tombigbee but streams in that area also drain into the Tennessee and the Mississippi. Further collecting in that section is needed to verify this record.

**Cambarus (Orthetramerus) Clarkii** Girard

Plate I, fig. 4; Plate II, fig. 4; Plate III, fig. 4; Plate IV, fig. 6.


**Distinguishing characters:** At a glance this species is readily recognized as one of the *blandingii* group. The rostrum is acute, deeply excavated, with lateral spines. Areola obliterated in adult specimens. Single thoracic spine. Carapace roughly granulated in large specimens. Proximal segment of telson bispinose. Suborbital angle weak. Postorbital spine present. Hands flat and broad. Hooks on third
and fourth walking legs of male. First abdominal legs with two large round plates on outside, one horny, the other white and soft with horny margin. Between the two round plates is a horny tooth which is barely noticeable. The inner part of the leg is prolonged into a sharp spine which extends obliquely slightly beyond the outer part. In the second form male the first abdominal legs have much the same shape but are not horny. The form of the annulus ventralis is rather constant for this species, the surface being smooth and rounded with the longitudinal fissure interlocking in a tongue-and-groove effect.

The color of this species varies with age, some young ones being olive green or mottled, while the largest adults are a brilliant red on the under side of the walking legs. On such specimens the spines on the chelae are red and the hands have brilliant red tubercles against a dark brownish-black background.

Biology: This species dwells in roadside ditches, ponds, and other habitats favored by C. blandingii acutus. It makes burrows in the sides and bottoms of ditches and retreats within these when alarmed. The writer has not secured any females with eggs or young attached, but very small specimens were collected throughout the winter and spring.

Distribution: C. clarkii apparently does not range far from the Gulf Coast. It has been reported from Alabama,
Arkansas, Florida, Louisiana, Mississippi, and Texas. It is the species sold for food in New Orleans and other Louisiana cities.

Mississippi records: Biloxi, Gulfport, Ocean Springs. It is strange that this species has not been found away from the coast in Mississippi, although collected as far north as Blytheville (R. N. Lobdell) and Little Rock (O. P. Hay) in Arkansas.

CAMBARUS (ORTHANNICUS) COOKAE, new species
Plate I, fig. 5; Plate II, fig. 5; Plate III, fig. 5; Plate IV, fig. 7.

Male, form I. Rostrum broad, depressed, triangular at apex, moderately excavated above with foveola at base; no lateral spines. No postorbital spines. Rounded, cylindrical carapace, punctate above and on sides, with blunt branchiostegian spine and slight angle behind antenna. Cervical groove sinuate, interrupted, without lateral thoracic spines. Distance from abdomen to cervical groove more than half the distance from cervical groove to tip of rostrum. Areola narrow in middle with wider anterior and posterior triangles. Abdomen broad, shorter than the cephalothorax. Proximal segment of telson bispinose usually, but some specimens may have a smaller third spine on each side. Uropods with short spines not reaching the margin. Epistoma variable, but usually truncate. Basal
segment of antennules with spine on inferior surface at mid-length. Antennae shorter than body; antennal scale broadest in distal half, rounded at apex, with short spine at base. Third maxillipeds sparsely thatched with stiff bristles, not concealing the teeth. Chelipeds slender, chelae subcylindrical, tubercolae ciliate anteriorly. Fingers as long as the hand, with tuberculate cutting edges, paralleled beneath, with some variations, by rows of impressed, ciliated dots. Carpus with one spine beneath and another on the inner margin. Merus with one dorsal spine usually more prominent, two rows of teeth beneath, the strongest on the inner margin. Strong hooks on third and fourth walking legs of male. Flattened tubercolae on basal joint of fourth leg of male, smaller rounded tubercolae at base of fifth leg. First abdominal legs reaching to the base of the third walking legs; tips curved backward, the outer part consisting of two flattened plates, the inner part prolonged into a strong spine extending backward at same angle as the tips of the legs and much exceeding the outer part in length, and a sharp tooth just posterior to the flattened plates which seems to arise from both inner and outer parts of the appendage.

Form II of the male differs only in having rudimentary hooks on the legs and soft, partially developed sexual appendages.

The female of this species has claws of the same shape as the male, instead of the shorter, broader chelae, found in
the females of most species of the *blandingi* group. The annulus ventralis of the female varies considerably in different individuals but in general it is flattened somewhat with a tongue-and-groove effect resembling that of *C. clarkii*, except that it is usually double-grooved instead of single. In some specimens each lateral division or half is drawn into a single prominence.

This crawfish is of fair size but no large specimens have been found. The largest male collected measures 90 mm. from tip to telson to tips of chelae, the largest female 95 mm. Living specimens collected by the author were a rather dull blue color.

**Biology:** This is a burrowing species. The author caught three specimens at night prowling on a grass and clover lawn in company with *C. hagenianus forestae*. However, some Works Progress Administration collectors on a biology project in Hinds County, under the supervision of Miss Fanny A. Cook of the State Game and Fish Commission, in whose honor the species is named, sent in some specimens which were collected from a lake. Nothing is known of the food or reproductive habits. Specimens were collected by the author on May 2 and by the Works Progress Administration workers on April 30, but none had eggs or young attached.

**Distribution:** Known only in Mississippi. Specimens
collected at Forest in Scott County and at Horse Shoe Lake, near Big Black River, 7 miles south of Cox's Ferry, in Hinds County.

CAMBARUS (ORTMANNICUS) EVICTUS, new species
Plate I, fig. 6; Plate II, fig. 6; Plate III, fig. 6; Plate IV, fig. 8.

Male, form I. Rostrum excavated, tapering gradually; acumen sharp, longer than width of rostrum at lateral spines. Antennae of moderate length, reaching to second or third segment of abdomen. Antennal scale long and slender, widest near base. Postorbital and branchiostegian spines present. Anterior margin of carapace slightly angulated. Two distinct tubercles on procarapace midway between cervical groove and base of rostrum. Procarapace 2½ to 3 times length of postcarapace. Cervical groove sinuate, interrupted, with single strong thoracic spine. Areola moderately wide. Chelae long, slender, subcylindrical, with curved fingers typical of the *blandingii* group. Hooks on third and fourth walking legs. Flattened plate on basal joint of fourth leg and sharp projecting plate on base of fifth leg. Proximal segment of telson with 3 or 4 spines on each side. First abdominal legs have same shape as in *C. blandingii acutus*, but the
three recurving horny teeth are more closely crowded in this species. Hidden in the bunch of setae behind the other teeth is a small horny tooth which is not present in acutus. The soft inner spine curves outward as in the other species.

The female has the same general appearance as the male and does not show the shortening and broadening of the hand so common in females of some other species of this group, such as C. hayi. The annulus ventralis is of varying shapes, some individuals having the overhanging lateral prominence usually found in mature specimens of blandinii acutus, while in others the annulus may have a wrinkled surface with a prominent tubercle in the middle, as though an extra fold had been squeezed out in its formation.

In coloration, some typical specimens are a dark reddish olive with lighter reddish telson and a light reddish stripe down each side of the abdomen. The hands are speckled with red and olive, with red on the under side. Some specimens are darker than others. One olive-green female became red after molting.

This species may usually be distinguished from C. blandinii acutus by the long antennal scale, the tri- or quadrispinose telson, and the longer procarapace in proportion to the postcarapace. The distance from the cervical groove to the tip of the rostrum is usually from 2½ to 3 times the
distance from the cervical groove to the abdomen. But confusing combinations are sometimes found, such as a quadrispinose telson with a body ratio of less than $\frac{3}{2}$, or a long slender antennal scale may be accompanied by a bispinose telson. The writer had tentatively identified this species as *C. lecontei* until he examined the *lecontei* specimens in the National Museum and the Harvard Museum of Comparative Zoology. The male appendages are quite different.

**Biology:** This species is found in about the same habitat as *C. blandingii acutus* and *C. clarkii*. Specimens have been collected in both stagnant and running water. No females with eggs or young attached have been found.

**Distribution:** This species apparently occurs rather generally in the southern part of Mississippi. It is probably present also in southern Alabama and Louisiana.

**Mississippi records:** Magnolia, Moselle, Ocean Springs, Wiggins.
CAMBARUS (ORTMANNICUS) SPICULIFER LeConte


**Distinguishing characters:** This species, like *C. versutus*, is readily separated from other members of the *blandinii* group by having two thoracic spines. It is distinguished from *C. versutus* mainly by having two strong spines on each side of the proximal segment of the telson instead of three or four. In all specimens examined by the writer the sides of the rostrum do not taper between the base and the lateral spines as described by Faxon. The first abdominal legs of the male are figured by Hagen, but the illustration given shows little difference from *C. blandinii acutus*. They are very much alike but those of *spiculifer* are more pointed at the tip.

The annulus of the female is peculiarly shaped, not like any other of the *blandinii* group. It has large prominent anterior walls with a cleft in the center, a sinuate cavity, and a large tubercle in the middle of the posterior wall, which is divided by a suture.
**Biology:** Previous records indicate that this species inhabits running streams. The only specimen collected in Mississippi, a small male of the second form, was taken from a swollen stream. The writer knows nothing of its reproductive habits.

**Distribution:** Previously recorded from Georgia and Texas, with the Texas specimen not typical.

**Mississippi records:** From Bayou Bernard at Landon (near Gulfport).

**Cambarus (Ortmannicus) Versutus Hagen**

Plate I, fig. 7; Plate II, fig. 7; Plate III, fig. 7; Plate IV, fig. 9.


