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CONTENTS OF VOLUME 3

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NOTROPIS ASPERIFRONS, A NEW CYPRINID FISH FROM THE MOBILE BAY DRAINAGE OF ALABAMA AND GEORGIA, WITH STUDIES OF RELATED SPECIES

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Nine small species of *Notropis* which possess 2, 4—4, 2 teeth, 7 or 8 anal rays, a dark lateral band on the side of the body (*hypsilepis* excepted) and, for most, a prominent basicaudal spot, are found in the eastern Gulf of Mexico drainages from the Apalachicola Bay drainage of Florida and Georgia to the Mobile Bay drainage of Alabama and Mississippi. Although most are common forms and some are used as bait fishes, their systematic status has been confused. Characters which differentiate the lowland forms, *N. roseus* and *N. petersoni,* and *N. chalybaeus,* and a definition of *N. xaenocephalus,* have recently been given by Bailey, Winn and Smith (1954). Two other forms, *N. baileyi* and *N. hypsilepis,* have been described and their relationships with *N. lutipinnis* and *N. chrosomus* elucidated by Suttkus and Raney (1955 a and b). This study describes a new species, gives comparative data for *Notropis xaenocephalus, roseus, petersoni,* and to a lesser extent for *chalybaeus,* and offers a key for the identification of the forms mentioned above.

Robert H. Gibbs and Philip P. Caswell, Cornell students, collected many of the types and comparative material housed in the Cornell University fish collection. Many of the specimens from the Black Warrior River system were obtained through Ralph L. Chermock, University of Alabama, and were collected by Bancroft Cooper, Herbert D. Gibson, G. Hollis, T. Taylor, and Barry D. Valentine. Charles D. Hancock assisted the senior author in obtaining the specimens collected in Wilcox County, Alabama, now housed at Tulane University. Helen J. Illick has made available the counts for the cephalic lateral line pores from her unpublished studies. Ernest A. Lachner of the U. S. National Museum, assisted us during our examination of type specimens and critically reviewed the manuscript, as did Reeve M. Bailey and Carl L. Hubbs. We are deeply indebted to all of the above for their assistance. Counts and measurements were taken as detailed in Hubbs and Lagler (1947: 8-15).

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NOTROPIS **ASPERIFRONS,** sp. nov.

Figs. 1 and 2, Map 1

Notropis xaenocephalus.—Gilbert, 1891: 154 and 157 (a complex of *N. roseus,* North R., Tuscaloosa, Ala. and *N. asperifrons,* Mulberry Fork, Blount Springs and Eight Mile Cr., Cullman, Ala.).

The type material consists of 91 specimens, 28 to 60 mm in standard length, which were seined from 12 localities in the Alabama River system. Additional material examined includes 69 specimens, 22-55 mm in standard length, taken from nine localities in the Black Warrior River system. Below, in parentheses, are indicated the numbers of specimens followed by the range of standard lengths in millimeters. In addition to standard abbreviations for states and compass directions, with the following "of" deleted, these abbreviations are used: Co. = County, Cr. = Creek, Hwy. = Highway, mi. = mile or miles, R. = River, trib. = tributary (of), coll. = collected, CU. = Cornell University fish collection, TU = Tulane University fish collection, USNM = United States National Museum.

Material.—Holotype, CU 28262, an adult female 50 mm in standard length, captured in the Alabama R. system in Holly Cr. at Ramhurst, 8 mi. N. Murray Co. line on U. S. Hwy. 411, Murray Co., Georgia, on June 12, 1952, by Robert H. Gibbs and Philip P. Caswell. Seven paratypes, CU 28263 (35-52), bear the same data as the holotype.

Other paratypes, listed below, are from the Mobile Bay drainage. Alabama: CU 28261 (1, 40), trib. Terrapin Cr., approximately 4 mi. N.E. Piedmont on Ala. Hwy. 74 at the Cherokee-Calhoun county line, June 14, 1952; CU 28260 (3, 38-58), Cheaha Cr., trib. Choocolocco R., 3.3 mi. S.W. Munford on U. S. Hwy. 21, Talladega Co., June 14, 1952; TU 4251 (28, 31-42), trib. Waxahatchee Cr., a trib. Coosa R., 4.7 mi. S.W. Columbiana on Ala. Hwy. 25, Shelby Co., June 15, 1952, and Wilcox Co., June 3, 1951: TU 3426 (8, 30-35), Pursley Cr., trib. Alabama R., 3.4 mi. S.W. Camden on Ala. Hwy. 11; TU 2974 (22, 28-36), Gravel Cr., trib. Pursley Cr., 6.3 mi. S. Camden on Hwy. 11; TU 3063 (5, 37-41), trib. Pursley Cr., 1.8 mi. E. Camden on Ala. Hwy. 10; UMMZ 111122 (2, 37-39), between Waverly and Opelika or between Waverly and Lafayette, September 13, 1930; UMMZ 111125 (7, 25-51), Sougahatchee Cr. (Loachapoka Cr.), October 24, 1930; UMMZ 162594 (2, 49-60), Sougahatchee Cr., 4 mi. N. Auburn, Lee Co., October 9, 1940. Georgia: USNM 164968 (1, 45.5) and 164969 (1, 47.9), Etowah R. (probably trib.), Rome by D. S. Jordan; UMMZ 139104 (3, 44-51), trib. Conasauga R., 7.3 mi. S. Dalton, U. S. Hwy. 41, Whitfield Co., August 7, 1936.

Other material examined from the Black Warrior River system, Tuscaloosa Co., Alabama is as follows: CU 19268 (2, 42-44), lower Cottondale Cr. near Hurricane Cr., approximately 2 mi. N. Cottondale, October 9, 1950; CU 28259 (10, 25-43), trib. North R., 1 mi. S.E. Sterling and 5 mi. S.E. New Lexington, June 23, 1951; CU 28258 (9, 30-41), Puro Cr., trib. North R., 4 mi. E. New Lexington, June

23, 1951; CU 28257 (6, 35-44), Blue Cr., trib. Black Warrior R., 25 mi. N.E. Tuscaloosa on Ala. Hwy. 63, March 3, 1951 and from the same locality, CU 28256 (16, 22-44), March 9, 1951; USNM 43474 (8, 33-42), Mulberry R., Blount Springs, coll. by P. H. Kirsch in 1889; USNM 36672 (11, 32-38), Eight Mile Cr., Cullman, coll. by Gilbert and Swain in 1884; UMMZ 88852 (6, 42-55), Blount Springs Cr., Blount Co., September 19, 1929; UMMZ 158285 (1, 39), trib. Locust Fork (flowing W.), 3 mi. N.N.E. Oneonta, Hwy. 32, Blount Co., September 5, 1939.

Diagnosis.—A small species of *Notropis* with 2, 4—4, 2 teeth and 7 anal rays as the typical counts. Other fin rays are: dorsal 8, pectoral 13 or 14, occasionally 12; pelvic 8, occasionally 9; caudal 19. Lateral line on body complete. Anterior lateral line scales, especially the second and third, elevated. Scale counts (typical): predorsal rows 14 or 15; above lateral line to dorsal origin 5; below lateral line to anal origin 3 or 4; in lateral line 36, occasionally 37; around body before dorsal fin 19 to 21; around caudal peduncle 12. Body elongate, wide and slightly compressed. Dorsal and ventral body contours only slightly elevated; caudal peduncle elongate. Head subtriangular as viewed from above and laterally; snout blunt. Mouth inferior. Jaw moderately inclined, rising anteriorly to the lower level of pupil. Dorsal origin slightly behind pelvic origin. Strong but narrow dark lateral band, not reduced on snout; dark chevrons present above and below the anterior lateral line pores. Prominent basicaudal spot continuous with and wider than lateral band on caudal peduncle. Temporal canal outlined by dark line. Mid-dorsal streak before dorsal fin obsolescent; streak behind dorsal lacking or developed only under the posterior base of the dorsal fin. Fins all relatively small. Size small, to 60 mm standard length. Allied to *Notropis xaenocephalus, hypsilepis, roseus* and *petersoni. Notropis asperifrons* is the undescribed form alluded to in the paper by Suttkus and Raney (1955b), under *Relationships.*

Description

Some fin and scale counts are included in Table 1 and measurements are given in Table 2. The count of the holotype is the modal count for a given character unless italicized in Table 1 or in the Diagnosis. Many characters are also indicated in Figures 1 and 2. Other descriptive data follow. The body is more elongate than in related species; it is relatively wide and rather sharply compressed. The dorsum is only slightly elevated; the contour is an almost straight line both before and behind the dorsal origin. The ventral contour is only slightly less elevated. The caudal peduncle is long and relatively thin.

The anterior lateral line scales, especially scales two and three, are somewhat more elevated than the others in the lateral line or elsewhere. In this character it is more extreme than *hypsilepis.*

When viewed laterally the head is a rather sharp triangle although the tip of the snout is bluntly rounded. The mouth is inferior; the

TABLE 1.