**Distinguishing characters:** *Cambarus versutus* and *C. spiculifer* are the only known species of the blandingii group having two spines on each side of the carapace. This serves readily to distinguish them from *C. evictus* which they greatly resemble in width of areola, form of antennal scale.
and general appearance. *C. versutus* has three or four spines on each side of the proximal segment of the telson while *spiculifer* has only two. Although Faxon states that the sides of the rostrum converge less between the base and the lateral spines in *C. versutus*, the opposite is true in all specimens examined by the writer including the types observed by Faxon, the sides of the rostrum in *C. spiculifer* being practically parallel from the post-orbital spines to the lateral spines, while they gradually taper in the same area in *C. versutus*. The first abdominal legs of the male have the general form of the *blandinii* group but the teeth are rounded and small, giving the appearance of a small rounded knob covered with a tuft of setae. The inner part of the leg terminates in a spine which curves straight outward and backward instead of obliquely to the side as in *C. blandinii acutus*. The annulus of the female is most like that of *C. clarkii*, the longitudinal fissure having the same tongue-and-groove effect. However, there is a slight depression in the surface of each half separated by the fissure, instead of being rounded and smooth as in *clarkii*.

Living specimens of *C. versutus* may be instantly recognized by the peculiar color pattern on the carapace behind the cervical groove. A clear light area covers almost this entire region, extending considerably beyond the margins of the areola on each side and back to the abdomen. It is bordered
on each side by a dark brown or mottled gray area. There is also a clear area down the abdomen bordered by a dark stripe on each side. There are black tubercles on the reddish hands.

**Biology:** This species apparently prefers running streams or clear lakes. Miss Alma Phillips of Moselle, Mississippi, in sending in an adult female states that it is never seen except in running water. Collectors for a Works Progress Administration biology project in Hinds County found specimens in a large lake and in a creek. No females bearing eggs or young have been collected.

**Distribution:** Alabama, Florida, Mississippi.

**Mississippi records:** Collins, Moselle, Edwards. (Horse Shoe Lake, 10 miles south of Edwards, and 14-Mile Creek, in same locality.)

**CAMBARUS (PARACAMBARUS) HARNEDI** new species

Plate I, fig. 8; Plate II, fig. 8; Plate III, fig. 8; Plate IV, fig. 10.

**Male, form I.** Rostrum rounded, depressed, moderately excavated above with raised margins; no lateral spines or acumen. No postorbital spines. Branchiostegian spine blunt. Suborbital angle well defined. Antennae rather short, not extending back to the abdomen; antennal scale widest at distal
end. Basal segment of antennules with spine on inferior surface at mid-length. Cervical groove sinuate, interrupted, without lateral spines. Areola narrow in middle. Cephalothorax cylindrical, punctate above and on sides, longer than the abdomen. Proximal segment of telson bispinose, but trispinose in some females. Uropods longer than telson and with long spines extending beyond the margin.

Chelifeds long; chelae with inflated palms and small fingers about two thirds length of palm; immovable finger with large tubercle about mid-length of cutting edge. Carpus with two or three spines on inner margin, single spine beneath. Merus with two small dorsal spines near the anterior end, outer and inner margins tuberculate beneath. Hooks on fourth walking legs only. Pointed process projecting posteriorly on basal segment of fourth leg, interlocking with flattened plate projecting anteriorly on basal segment of fifth leg.

First abdominal legs long, slender, truncate, with small inside spur at base of each; outer part closely applied to the inner, tips slightly recurved; outer part ending in a sharp horny tooth and a broad horny plate; the inner part ending in a sharp spine directed outwardly.

No second-form males have been found.

In female specimens the same size as the male described the hands are considerably smaller and the palms less inflated,
although of the same peculiar shape as in the male. The only male specimen in the collection has two spines on each side of the proximal segment of the telson, while two females examined had trispinose telsons. The annulus ventralis has the form of a rounded movable button deeply split longitudinally into prominent halves.

This is a comparatively small species judging from all the specimens collected, the male measuring 70 m.m., another 65 m.m. The writer has seen no living specimens and knows nothing of the colors of this species.

This species is named in honor of Professor R. W. Harned, for 25 years head of the Zoology and Entomology Department of Mississippi State College.

Distinguishing characters: This is the only species known in the United States at this time with hooks only on the fourth legs of the male. Apparently it is related to C. (Paracambarus) paradoxus Ortmann, a Mexican species, which is the only other species of Cambarus having hooks only on the fourth legs. (Ortmann, 1906b). The sexual appendages are somewhat like those of C. paradoxus but also resemble those of the blandingii group except in being more slender and less recurved at the tips. The females differ greatly from C. paradoxus in not having the peculiar sternal spine found in that species.
Biology: The writer knows nothing of the biology of this species as this description was written from a study of one male and four females in the Mississippi State College collection, bearing only the label "Bayou Bernard near Landon". Presumably they were collected by Professor R. N. Lobdell about 1923.

Distribution: Known only from Mississippi at Bayou Bernard (near Gulfport).

CAIMBARUS (CAMBARELLUS) SHUFELDTII Faxon

Plate II, fig. 9; Plate III, fig. 9; Plate IV, fig. 11.


Distinguishing characters: This is the smallest known crawfish in the United States. Mature females bearing eggs and young measure 3/4 inch to 7/8 inch in length. It is so small it is likely to escape the attention of collectors looking for adult specimens. Its small size and the presence of hooks on the second and third walking legs of the male distinguish it from any other species in the United States. Cambarus montezumae and its varieties, occurring in Mexico, also have hooks on the second and third legs. The rostrum
has a sharp acumen, with strong lateral spines. Postorbital spine strong. Single well developed thoracic spines. Branchiostegian spine present, also spine at base of antennal scale. Telson bispinose. Areola of moderate width. Suborbital angle present. Male hand slender and cylindrical; female hand shorter and broader. First pair of abdominal legs ending in two straight sharp teeth on the outside, with inner part also drawn out in a straight spine. The peculiar annulus is best described in the words of Faxon as "a transverse curved ridge, the hind side of the ridge concave."

The color of living specimens is characteristic. The claws are light and dark olive mottled, as is also the area in front of the cervical groove. A wide light stripe extends all the way down the dorsal surface to the telson, bordered on each side by a narrower dark olive stripe, which is also present in the telson.

Faxon states that this species is distinguished from its close relative, C. montezumae, by having a thoracic spine and by its male appendages, those in C. montezumae being recurved at the tips with the inner part flattened at the end into a spoon-shaped surface.

Biology: Specimens in Mississippi have been collected in a clear lake (Tibbee Lake) where water flows in from an
artesian well and from another pool (Rest-a-While Camp, Columbus) fed by an artesian well.

A collection by Mr. J. W. Ward at Tibbee Lake in late October, 1935, contained one female with 18 eggs, another with 8 eggs, another with 3 young attached, and two others without eggs or young.

**Distribution:** Illinois, Louisiana, Mississippi.

**Mississippi records:** Tibbee Lake (near West Point), Columbus.

**CAMBARUS (FAXONIUS) LANCIFER Hagen**


This species, belonging to the same group as *C. mississippiensis* and *C. palmeri*, was described by Hagen from a first form male sent to the Museum of Comparative Zoology sometime prior to 1868 by a Mr. Wailes of Root Pond, Mississippi, a locality which was unknown even at the time Hagen wrote the description. Since the original description is in Latin, the writer is listing below the distinguishing characters from a study of the type specimen at Harvard.

**Male, form I.** Rostrum long, with long, slender, sharp,
lance-like acumen, its most distinguishing character; deeply excavated, with lateral spines. Strong postorbital spines. Single strong thoracic spine with bunch of hairs springing from the cervical groove beneath it. Areola linear in middle with small anterior and larger posterior triangles. Antennal scale long, slender, with strong spine at base and a smaller one on first joint of antenna. Suborbital angle present. Branchioptegian spine present. Chelae long, slender. Meros with spine above and below. Double-pointed hooks on third walking legs. Posterior part of carapace about one-third length of anterior part including acumen. First abdominal legs peculiarly twisted, the outer part with broad horny tip extending beyond the inner part which has a tip not quite so broad. Because of the twist the tips of the inner parts rest on the outside of the outer parts. Proximal segment of telson with one or two spines on each side.

Second form males have insignificant hooks on the third walking legs, with no indication of the double points present in the first form males.

The annulus of the female resembles that of *C. blandinii scutus*, having an overhanging lateral tubercle.

**Biology:** Nothing is known of its biology except that Meek found it in the St. Francis River in Arkansas.
-70-

**Distribution:** Arkansas and Mississippi.

**Mississippi records:** Type from Root Pond (Unknown); Vicksburg.

**Cambarus (Faxonius) Mississippiensis Faxon**

Plate I, fig. 9; Plate II, fig. 10; Plate III, fig. 10; Plate IV, fig. 12.


**Distinguishing characters:** Rostrum twice as long as broad, slightly excavated, without lateral teeth; acumen sharp, its length equal to half the width of rostrum between eyes. "Areola linear anteriorly to the middle, with a small anterior and a larger posterior triangular field." (Faxon). Antennal scale widest in middle with spine. Postorbital ridges ending in short very blunt spines, broken off in some specimens. Branchiostegian spine present. Single lateral thoracic spine. Proximal segment of telson bispinose. Suborbital angle weakly expressed. Chelae large, long, inner margin of hand short; fingers excised at base, with dentiform
tubercles on cutting edges, one large one on the outer finger; immovable finger bearded at base below. First pair of legs hooked in male. First abdominal legs deeply cleft, both branches recurved at tip, outer branch horny and sharp pointed, inner branch soft, flattened, and grooved on surface next the outer branch.