SCALE AND FIN RAY COUNTS IN FIVE SPECIES OF *Notropis*. THE COUNT FOR THE HOLOTYPE OF *N. asperifrons* IS THE MODAL COUNT EXCEPT FOR THOSE IN ITALICS.

Species	Anal Rays		Pectoral Rays					Predorsal Scale Rows				
	7	8	12	13	14	15	16	13	14	15	16	17
hypsilepis	47	—	—	3	12	6	1	—	—	8	2	1
asperifrons	38	2	*2*	*8*	10	—	—	1	4	5	—	—
xaenocephalus	148	9	—	—	10	10	—	—	2	7	1	—
roseus	25	1	2	3	11	2	2	—	2	6	2	—
petersoni	191	7	—	15	5	—	—	—	1	5	2	2

Species	Lateral Line Scales					Total Circumferential Scales											
	34	35	36	37	38	19	20	21	22	23	24	25	26	27	28	29	30	31
hypsilepis	—	10	9	—	—	—	—	1	7	5	3	2	1	—	—	—	—	—
asperifrons	—	—	8	2	—	3	4	*3*	—	—	—	—	—	—	—	—	—	—
xaenocephalus	1	1	23	4	—	—	—	1	15	11	4	—	1	—	—	—	—	—
roseus	—	1	6	1	1	—	—	—	—	1	7	7	11	2	—	—	—	1
petersoni	3	7	—	—	—	—	—	—	—	—	3	1	6	—	—	—	—	—

Species	Circumferential Scales														
	Above Lateral Line								Below Lateral Line						
	8	9	10	11	12	13	14	15	8	9	10	11	12	13	14
hypsilepis	—	—	1	16	2	—	—	—	—	8	5	4	2	—	—
asperifrons	1	6	2	1	—	—	—	—	4	5	*1*	—	—	—	—
xaenocephalus	—	—	1	26	3	1	—	—	1	26	8	6	—	—	—
roseus	—	—	—	13	4	11	—	1	—	—	1	18	9	—	1
petersoni	—	—	—	3	3	3	1	—	—	1	1	5	1	1	—

tip of the snout overhangs the upper lip and the lower lip is included within the upper lip. The mouth is moderately oblique; the gape rises anteriorly to the lower level of the pupil. The posterior tip of the lower jaw just reaches a vertical line projected from the front of the eye. The length of the eye is slightly less than the snout.

All fins are relatively short (Table 2). In the erect position, the posterior border of the dorsal and anal fins is almost straight; when depressed the tip of the first ray greatly exceeds that of the last ray in both.

The pharyngeal arch is moderately developed and is less strong than in *xaenocephalus*. The shelf bearing the lesser row is narrow. The uppermost three teeth in the main row are compressed, pointed and hooked at the tip; the fourth is a cone only slightly curved at the tip. The grinding surface has crenulate edges and is long and well developed on the upper two teeth, is only about half as long in the third, and is practically missing in the lowermost. The two teeth in the lesser row are about half as long as the longest in the major row; each has a well developed grinding surface and a small hook at the tip. The teeth are somewhat more hooked than in *xaenocephalus*.

The tooth count in the holotype of *asperifrons* is 2, 4—4, 2 but apparently this character is subject to considerable variation. In paratypes from the type locality the counts are 2, 4—4, 2 (2); 2, 4—4, 1 (1); 1, 4—4, 2 (1); and 1, 4—4, 1 (3). In another series from the Alabama R. system the count is 2, 4—4, 2 (3). In the Black Warrior R. system variability was noted also although 2, 4—4, 2 was counted in nine out of 16 fish; other counts were 2, 4—4, 1 (2); 1, 4—4, 2 (2); 1, 4—4, 1 (1); 1, 3—4, 1 (1); and 2, 4—3, 1 (1). The reduction in number noted above in the main row is unusual. When reduction occurred in the lesser row no indication of a basal tubercle or socket was discernable and the shelf of the pharyngeal arch often did not seem wide enough to hold another tooth. A summary of the 27 tooth counts follows: 2, 4—4, 2 (15); 2, 4—4, 1 (3); 1, 4—4, 2 (3); 1, 4—4, 1 (4); 2, 4—3, 2 (1); and 1, 3—4, 1 (1).

In five small series of *xaenocephalus* the teeth were 2, 4—4, 2 (16); 1, 4—4, 2 (2); and 1, 4—4, 1 (2). A count of 2, 4—4, 2 was found in *roseus* (4) and in *petersoni* (6).

On the first arch the gill rakers are all small and, including rudiments, number 11 or 12. The vertebrae usually number 36 or 37 (Table 3).

The nape is fully scaled as is the breast as far forward as a line joining the posterior limit of the pectoral fin bases.

The cephalic lateral line canals and pores of five species (*asperifrons, xaenocephalus, roseus, petersoni* and *chalybaeus*) have been compared. The number of specimens counted is given in parentheses. The anteriormost pore is designated number one. The pore counts

TABLE 2.

MEASUREMENTS OF *Notropis* IN THOUSANDTHS OF STANDARD LENGTH. FOR EACH CHARACTER IS GIVEN THE RANGE OF VARIATION AND BELOW (IN PARENTHESES) THE MEAN. THE MEAN VALUES FOR *asperifrons* INCLUDE THE HOLOTYPE.

Species	*asperifrons*		*xaeno-cephalus*	*roseus*	*petersoni*
River System	Alabama		Alabama	Alabama, Black Warrior, Perdido	Ogeechee, Apalachicola
No. and sex of spec.	Holotype ♀	Paratype 6 ♀, 3 ♂	5 ♀, 5 ♂	5 ♀, 5 ♂	5 ♀, 5 ♂
Standard length	51.6	35-58	45-55	38-51	41-54
Dorsal origin to snout tip	504	494-528 (506)	490-513 (502)	492-509 (498)	493-525 (507)
Dorsal origin to caudal base	524	491-542 (521)	523-539 (531)	514-540 (529)	496-530 (519)
Dorsal origin to occiput	312	289-320 (305)	288-313 (300)	284-315 (302)	290-314 (303)
Pelvic insertion to snout tip	492	475-506 (483)	472-494 (487)	472-499 (489)	480-512 (492)
Anal origin to caudal base	330	322-351 (335)	327-348 (337)	328-368 (345)	317-349 (333)
Body depth	184	175-197 (187)	199-227 (209)	201-233 (220)	184-234 (211)
Body width	136	125-145 (136)	121-143 (129)	109-146 (127)	115-146 (127)
Dorsal origin to lateral line	113	113-127 (120)	126-143 (129)	125-153 (137)	111-157 (134)
Pelvic insertion to lateral line	079	072-088 (080)	070-090 (081)	081-110 (094)	083-120 (096)
Caudal peduncle length	233	227-257 (242)	206-232 (219)	208-233 (221)	222-259 (233)
Caudal peduncle depth	082	080-091 (086)	088-101 (093)	092-102 (097)	084-097 (092)
Head length	252	236-254 (245)	238-259 (248)	220-259 (247)	229-268 (256)
Head depth	139	136-188 (150)	151-164 (155)	149-165 (157)	150-166 (158)
Head width	126	116-132 (124)	122-136 (128)	122-135 (129)	121-136 (131)
Interorbital, least fleshy	082	079-085 (081)	077-090 (083)	080-092 (086)	081-090 (088)
Snout length	078	073-083 (078)	068-083 (075)	068-084 (074)	077-086 (082)
Eye length	074	069-077 (072)	073-085 (078)	068-084 (076)	076-086 (081)
Upper jaw length	074	059-074 (067)	073-085 (078)	063-077 (069)	072-084 (077)
Suborbital least width	025	016-027 (023)	017-025 (021)	021-028 (025)	024-032 (029)
Dorsal fin, depressed length	210	198-223 (210)	223-256 (235)	226-273 (243)	231-258 (249)
Anal fin, depressed length	143	140-151 (146)	177-192 (185)	162-197 (184)	173-215 (189)
Caudal fin length from base to tip of longest ray	235	213-245 (236)	238-275 (258)	262-277 (269)	272-303 (284)
Pectoral fin length	178	161-185 (172)	186-233 (207)	171-200 (188)	177-220 (201)
Pelvic fin length	153	139-153 (146)	142-178 (161)	159-186 (170)	155-185 (170)

are summarized in Table 4 and are not repeated in the description below.

The supratemporal canal is always incomplete in the five species. *N. asperifrons* has two pores on each side (5). *N. roseus* has two pores on each side (3), or one pore on each side plus a short branch from the junction with the infraorbital with a pore (1), or a canal with two pores located more dorsally on each side (1). *N. xaenocephalus* has two pores on each side (6), or two pores on the left and one on the right (1). *N. petersoni* has on the average fewer pores, with one pore on each side (3), or two pores on one side and one on the other (2), or one pore on both sides and a short canal of two pores on the left side (1), or two pores on each side (1). *N. chalybaeus* has a higher average pore count and exhibits greater variation than the other species.