Second form male: Hands smaller, hooks on legs smaller, first abdominal legs stouter and split only short distance from tip. Faxon reports the rostrum with small lateral teeth, but several second form males examined by the writer show no noticeable teeth, although the margins are interrupted abruptly, which does not occur in the first form male.

Female: Hands much shorter. Rostrum similar to second form male. Annulus deeply excavated anteriorly.

Color: Living specimens of *C. mississippiensis* may be readily recognized by the peculiar grayish-green mottled pattern which covers the hands and the entire dorsal surface of the body, but is especially noticeable on the abdomen. The hands have dark green splotches on a light green background.

Biology: This species may be found in roadside ditches, sluggish streams, and perhaps ponds in the area in which it occurs. In a ditch at Egypt the writer found this species living with *C. blandingii acutus* and an unidentified species, probably new. Females carrying eggs were collected on
March 20, the first young hatched on April 3, and most of them were free-swimming four days later. More than 200 hatched from a single clutch of eggs, but the mother soon ate them. Some mortality of this kind undoubtedly occurs in nature.

**Distribution:** *Q. mississippiensis* has been recorded only from Mississippi, but its presence in the watershed of the Tombigbee would indicate that it might be found in western Alabama in the area drained by this stream.

**Mississippi records:** Egypt, Macon, State College.

**CAUBERUS (FAXONIUS) CREASERI, new species**
Plate I, fig. 10; Plate III, fig. 11; Plate IV, fig. 13.

**Distinguishing characters:** Male, form I. Rostrum fairly long, length more than twice width between the eyes; deeply excavated, tapering slightly to the moderately prominent lateral spines; acumen short, about one-fifth length of rostrum. Antennae reaching about the fifth segment of the abdomen. Antennal scale widest in middle with strong terminal spine and fairly prominent basal spine. Strong postorbital spine. Anterior margin of carapace slightly angulated just above spine at base of antennal scale. Branchiostegian spine present but not prominent. Areola
linear with small anterior and larger posterior triangles. Single strong lateral thoracic spine. Cephalothorax punctate above and granulated on sides; posterior part more than half (12 mm. to 23 mm.) length of anterior part. Hand rather long, equal to distance from abdomen to tip of rostrum. Palm inflated with fingers flattened. Both movable and immovable fingers bearded within at base. Carpus not deeply grooved on upper surface; tuberculate above on inner margin with a short sharp spine anteriorly located on upper inner margin; inner lateral margin with one strong spine and two smaller ones; ventral surface with two sharp anterior spines. Metasoma with two prominent spines on the upper ridge, and one sharp spine at the outer lateral tip and a double row of strong sharp spines beneath. Hooks on third walking legs. Sternum with thick bunches of setae about bases of walking legs. First abdominal legs cleft for half their length, tips curving at less than right angle; both inner and horny outer part ending in slender acute tips; inner part flattened and grooved as in _H. mississippiensis_ but ending in sharper point. Proximal segment of telson bispinose.

No second form males or females have been seen by the writer.

This species is not conspicuously colored, but the only living male caught had orange tips on the fingers with a dark
blue band back of the orange. The hand had dark blue or violet splotches on a dull olive background, which is the general body color.

This species is closely related to *C. palmeri* but apparently is nearest to *C. (Faxonius) creolanus* Creaser (1933), which the writer has not seen. It was collected in south central Mississippi, not greatly distant from the locality of *creolanus* in Louisiana. It differs from all the species of the *Faxonius* group represented in the Museum of Comparative Zoology and in the National Museum. It is named in honor of Dr. E. P. Creaser who has made substantial additions to the information about the crawfishes of the United States.

Although this species greatly resembles *creolanus*, judging from the description of the latter, it apparently differs slightly in the form of the sexual appendages, in the ratio of the posterior section of the cephalothorax to the anterior, in the length of the antennae, and in lacking a faint median carina on the rostrum.

**Biology:** The one specimen caught was taken with a net by dipping in a swollen, swiftly-flowing stream. The writer knows nothing of its reproductive or food habits.

**Distribution:** Known only from a single first form male taken at Brookhaven, Mississippi, by the writer on November 12, 1935.
CAMBARUS (CAMBARUS) DIOGENES Girard

Plate I, fig. 11; Plate II, fig. 11; Plate III, fig. 12; Plate IV, fig. 14.


**Distinguishing characters:** Rostrum short, moderately excavated, sides converging; no lateral spines, acumen short, triangular. Areola linear in middle with small anterior and larger posterior triangles. Antennal scale rectangular, very small. No postorbital, branchiostegian, or lateral thoracic spines. Telson bispinose usually, but trispinose in some specimens; basal segment shorter than terminal segment. Eye small, suborbital angle well defined. Claws broad and massive. Hooks on third walking legs. First abdominal legs of male with two right-angled curved tips, typical of this group, the outer tip horny, the inner soft. Second form male with both tips soft, blunt and shorter. Annulus ventralis of female
oval-shaped, with high steep walls, rounded at the top.

The color of *C. diogenes* is a brownish or olive-green, lacking the brilliant markings of the related species, *C. diogenes ludovicianus*. In size it is one of the largest species, the writer having captured one specimen 155 mm. in length, with the carapace 31 mm. wide.

Some of the specimens in the National Museum and in the Museum of Comparative Zoology labeled as *diogenes* are almost indistinguishable from the variety *ludovicianus* which varies greatly in several characters. In the Mississippi State College collection there is a specimen identified by Dr. Faxon as *diogenes* which is entirely different from some in the National Museum and at Harvard. Ortmann (1931, p. 156) calls attention to the differences between the eastern and western forms of *diogenes* and mentions intergrading specimens from Tennessee. It is possible that careful study of living specimens might result in a change in the present status of these species, perhaps even restoring the name *obesus* given by Hagen (1870, p. 81.) to a specimen from Monticello, Mississippi.

**Biology:** *C. diogenes* is a burrowing species but may also be found in ditches, ponds, and streams. The writer has captured some at night emerging from their large open-mouthed burrows during heavy rains, and has also found them
at night in shallow ditches within a few feet of their burrows in the side of the ditch. No females with eggs or young attached have been observed by the writer. Turner (1936) records observations of such females by Pearse, Hay, Williamson, Bundy, Harris and Ortman during the months of January, April, May, and June.


**Mississippi records**: This species is probably widely distributed in Mississippi, but on account of its burrowing, nocturnal habits it is seldom collected, in contrast to *C. diogenes ludovicianus* which seems to be second only to *C. blandingii acutus* in general occurrence. Specimens have been collected at State College, Eupora, Muldon, Corinth.
CAMBARUS (CAMBARUS) DIOGENES LUDOVCIANUS Faxon

Plate II, fig. 12; Plate III, fig. 13; Plate IV, fig. 15.


Distinguishing characters: This is one of the most common crawfish in Mississippi and should be readily recognized when alive by the brilliant red markings on the green background. The red color is found on the margins of the rostrum, the postorbital ridges, bordering the distal edges of each joint of the chelipeds, the tips of the fingers, the dorsal posterior margin of each segment of the abdomen, and on the outer border of the lobes of the telson. Some specimens may show more red than others and occasionally orange or yellow tints add to the striking appearance of this handsome species.

Preserved specimens greatly resemble C. diogenes but may be distinguished by the form of the anterior part of the carapace which is full and rounded in C. diogenes but converges sharply in ludovicianus with the sides of the carapace dropping almost vertically from the postorbital
ridges. The rostrum in some specimens is slightly concave between the eyes. The suborbital angle is more pronounced than in $G. \text{diogenes}$. The areola is obliterated in $\text{ludovicianus}$, usually linear in $\text{diogenes}$. The abdomen is longer and wider than in $\text{diogenes}$. In size it is fully equal to $\text{diogenes}$ or larger. A large male in the collection, with claws extended, measures 205 mm. The hand is 27 mm wide and the movable finger 48 mm long. Length of antenna to first joint 91 mm. The writer has observed no marked differences in the male appendages. The annulus ventralis of the female consists of a strong circular wall with a large open central cavity.

**Biology:** The burrows of this species may be found along ditches or streams just above the normal water level. Such burrows usually open into the stream at the bottom. Burrows may also be found in low fields or pastures, in which case the crawfish is at the water level several feet below. In captivity this species will eat insects or meat, but shows no interest in grasses or clovers.

A female with about 50 eggs attached and the empty shells of many others was received from Corinth on April 27. Another with eggs attached was received from the same locality on May 20.

**Distribution:** This species is recorded from Louisiana,
Indiana, and Mississippi, but probably occurs in other southern states.

**Mississippi records:** Found in all parts of the state apparently. Collections from: Landon (near Gulfport), Corinth, Brookhaven, Porterville, Jackson, Collins, Koselle, Florence, Louin, Rosedale, Bogue Chitto.

**Cambarus (Cambarus) Latimanus LeConte**
Plate II, fig. 13; Plate III, fig. 14; Plate IV, fig. 16.


**Distinguishing characters:** This species so greatly resembles *C. diogenes* in general appearance and in so many morphological characters that it is difficult to separate them, especially since there are geographical races of both species.
The rostrum is broad, deeply excavated, with short triangular acumen and no lateral spines. The areola is practically obliterated and is longer than in diogenes. The hands are heavy and broad, of the same shape as diogenes. The carpus in most cases has paired or seemingly double spines of almost the same size on the inner surface as compared with one strong spine and other small ones in diogenes. There are no post-orbital or lateral thoracic spines. The cervical groove is not interrupted. Proximal segment of telson is bispinose. Third walking legs armed with hooks. The male sex appendages have the same form as in diogenes.

The annulus ventralis of the female is oval-shaped, with high steep walls and rounded at the top. A shallow depression leads up the face of the anterior wall, becomes deeper, winds to the right or left (of 5 females examined, the depression swung to the right in 4), then back to the middle of the posterior wall, which is continuous.

The color apparently varies considerably. It is reported as usually being a greenish gray or a greenish brown, but several specimens captured by the writer had at the time of capture a decidedly blue-green color which soon faded from the preserved material.

**Biology:** This species apparently lives under about the same conditions as G. diogenes. The writer has captured them
at night during a heavy rain in shallow rivulets of water on the surface of the ground.

**Distribution:** Known in South Carolina, Georgia, Alabama, Tennessee, and Mississippi.

**Mississippi records:** West Point, State College.

**Cambarus (Cambarus) argillicola** Faxon

Plate II, fig. 14; Plate III, fig. 15; Plate IV, fig. 17.


**Distinguishing characters:** Resembles *C. diogenea* but is much smaller. Rostrum short, broad, depressed at tip, well excavated, with marked foveola at base; acumen short, without lateral spines. Areola linear or obliterated in middle. Antennal scale small, rectangular. No suborbital angle. Telson bispinose usually. Hooks on third walking legs. Immovable finger bearded at base, although Mississippi specimens have only slight beards as compared with the types. First abdominal legs of male with two tips curved at right angles, typical of this group. Annulus ventralis of female resembles that of *C. diogenea*. 
The non-anfrugulated anterior margin of the carapace is the best character to distinguish this species from small specimens of *C. diogenes*. In size and general appearance it is very much like *C. lobdelli*, but may be distinguished by the longer rostrum, rounded epistoma, larger rectangular antennal scale, less inflated palm, the absence of strong bristles between the two rows of teeth on the under side of the meros, and the presence of a spine on the under side of the first joint of the antennule midway its length.

**Biology:** *C. argillicola* is a burrowing species and in Mississippi seems to prefer sandy land where the water table is not too far below the surface. The writer has collected them at the entrance of their burrows at night during a heavy rain. Their burrows usually have rather tall slender chimneys which are frequently blocked about an inch from the top. Turner (1926) records several observations of females carrying eggs or young, all in April, made by Pearse, Hay and Williamson. No female with eggs or young has been collected in Mississippi during this study.

**Distribution:** Ohio, Indiana, Ontario, Michigan, Illinois, Louisiana, Mississippi, Alabama, Texas.

**Mississippi records:** Bay St. Louis, West Point.
CAMBARUS (CAMBARUS) LOBEDHILLI new species

Plate II, fig. 15; Plate III, fig. 16; Plate IV, fig. 18.

Male, form I. Rostrum very short, broad, depressed at tip, well excavated, with distinct foveola at base; acumen short, obtusely triangular, without lateral spines. Areola obliterated in middle. Postorbital spines, suborbital angle, and branchiostegian spines missing. Cervical groove sinuate, hardly interrupted, without lateral thoracic spines. Antennal scale very small, almost rectangular, but wider at distal end. Antennules lack the usual spine on the under side of the first joint midway its length. Epistoma obtusely triangular or broadly oval, almost truncate. Chelae massive, palm greatly inflated; immovable finger bearded at base; both fingers excised at base, two or three large tubercles on cutting edge of each. Carpus with strong spine on inner margin and lesser spine beneath. Metas broad and flat, smooth dorsal margin and only small tubercles on outer and inner margins beneath. Third walking legs hooked. Fourth legs with horny plate at base. Telson bispinose, with very small spines on uropods not reaching to margin. First abdominal legs with two tips curved at right angles typical of this group, the outer tip horny.
The female has the same appearance as the male, the form of the chelae being the same in both sexes. The annulus ventralis of the female is of the diogenes type, a wide break in the anterior wall with an inner fossa swinging to the right, then back to a suture in the middle of the posterior wall.

This is a small species, two males measuring 68 mm. and 63 mm., respectively, while two females measured 70 mm. each from tip of telson to tips of extended chelae.

**Distinguishing characters:** This is readily recognized as belonging to the diogenes group but may be distinguished from small specimens of *diogenes* by the absence of a suborbital angle. *C. arrillicola* also has no suborbital angle but *C. lobdelli* may be distinguished by the shorter rostrum, the very obtusely triangular or broadly oval epistoma, a more inflated palm and the absence of the spine on the under surface of the first joint of the antennules. Like *C. arrillicola* this species has a beard at the base of the immovable finger, but it is heavier than in specimens of *arrillicola* collected in Mississippi.

This species is named in honor of Professor R. N. Lobdell, who apparently collected it in 1923, but did not describe it. In the Mississippi State College collection this species was found in the same jar with *C. harnedii* and the only information...
given was: "Bayou Bernard near Landon".

**Biology:** The writer knows nothing of the biology of this species.

**Distribution:** Known only from Mississippi at Bayou Bernard (near Gulfport).

**Cambarus (Paxonella) Clypeatus Hay**

Plate I, fig. 18; Plate II, fig. 16; Plate III, fig. 17; Plate IV, fig. 19.


**Distinguishing characters:** The males of this species may be recognized at once since no other species in the United States normally carries the first abdominal legs with the tip of one crossed over the tip of the other or has the inner branch of the leg only one-third the length of the outer horny branch. The rostrum is almost plane, slightly excavated, without lateral spines or noticeable acumen.
Areola wide. Antennal scale large, widest at middle, spine at base of scale and another at base of antenna. Postorbital spines in some specimens, lacking in others. Weak branchiostegian spines, no lateral thoracic spines. Basal segment of telson bispinose. (Hay states that there are four or more, but in all the specimens examined by the writer there are only two well developed spines on each side.) No suborbital angle. Strong hooks on third legs of first form males, very weak in second form. Outer branch of the first abdominal legs of the male long, slender, and horny in the first form, ending in a sharp point; inner branch soft, reaching only one third the length of the outer. In the second form both branches are soft and somewhat larger than in the first form, the outer ending in a straight sharp point.

The annulus of the female is subcircular, with a low anterior opening on one side of center, the fissure bending sharply back under the anterior walls, whence it winds about returning to the middle and splitting the posterior wall in the center line usually, but sometimes to one side of the center.

The color of living specimens collected by the writer is mottled olive-green with reddish tinges. A wide light stripe with definite boundaries extends down the dorsal surface of the body from the base of the rostrum to the telson.
There is also a light stripe on each side of the abdomen, separated from the light center stripe by an olive-green stripe. This differs slightly from Greaser's description.

This is apparently a rather small species. Hay's type was 2 inches long. Greaser mentions one specimen 41.2 mm. in length while the largest specimen studied by the writer is the same length (1 5/8 inches from telson tip to rostrum tip, and 2 inches from telson tip to tip of claws.)

This species was described in 1899 by Professor W. P. Hay from a single female caught in a small boat at Bay St. Louis, Mississippi, by the U. S. Biological Survey in 1892. It was not found again until 1931 when W. P. Greaser, on an expedition for the University of Michigan, took it in southern Alabama and Louisiana. He redescribed the species, giving the characters of both first and second form males, which had not been known until that time.

**Biology:** Specimens were collected by the writer in a small clear pool where a typical "Piney Woods" branch crossed a highway. It was found in company with *C. evictus*. Mr. J. P. Kislanko of Wiggins collected this species, again with *evictus*, "from a shallow pool in a roadside ditch. The ditch was dry until recent rains." This indicates strongly that it is a burrowing species, as Greaser has surmised. Mr. H. Gladney of Ocean Springs collected several specimens at Handsboro in
a roadside ditch in company with *G. clarkii*. Mr. C. L. Bond also found them in a roadside ditch at Moss Point.

No females with eggs have been found, although these collections were made on March 29 (all males), May 30, November 20, and December 14.

**Distribution:** Alabama, Louisiana, Mississippi, Oklahoma.

**Mississippi records:** Handsboro, McLain, Moss Point, Wiggins, all in the extreme southern part of the state.
THE BIOLOGY AND CONTROL OF CAEBARUS HAGENIANUS
FAXON AND ITS SUBSPECIES

Introduction

Distribution

The distribution of this species and its subspecies in Mississippi and Alabama has been mentioned briefly already (page 43). The accompanying map (figure 4) indicates the areas probably occupied by each subspecies based on present records. *C. hagenianus hagenianus* apparently is the only one of the group which extends into Alabama, although no extensive survey has been made in that state. Each subspecies seems to be entirely separated from the others. *C. hagenianus forestae* is known only in the Central Prairie soil belt of the State, while *C. hagenianus hagenianus* occupies a strip of the Northeast Prairie extending southward from Tibbee Creek and swinging eastward into Alabama toward Montgomery. Specimens received from Allenville, Alabama are indistinguishable from those occurring around State College and Macon. *C. hagenianus evansii* is found in the lime soils north of Tibbee Creek and west of the Tombigbee River. *C. hagenianus carrii* has been found only
Figure 4. The prairie sections of Mississippi and Alabama, showing the areas known to be infested with *Cambarus hagenianus* Faxon and its subspecies
at Houston and is apparently adapted to the Flatwood soil belt. Further collecting is necessary to outline the exact range.

The prairie soil types in which crawfish damage is greatest are known as "black prairie" and "post oak", both derived from the weathering of the underlying limestone, or Selma Chalk. The "black prairie" soil is fittingly named and is one of the most productive soils of the state, being especially adapted to clovers and other legumes and grasses. The "post oak" soil is generally of a yellowish-gray color and receives its name from the typical post oak stands found on it. It is usually not so fertile as the black soil but is very satisfactory farm land.

In these sections the crawfish infestations are not continuous, as some farms may be heavily infested while only a few hundred yards away there may be few or none. Apparently the most desirable conditions are provided when a layer of limestone occurs fifteen to twenty-five feet below the surface and so lying as to prevent the escape of the soil water. Under such conditions heavy infestations may be found on rather steep slopes or even on hilltops.

Economic importance.

Since the first settlement of the Northeast Prairie section of Mississippi, damage by crawfish has been regarded
as one of the hazards to farming there. Maximum infestations range from about 5000 burrows per acre in the soils around State College and Starkville to 15000 or more per acre in Clay, eastern Chickasaw, and western Monroe Counties. With such infestations a crop of cotton or corn may be almost completely destroyed during a warm rainy night in April, May, or early June. Although older cotton plants may be damaged, the heaviest loss occurs when the seedlings are only two or three inches above ground and before secondary leaves appear. Cotton is apparently preferred, but young corn plants suffer about as much. Crops may be replanted and destroyed several times before a final stand is secured. In a field where a stand of corn was secured only after four plantings there were 34 burrows in a measured space 10 feet square. The repeated loss of seed adds considerable to the cost of the crop and the replanting must be done at a time when all labor on the farm is badly needed for hoeing and other operations. Furthermore, since the advent of the boll weevil it usually has not been practical to replant cotton as the late crop is often exposed to heavy attacks by this insect. Stands of alfalfa and clover in meadows are damaged to some extent while the chimneys over the burrows are serious obstacles to the use of the mowing machine.
Methods of study

Since this crawfish spends practically all of its life in deep burrows in the ground, a study of its life history is not a simple matter. The excavation of a single burrow usually requires hours of back-breaking toil. Most of the occasions when it is out of the burrow occur during heavy or long-continued rains at night. For more than a year the writer spent practically every rainy night, both winter and summer, in slicker and hip boots collecting and making flashlight observations.

In addition to the field observations studies were conducted in the laboratory by means of two large glass cages with 3" compartments filled with soil and standing in about six inches of water. Young and adults of both sexes were placed in these cages singly and in pairs. Five-gallon jars and large enameled dish pans partially filled with soil also made very satisfactory cages. Field cages were prepared by locating an uninfested area and drilling artificial burrows about three feet deep in plots which were covered and enclosed on all sides with small mesh heavy wire screen. Various combinations of the subspecies of C. hagenianus were placed in
these cages but it was soon found that the females killed the males at the first opportunity. Observations were difficult to make so these outdoor cages were abandoned. It was found that specimens in the laboratory cages apparently made normal growth anyhow, making the field cages unnecessary. When first caught, this species is very restless and for three or four days will try ceaselessly to escape from containers, but after this time they become quiet and will lie motionless for long periods unless disturbed.

General habits.

Burrows. As previously stated, this is a true burrowing species and its burrows are located without any relation to surface water. The burrows are from one to two inches in diameter and generally extend downward with slight deviations from the vertical. (fig. 5). Burrows frequently have two or three branch openings which sometimes enter the main burrow at almost right angles, increasing the difficulty of applying control measures. In sod land or meadows burrows may often open under a clump of grass or stool of alfalfa and may not be covered by a chimney, although chimneys are built in large numbers in such fields. The depth of the burrow varies with the time of year. During the winter and early spring when the ground is saturated with water, the crawfish may be found
Figure 5. A burrow of Cambarus hagenianus evansi, excavated to a depth of approximately 10 feet, showing two outlets to the surface and a double channel in two sections of the burrow.
within two to six feet of the surface, having blocked their burrows with mud a few feet from the top. For example, in 17 burrows excavated on October 8 after a few heavy rains the water level was 3" inches from the surface and specimens were found at depths varying from 3" inches to 73 inches, averaging 50 inches. In the same location three weeks later, after more rain, the water in the burrows was only 8 inches from the surface and specimens killed by poison were found at 12 and 18 inch depths. A burrow excavated in June was ten feet in depth, while some in July were found by Lobdell (1917) to be about 14 or 15 feet deep, ending in limestone. After observing the construction of several chimneys on the burrows of this species, it is the writer's opinion that they are merely the result of the piling of the pellets of excavated mud around the opening and probably serve no useful purpose. Not all individuals construct chimneys as many burrows may be found without them. The writer kept a number of adults in glass cages of soil with the bases resting in about six inches of water and some of the specimens worked tirelessly, piling up large mounds of mud, while others a few inches away under identical conditions made no effort to build chimneys. Also some individuals would seal the entrance to the burrows and others under the same conditions would leave them open. A young male placed in a cage on September 17 sealed his
burrow at once and did not open it until October 6, while an adult female reopened hers in less than 48 hours.

Food and feeding habits. This species undoubtedly gets most of its food from vegetable sources but also relishes earthworms and other animal foods, including weak or molting individuals of its own kind. Cotton, Corn, alfalfa, clovers, vetch, and various grasses are readily eaten. Cotton seeds are quickly hulled and the contents consumed. While green food is preferred, the writer has observed many individuals tugging away at clumps of dry bromusedge just as though it were a choice delicacy. One was noticed carrying a dead oak leaf into its burrow.

Foraging is done only at night and especially on rainy nights when the temperature is above 55° Fahrenheit. At air temperatures of about 55° F. and lower this species may be found sitting at the mouth of the burrows at night, especially if it is raining, but they are not likely to leave the burrow for any foraging as shown in these extracts from field notes:

Dec. 9—Drizzling rain all day, almost sleet. Went out on pasture at 7:00 P.M. and stayed for an hour. A few crawfish in the entrances of the burrows but not one outside. Probably too cold, temperature 34° F. A few green alfalfa leaves in burrows, indicating recent feeding.
Dec. 11—Went out at 7:00 A.M. after rain all night but no crawfish out. Rained all day.---
Out again at 6:30 P.M., temperature 48°F. Caught one half-grown female crawling and saw good many sitting in entrances to burrows.

Feb. 7—Rained all day but only slight mist at 7:00 P.M. No signs of crawfish even at entrances of burrows. Air temperature dropping rapidly—38°F. Water in burrow 12 inches from surface, 50°F.

Feb. 8—Temperature at 8:00 A.M.—16°F. In laboratory, 38°F.

Feb. 9—Temperature at 8:00 A.M.—30°F.

Feb. 14—Drizzled occasionally during day with showers between 8:00 and 9:00 P.M. Went out on golf course about 9:30 P.M. and found many crawling around, large numbers sitting in mouths of burrows. Some cutting clover, others trying to get back into holes already occupied. Air temperature, 60°F. Slight drizzle most of time. In 11 hours caught 178 females and 4 males.

Feb. 17—Showers and misty drizzle all day. Out at 7:00 P.M., but no crawfish out although they were sitting in their burrows as the water stood at the top of the holes. Air temperature, 54°F.

While both sexes may be found foraging at some distance from their burrows, the writer has observed the males ranging much more widely. Females will usually be found tugging at bunches of grass or clover only a few inches from the burrow or carrying a handful of forage back to the entrance, while males are generally moving in a definite direction and seem
in a hurry to reach their destination. Just what distances they will go for food the writer is unable to state, but fresh alfalfa leaves were once found in a cleanly cultivated field about one hundred feet from an alfalfa meadow. Whether they always try to return to their own burrow is also unknown for the writer has observed many of them attempting to get in burrows already occupied and guarded.

This species is able to live for long periods without food. Some young specimens about a year old were kept in tap water without food from October 9 until June 8 of the following year, or 8 months. They were not dead but the experiment was closed as the writer was leaving home for several months. Two adult females placed in individual containers with only soil and water on May 27, 1933, lived without food until March 6 and March 14, 1934, except for a few cotton seed given them once during the previous June.

Reaction to physical factors. As previously indicated, the activity of this crawfish is governed to a large extent by temperature. The water deep in the burrow probably never gets warmer than 70 to 75° F. in summer nor colder than 50° in winter. In laboratory tests of both sexes of _O. hagenianus_ and _O. hagenianus evansi_ in ice water they became sluggish at about 48 to 50° F. Almost all activity ceased at 40 to 42°, although slight movements of legs and antennae
were noticed at 36 to 38°. There was no mortality in cages in the laboratory when the temperature during a cold spell fell to 38° F. for a good part of the night and the same was true of a batch placed in a refrigerator over night at a temperature of 44° F. A group of both species and sexes showed restlessness when the tap water in which they were placed was raised from 78° F. to 95° for 30 minutes. Further raising it to 98° for 10 minutes produced increased restlessness with abdomens elevated in the water. At 100° they began turning over on their sides, but all recovered when placed in fresh tap water at 78° after remaining two minutes at the higher temperature. In another test half of them were killed by a minute exposure to 102° F. after remaining 30 minutes at 94° and 10 minutes at 96-98°. Temperature has a marked effect on the results with some poisons as will be noted later.

Although moisture is absolutely essential for crawfish and this species does not usually leave its burrow except during nights with rain or heavy dew, it is able to survive in the laboratory for rather long periods under adverse conditions. A young male placed on damp soil with water 12 inches below, made no effort to burrow to the water and lived 27 days on top of the soil. In another case a number of young males and females on moist soil had suffered no ill effects when moved at the end of 18 days. However, those
which fail to return to their burrows on rainy nights die quickly if exposed to sunshine the next morning.

In captivity crawfish naturally try to hide from light as their burrows are dark at all times. In collecting them with a flashlight they usually do not retreat from the light but the motion of the hand in front of them will cause them to dart back at once. The light apparently blinds them. Other investigators have dealt with the responses of crawfish to food, contact, and other physical stimuli, and no effort was made in this investigation to study any factors except those which might have some value in connection with control measures.

Life history

Mating. Mating has never been observed in this species, but the writer believes it probably occurs on the surface of the ground on warm, rainy spring nights, as this is the most favorable time for the sexes to meet, although close observation on many such nights has failed to find a pair in copulation. The females usually destroy any males paired with them in captivity and this may also occur in nature to cause the unequal ratio of the sexes which will be discussed later. The writer has never found both sexes in the same burrow, nor, in fact, two adults in one burrow.
Oviposition. This species lays eggs in the fall. The earliest date on which the writer found egg-bearing females was October 6, but some individuals undoubtedly oviposit in September for on one occasion a tiny pink specimen apparently about 10 days old was found on October 9. Eggs and very tiny young were found as late as December. Observations on egg-bearing females can be made only by excavating the burrows, for although thousands of females have been caught at the surface of the ground on rainy nights, not one has been found with eggs. Only a small percentage of the females produce young each year. Of 93 adult females dug from individual burrows during October, November, and December, 1933, when eggs or young should have been present, only two carried eggs and only one burrow contained recently-hatched young. Of 57 females dug from burrows in the fall of 1933, three had a total of 9 young and six others carried a total of 11 eggs. The number of eggs laid by this species, averaging probably 25 to 30, is very small compared to the hundreds produced by Q. mississippiensis and Q. diogenes ludovicianus. Since the young are confined in the burrow with the mother for many months, it is doubtful if this species feeds on its young as do those living in streams and lakes.

Incubation. Although it was not possible to determine the exact period from oviposition to hatching, since all
females with eggs had already oviposited when captured, several weeks are required for incubation in this species. A female captured on October 8 with about 30 eggs was placed in a large dishpan with an island of mud and turf in the center and water surrounding. A burrow was made for her, which she accepted and in which she remained sealed for several weeks. On November 9 she was removed and examined, at which time the eggs were very reddish with the outline of the embryo showing plainly through the membranous shell. On November 15 they had hatched but were still attached to the mother. A week later they had all left and were hidden in the mud. Only six hatched, as the female gradually lost the eggs in crawling around through the mud. This usually happens in nature also, for the average number of young found in the burrows was 5 or 6, with a maximum of 10.

Molting. This species probably differs very little in its molting from others that have been studied. The excellent work of Andrews (1907) could hardly be improved upon, and no extensive effort was made in this investigation to record the number of molts or intervals between as the economic basis of the study did not require this information. It was observed that there is a difference in the amount of molting from year to year which the writer is unable to explain. All of the young caught in the fall of 1932 molted
within a few weeks, while of a large number apparently of the same age caught in the fall of 1933, including 20 in one burrow on October 6, not a single individual had molted by March 20, 1934, although kept under exactly the same conditions as during the previous fall. Adults also showed a higher percentage of molts in 1933.

The color in this species may be changed by molting, as some reddish individuals became pale blue after molting.

Sex ratio. The adult females far outnumber the males of C. hagenianus proper, all collections showing this unequal ratio. A few examples of collections, taken at random, are:

February 8—Males 10...Females 175
February 14—Males 4...Females 178
March 24—Males 6...Females 351
November 6—Males 0...Females 28

This unequal proportion could be due to a greater propensity of the females to come out and wander around on rainy nights, but the excavation of poisoned and unpoisoned burrows indicates that this is not the case. Of 105 adult burrows excavated during one fall, 88 contained females and 17 had males. The sexes occur in about equal numbers at hatching and until they begin to construct burrows of their own. Of 62 young caught in several burrows during a certain period, 38 were females and 34 were males. In the largest
number found in a single burrow—^0, there were 12 males and 8 females.

The small number of males may be due to the murderous nature of the females as they killed the males in practically every case where they were confined in pairs. Also, as previously mentioned, the males range farther away from their burrows during rains and more of them may be caught by enemies, or, failing to find their own burrows on returning may be killed when they enter those occupied by females.

This unequal ratio does not exist in C. hagenianus evansi, as a collection of 1000 individuals on one occasion contained 527 females and 473 males. Only a small number of specimens of C. hagenianus carri and C. hagenianus forestae have been collected, so no study of the sex ratios in these has been made.

Maturity and longevity. The mode of life of this species under natural conditions and the hazards of rearing it in the laboratory over the long time necessary for accurate data on maturity and longevity make definite information difficult to secure. During this study the writer made several attempts to rear young from the egg to the adult but in only one case was even partially successful. One promising group died suddenly without apparent cause when a fresh batch of clover and soil was added to the cage. The absence of the writer for
several months at a time on some occasions caused a loss of specimens through lack of care. However, a young male hatched in the laboratory on November 15, 1932, made normal growth based on comparisons with other young individuals caught in the field each year, and apparently was about half grown when it disappeared from the cage about June 15, 1936. It had been observed only a few days before and its disappearance was a mystery, as it could hardly have escaped, and no traces of its remains were found in the cage. It had lived almost exclusively on clover and grass, although on two or three occasions during the nearly four years it received small bits of meat. From this life history and from many field observations the writer believes that this species requires six to seven years to attain full size, although becoming sexually mature much earlier. The youngest female found with eggs was about three years old apparently. The many collections of young of two practically uniform sizes while excavating indicate rather definitely that the young usually remain in the burrow with the mother until the second spring after hatching before starting their own burrows. For example, the young hatching in the laboratory on November 15 were about one-half inch long on December 6, very tiny and pink with prominent black eyes. On the same date tiny pink ones of the same size were dug out of a burrow,
while two months earlier young ones measuring about 1½ inches in length had been found, indicating that they were hatched the previous winter.

As to longevity, there is good reason to believe that this species lives ten years or longer. An adult female captured by the writer on August 18, 1939, and evidently not less than six or seven years old at that time judging by her size, showed no indications of old age when she escaped from her container in the laboratory in October, 1935. She had molted several times and regenerated a claw which was missing when she was captured.

Control

Early efforts. Apparently the earliest control measure against this pest was collecting them on rainy nights with lanterns or torches. A quicker method would have been merely to kill them in the field by stepping on them or striking with a stick, but since the planters paid for them at the rate of a barrel of flour for a barrel of crawfish, the negro tenants collected them in large quantities. Lobdell (191?) describes such a collection:

"About 31 negroes—men, women, and children, are strung in a line across as many rows, every third person carrying a lantern. As they walk along the crayfish are gathered into buckets and later poured into barrels at the turn road. The hands have been paid at the rate of 7½ to 10 cents per hour and the total cost has been $7.50 (for
15 acres). There is now a good stand of cotton and corn on
the land but it is from the fifth planting this spring."

Hundreds of barrels of the pests were collected on some
plantations over a period of a few years. Mixed with corn meal,
ground and dried, the crawfish made a good food for poultry.

Cultural measures have also been advocated by some planters.
Having cotton "barred off" or on a high narrow ridge in pre-
paration for hoeing at the time of a rain is thought by some
to reduce the damage greatly. Others believe that an infested
field can be almost freed of crawfish in three or four years
by intensive cultivation during the early spring and delaying
the planting of a crop until in June. Cultivation undoubtedly
gives less favorable environment than in a meadow, but infest-
ations of 15,000 to 15,000 per acre have been observed on land
that has been regularly cultivated for many years. The planters
with the heaviest infestations and longest experience are con-
vinced that cultural measures will not greatly reduce the damage
in badly-infested fields. Early experiments by Lobdell (1911)
in attempting to reduce the water level in infested fields by
dynamiting, tiling, and the digging of wells proved unsuccess-
ful.

The earliest record of chemical tests are those reported
by Fisher (1911) who found carbon bisulphide, chloride of lime,
and calcium carbide effective. He recommended that killing by
mechanical means on rainy nights be supplemented with carbon bisulphide applied to the burrows by squirting a few drops in each from a long-nozzle oil can, then closing the burrow with the foot. He estimated the cost of the carbon bisulphide at one cent for 75 holes, or $1 to $1.50 an acre. The next year Lobdell reported testing calcium carbide, kerosene, sodium chloride, potassium cyanide, carbon bisulphide, sulphuric acid, copper sulphate, iron sulphate, calcium chloride and formalin. He found carbon bisulphide uniformly effective at the rate of one teaspoonful to the burrow, with six drops sufficient where the air space above the water was not too large. Potassium cyanide was also successfully used but was not recommended on account of the cost and danger in handling. Lobdell also mentions very briefly that promising results were secured with a miscible oil from coal tar, but there is no indication of further tests with this material.

Although carbon bisulphide was recommended by the Mississippi Agricultural Experiment Station for many years, it was not used to any extent by the planters because of the cost and the difficulty of application. Probably the most widely-used chemical treatment was a cyanide pill made by the Kill-Craw Company of West Point, Mississippi. This firm combined sodium or potassium cyanide with common salt, molded the mixture in pellets and marketed them in gallon buckets at $5.00 per gallon. The originator of the pellets is dead, but his
-I-I-

son, Mr. Frank Strong of West Point, still sells them although he is not pushing the business to any extent. In tests by the writer the pellets have not been found practical since they usually lodge in the burrow within a few inches of the opening.

Because of severe damage to crops in the spring of 1933, planters from the crawfish-infested prairie counties appealed to Mississippi State College for more research on this problem. The writer began the investigations in the fall of 1933, but on account of other college duties only a relatively small amount of time has been devoted to this project each year.

Summary of poisoning tests.

Procedure. It was recognized in the beginning as almost certain that any practical control would have to be applied to the burrows. A broadcast treatment which would lie on the ground until the crawfish came out and ate it was suggested by some of the planters but the obstacles to such a plan were at once apparent as the same rain which would bring the crawfish from their burrows would wash away the poisoned bait, to say nothing of leaching out any soluble poison. A Bureau of Biological Survey investigator, Mr. Carlyle Carr, who was assigned to this problem for a few weeks in 1936, failed to secure satisfactory results from a broadcast application of cotton seed impregnated with bichloride of mercury, which he
had found effective in the laboratory. The tests conducted by the writer were confined to materials adapted to burrow applications.

In nearly all the tests, involving several thousand specimens, fully-grown females weighing from 10 to 13 grams each were used, as it was found that small specimens succumbed to a much greater dilution of the poisons. These were usually held in the laboratory for a few days before testing as the heaviest mortality in confinement generally occurred within two or three days after capture. Specimens in captivity for a month or more without food exhibited just as much resistance to poisons as when freshly caught. Tests were made in 5-gallon stone jars, generally with only one specimen to the jar, although recently tests have been made with as many as five to the jar. Treatments were generally replicated from four to ten times and repeated whenever any uncertainty as to results existed. Many cases of survival from lethal dosages could be explained only on the basis of individual resistance. To facilitate the computation of the minimum lethal dosages, each jar was filled with 1000 c.c. of water, which, incidentally, was estimated as about the average amount of water in each burrow, based on many excavations. Preliminary tests were conducted with tap water at temperatures varying from about 70° to 78° F. The more effective materials were given further
tests at the lower temperatures occurring within the burrows. All materials showing promise in the laboratory were given extensive tests in the field, measured amounts being applied to selected burrows which were marked and later excavated.

The importance of these field tests was demonstrated when one of the most toxic materials in the laboratory failed to give control in the field. In addition, large scale demonstrations covering many acres were made of the more important materials in order that there might be no question as to the effectiveness and practicability of the treatment.

**Effective materials.** The materials listed below were found effective at the concentrations indicated:

<table>
<thead>
<tr>
<th>Materials</th>
<th>Dilution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrethrum (liquid-23% extractives)</td>
<td>1-—250,000</td>
</tr>
<tr>
<td>Pyrethrum (powder-0.9% Pyrethrins)</td>
<td>1-—125,000</td>
</tr>
<tr>
<td>Commercial creosote stock dips</td>
<td>1—12,500 to 50,000</td>
</tr>
<tr>
<td>Coal Tar Creosote</td>
<td>1—30,000</td>
</tr>
<tr>
<td>Orthodichlorobenzene</td>
<td>1—12,500</td>
</tr>
<tr>
<td>Sodium cyanide</td>
<td>1—12,500</td>
</tr>
<tr>
<td>Turpentine</td>
<td>1—10,000</td>
</tr>
<tr>
<td>Ortho cresol</td>
<td>1—10,000</td>
</tr>
<tr>
<td>Cresylic acid</td>
<td>1—10,000</td>
</tr>
<tr>
<td>Miscible mine oil</td>
<td>1—5,000</td>
</tr>
<tr>
<td>Nicotine (free - 40%)</td>
<td>1—5,000</td>
</tr>
<tr>
<td>Nicotine sulphate (20%)</td>
<td>1—5,000</td>
</tr>
<tr>
<td>Carbon bisulphide</td>
<td>1—3,000</td>
</tr>
<tr>
<td>Thiodyphenylamine (ph nothiazine)</td>
<td>1—2,000</td>
</tr>
<tr>
<td>Calcium cyanamid</td>
<td>1—2,000</td>
</tr>
</tbody>
</table>

A brief explanation about some of the more important materials may be of interest:
Pyrethrum was very toxic in all laboratory tests, apparently causing a violent nervous shock which was usually indicated by the snapping off of the walking legs. It was a surprising disappointment to find that it did not give satisfactory control in the field, about 50% kill resulting usually. As the laboratory tests had been made with tap water it was decided that the failure might be due to the lower temperature in the burrows. Accordingly, a comparison of a lethal dosage on one series in tap water at 78° F. and another series in water maintained at 55° F. gave almost 100% mortality in the tap water within four hours, at which time all those in the cold water were still alive. The lower temperature in the burrows apparently enabled the crawfish to resist the effects of the pyrethrum until it was dissipated in the soil.

Commercial creosote stock dips varied in toxicity according to the brands tested. They also vary greatly in price but the price is no index to the toxicity. These dips are miscible in water and are ready to use without further treatment except dilution.

Coal tar creosote was used in the form of an emulsion consisting of equal parts creosote, potash fish oil soap (40%), and water, which was diluted 100 times for field use. Coal tar creosote varies so in its composition it was doubtful whether
it should be recommended. However, samples from several sources, including creosote oil, gave practically the same results. This emulsion is disagreeable to handle and requires constant agitation after dilution.

Turpentine was used as an emulsion made by heating together 18 parts of turpentine and one part of a 10% laundry soap solution, using a brush for mixing. This formed a stiff emulsion but was not always easy to make. For general use an emulsion of 9 parts turpentine and one part of 10% laundry soap solution (hot) was more desirable as it emulsified readily, although it soon broke down. Vigorous shaking or stirring would again form the emulsion. For field applications this was diluted 50 times.

Orthodichlorobenzene was one of the first materials found effective. It was emulsified by mixing 1 part of a 12½% potash fish oil soap solution with 19 parts orthodichlorobenzene and stirring vigorously for several minutes with a brush. Emulsification was almost instantaneous when it did occur, a thick white emulsion resulting which would remain stable for several months usually. This was very effective in field tests when diluted 50 times.

Sodium cyanide was used at the rate of one ounce per gallon of water and this solution applied to the burrows at 30 to 50 c.c. each. This method is much more effective than the cyanide pellets but on account of the danger in handling it with
ignorant, unskilled laborers this material is not recommended in any form.

**Ineffective materials.** This list includes only materials tested by the writer and found ineffective. It does not include materials previously tested by others and found valueless.

- Calcium chloride
- Picric acid
- Calcium oxide
- Potassium sulfo-carbonate
- Calcium cyanide
- Potassium chlorate
- Copper oxychloride
- Pyridine
- Derris
- Resorcinol
- Lubricating oil emulsion
- Rotenone (pure)
- Mustard
- Sodium arsenite
- Paris green
- Thallium sulphate

Some of the materials in this list might be toxic to crawfish at concentrations which would be impracticable because of the cost. For example, Fisher (1911) reported that 1 pound of calcium chloride in 3 gallons of water was effective, but in this test it was considered ineffective because it had no effect on the specimens at any dilution and cost comparable with other materials. However, the rotenone-containing materials, picric acid, and the arsenicals apparently were ineffective at any concentration. Soaked cotton seed, rolled in Paris green, were consumed without any noticeable effect. Calcium cyanide had been recommended by Metcalf and Flint (1909) but tests of this material both as a powder and in aqueous solution gave very unsatisfactory results. Green
mustard was fed in quantities as rumors were abroad that it was poisonous to crawfish and had been used as a trap crop to rid gardens of them. They consumed it ravenously with no harmful effect.

Methods of application.

The application of all treatments to the burrows in liquid form was found most practical. The equipment used depended upon the size of the area to be treated. In small yards or very small gardens, the solutions could be poured down the burrows with a dipper or a watering pot with the cap removed. For somewhat larger areas, even several acres, a compressed air spray pump of three or four gallons capacity, such as is ordinarily used in gardens, with a solid stream nozzle on the curved end of a 3-foot extension rod, was found most practical. On large plantations the most satisfactory machine was a double-acting force pump mounted on a wagon, from which three leads of 50-foot hose on swinging booms were operated. (figures 6 and 7). Four men or boys are required to operate this outfit which will treat from three to seven acres per day, depending upon the degree of the infestation. The spray rods are made of five-sixteenths inch iron pipe, fitted with a hand shut-off valve at the base. The rods in the illustration are not equipped with nozzles but would give more economical operation
Figure 6. Poisoning *C. hugenianus evansi* on a large plantation in Monroe County, Mississippi.
The piece of machinery on the platform in the middle of the wagon is an agitator, which is unnecessary with some of the more readily miscible materials.
if they used the inexpensive solid-stream nozzles advised for the compressed air pumps, as some spray is lost from the open ends of the pipes. About 40 pounds pressure is maintained, which is sufficient to prevent the rods from clogging with the heavy clay as the tips are pushed through the soil to burrows that are sealed over.

Recommendations.

For small gardens and yards it will be easiest to buy a bottle of one of the commercial creosote stock dips such as Parke-Davis Kreso Dip No. 1 or Kyso Disinfectant. A quart will make 25 to 30 gallons of solution which should be applied at the rate of 1 to 2 ounces per burrow when the water is within a few inches of the surface of the ground. After heavy rains at any time during the late winter or early spring, conditions will usually be satisfactory for applying the poison. If the water in the burrow cannot be seen from the surface a heavier dosage is advisable. If these stock dips are not available locally or one prefers to go to a little trouble to make a cheaper solution, one-fourth pound of laundry soap may be dissolved in a quart of hot water and mixed at once with 2 quarts of turpentine. This stock emulsion should be diluted with 50 parts of water and used immediately
as it has a tendency to break up in a short time. It is applied at the same rate per burrow as the stock dips. Although the creosote emulsion is more toxic than the turpentine, it is more disagreeable to make and the materials are not usually available in rural sections of Mississippi, hence it is not recommended for application on a small scale. As previously indicated, a watering pot or compressed air sprayer will be found most practical for the small yard or garden.

For large areas at least four materials are available at costs which make them very practical and economical, namely, turpentine, coal tar creosote, orthodichlorobenzene, and the commercial creosote stock dips. The approximate cost of these materials in large quantities at the shipping points on the basis of 100 gallons of diluted solution is as follows:

- Turpentine............$0.52
- Orthodichlorobenzene... .80
- Coal tar creosote...... .40
- Creosote stock dips... .28 to .60

The most economical stock dip tested was sold by Thompson-Hayward Chemical Company of New Orleans and known as "Creosote Dip Coefficient No. 3". On large-scale operations the purchase of this dip in 50-gallon drums will make the cost for material very low. In testing some other materials, 31 gallons of the diluted solution effectively treated 4,688 burrows, or
approximately 150 burrows per gallon. For field use with the equipment shown in figures 6 and 7, this stock dip should be diluted 150 times and applied more liberally than in the example just given, or from 2 to 3 ounces per burrow. Even treating only 50 burrows per gallon, the cost of material for an acre with 10,000 burrows would be only 56 cents. The home-made coal tar creosote emulsion, turpentine, and orthodichlorobenzene are not likely to be used as long as the stock dips are near their present prices.

The double-acting force pump and attachments will cost about $50.00 and will last almost indefinitely except for replacement of the hose occasionally. The labor cost need not be counted in most cases as it should be a satisfactory arrangement for the tenant to provide the labor where the landlord furnishes the materials, equipment and team, since both will profit from the eradication of the pests. On plantations where labor is hired by the month or year, crawfish eradication can be conducted without any additional expense for labor in most cases, taking advantage of any occasions during the late winter or early spring months when the land is too wet for the plow or when other tasks are not pressing.

Mr. J. E. Evans of Suldon, Mississippi, who had a badly-infested farm, has cooperated with the writer throughout these
investigations. He rigged up the spray equipment illustrated and also initiated the use of the coal tar creosote emulsion. He has treated several hundred acres, using some of the effective materials with very successful results. Some of his land which was so badly infested two or three years ago he would not have dared plant it in cotton, produced 1½ bales of cotton per acre in 1936. Mr. Evens estimates that five successive annual applications will be required to eradicate crawfish on any extensive area, but this long period is due to his use of small negro boys for this work who are probably not as careful about locating all of the burrows as older operators.

The small farmer with 15 to 25 acres of infested fields probably will find it most economical to make his applications with compressed air sprayers unless he can rent one of the larger pumps. The stock dip may be bought in half barrels or smaller quantities, although he may find it more economical to prepare the turpentine emulsion, depending upon local prices for this material. On such a farm the writer saw a perfect stand of cotton in 1935 on the area treated with turpentine while an untreated adjacent field was a total loss.

Because of the difficulty in locating all of the burrows in meadow or pasture lands, eradication is much more economical in cultivated fields. Therefore, when meadows and pastures
are changed to cultivated crops they should be broken deeply in the fall and the surface disked smooth so that burrows may be easily found and poisoned before the crop is planted.

The control measures recommended herein have been found very effective and inexpensive. They have been tested on a large scale and their practical application demonstrated. Their general use through the Northeast prairie section of Mississippi and similar lands in Alabama should result in a greater and much more profitable production of staple crops over this area. The chief obstacle to their general adoption is that much of the land belongs to the Federal Land Bank, insurance companies and other absentee owners. However, these absentee owners may realize eventually that the only way to restore profitable production on these farms and create a demand for them is to eradicate the crawfish from them.
LITERATURE CITED

Andrews, E. A.
1907. The young of the crayfishes Astacus and Cambarus. Smithsonian Contributions, 35, No. 1718:1-79.

Bailey, Vernon.

Cope, F. D., and Packard, A. S., Jr.

Cottam, Clarence.

Creaser, E. P.


and Ortenburger, A. I.
-137-

Dearborn, Ked.

Dimich, R. E., and Note, Don C.

Engle, E. T.

Faxon, Walter.


Fisher, A. K.

Fowler, H. W.

Girard, Charles.

Hagen, H. A.

Hay, W. P.


Hegner, R. W.

Howell, A. H.

Huxley, T. H.

Kellogg, Remington.
LeConte, J. L.

Lobdell, R. N.

McAtee, W. L.


McIlhenny, E. A.

Mabbott, D. C.

Meek, S. E.

Metcalf, C. L. and Flint, W. P.

Newcombe, C. L.

Ortmann, A. E.

Ortmann, A. E.


Turner, C. L.
ACKNOWLEDGEMENTS

The writer is deeply appreciative of the assistance received on this problem. Several inspectors of the State Plant Board of Mississippi, various college and high school biology teachers, employees of the Works Progress Administration, and others made helpful collections. Thanks are due Dr. Thomas Barbour, Director of the Harvard Museum, and Dr. Waldo Schmitt of the United States National Museum for courtesies extended while studying the collections in those institutions. The writer is also grateful to Dr. Halbert M. Harris for many helpful suggestions.
Plate I

1. First abdominal leg, *C. hagenianus* and its subspecies, side view.

2. C. *blandingii acutus*, side view.

3. C. *baxy*, side view.

4. C. *clarkii*, side view.

5. C. *cookae*, side view.

6. C. *evictus*, side view.

7. C. *versutus*, side view.

8. C. *harnedi*, side view.


11. C. *diogenes*, *C. diogenes ludovicianus*, *C. iatimanus*, *C. arrilliccola*, and *C. lobdelli*, side view.

PLATE I

Male sex organs of Mississippi crawfishes
Plate II

1. Annulus ventralis of *C. bagoniatus* and its subspecies.
2. *C. blandingii acutus*.
3. *C. havi*.
4. *C. clarkii*.
5. *C. cookae*.
6. *C. evictus*.
7. *C. versutus*.
8. *C. hornedi*.
9. *C. shufeldtii*.
10. *C. mississippiensis*.
11. *C. diorensis*.
12. *C. diorensis ludovicianus*.
13. *C. latimans*.
14. *C. arillicola*.
15. *C. lobdelli*.
16. *C. clyreatus*. 
Female sex organs of Mississippi crawfishes
<table>
<thead>
<tr>
<th>Plate III</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rostrum of <em>C. hagenianus</em> and its subspecies.</td>
</tr>
<tr>
<td>2. <em>blandingii acutus</em>.</td>
</tr>
<tr>
<td>3. <em>havi</em>.</td>
</tr>
<tr>
<td>4. <em>clarkii</em>.</td>
</tr>
<tr>
<td>5. <em>cookae</em>.</td>
</tr>
<tr>
<td>6. <em>evictus</em>.</td>
</tr>
<tr>
<td>7. <em>versutus</em>.</td>
</tr>
<tr>
<td>8. <em>harnedii</em>.</td>
</tr>
<tr>
<td>9. <em>shufeldtii</em>.</td>
</tr>
<tr>
<td>10. <em>mississippiensis</em>.</td>
</tr>
<tr>
<td>11. <em>cresseri</em>.</td>
</tr>
<tr>
<td>12. <em>diogenes</em>.</td>
</tr>
<tr>
<td>13. <em>diogenes ludovicianus</em>.</td>
</tr>
<tr>
<td>14. <em>latinanus</em>.</td>
</tr>
<tr>
<td>15. <em>argillicola</em>.</td>
</tr>
<tr>
<td>16. <em>lobdelli</em>.</td>
</tr>
<tr>
<td>17. <em>clypeatus</em>.</td>
</tr>
</tbody>
</table>
PLATE III

Rostrums of Mississippi crawfishes
Plate IV

1. Antennal scale of C. hagenianus.
2. C. hagenianus evansi.
3. C. hagenianus carri.
4. C. hagenianus forestae.
5. C. blandinii acutus.
6. C. clarkii.
7. C. cockae.
8. C. evictus.
9. C. versutus.
10. C. barnedi.
11. C. shufeldtii.
12. C. mississippiensis.
13. C. creaseri.
14. C. dorenes.
15. C. dioeces ludovicianus.
16. C. latinanus.
17. C. argillicola.
18. C. lobdelli.
19. C. clypeatus.
Antennal scales of Mississippi crawfishes