The supraorbital canal is complete in *asperifrons, roseus, xaenocephalus,* and *petersoni,* and incomplete in *chalybaeus.* In *asperifrons* a vertical projected dorsally from the posterior margin of the eye falls between pores six and seven in those with a count of eight and between seven and eight when the count is nine. *N. roseus* is essentially the same. In *xaenocephalus* a vertical projected from the posterior margin of the eye falls between pores six and seven (1) or on pore seven (6). In *petersoni* a projected vertical falls on the next to the last pore (6) and between pores six and seven (1). In *chalybaeus* the canal is complete with a count of eight (4) and incomplete with a count of nine (2); breaks occur between pores two and three and between five and six. The supraorbital canal ends above the posterior margin of the eye or at a point just posterior of this point; a projected vertical falls between the last two pores.

The infraorbital canal of *asperifrons* is complete in specimens with a pore count of thirteen (2) and fourteen (2); in the specimen with the incomplete canal the pore count is fourteen with a break between pores twelve and thirteen. A vertical projected from the anterior margin of the eye falls between pores four and five (4), and between three and four (1). In *N. roseus* this canal is complete in three specimens which have a pore count of thirteen, fourteen and fifteen. One of the specimens with an incomplete infraorbital canal has a pore count of twelve, with a break between pores three and four, and the other canal has fifteen pores with a break between pores twelve and thirteen. A vertical projected from the anterior margin of the eye falls between pores four and five. In *xaenocephalus* the canal is always complete. A vertical from the anterior margin of the eye falls between pores four and five. In *petersoni* the canal is complete in six of the seven specimens studied and the pore count is lower than in the four other species compared here. The incomplete canal has a pore count of twelve with a break between pores ten and eleven; a vertical from the anterior margin of the eye falls between pores three and five. In *chalybaeus* the canal is incomplete in all; a break occurs between pores ten to thirteen.

TABLE 3.

VERTEBRAL COUNTS IN FOUR SPECIES OF *Notropis*

	Number of Vertebrae											
	Trunk				Caudal			Total				
	17	18	19	20	17	18	19	34	35	36	37	38
asperifrons	—	7	19	2	9	18	1	—	—	15	11	2
xaenocephalus	—	11	41	1	4	41	8	—	—	8	44	1
roseus	—	6	21	—	11	15	1	—	1	15	10	1
petersoni	1	12	6	—	11	7	1	1	5	11	2	—

A vertical from the anterior margin of the eye falls between pores three to five (5) or on pore six (1). Contrasting with *N. chalybaeus, xaenocephalus* has the canal complete (7), and *petersoni* (6 out of 7) and *asperifrons* (4 out of 5) have the canal normally complete. In *roseus, xaenocephalus* and *petersoni* the infraorbital ducts are usually two or three-pointed ventrally; *roseus* also may have two or more ducts between pores two and five. In these three species, pores one through four or five are larger than those more posterior on the infraorbital canal. In *chalybaeus,* the pores, except for one and two, are small. The pore ducts of *chalybaeus* are short and usually only infraorbital duct number two points ventrally, whereas ducts number two and three do so in the other species being compared.

The preoperculomandibular canal is complete in all of the species except *chalybaeus,* in which it may be complete (3) or incomplete (3), with a break between pores five and six. It also has a high average pore count. In all five species under consideration, a vertical projected from the rictus almost always falls between pores three and four.

A close comparison reveals numerous consistent pigmentary characters which permit separation of the five related species, mentioned above, with 2, 4—4, 2 teeth and 7 or 8 anal rays. These differences are brought out in the following comparisons. The species, none of which have been adequately described in the literature, are treated in the following order: (1) *asperifrons,* (2) *xaenocephalus,* (3) *roseus,* (4) *petersoni,* and (5) *chalybaeus.*

Dark lateral band on body.—*N. asperifrons.*—Well developed but narrower than pupil throughout; wider and more diffuse on anterior half. Dorsal aspect of the band a low arch on the anterior half, but straight on the posterior half. Ventral aspect of anterior half of the band consists of dark chevrons formed above and below each lateral line pore. Rarely do melanophores, which are found near the border of the scale, extend more than half scale depth below a lateral line pore in front. Posteriorly the ventral edge of dark band straight and entire. Lateral line dips below the band anteriorly but is included within the posterior half of the band. Paralleling the dark band above is a prominent light band, which is approximately double its width on the posterior half. *N. xaenocephalus.*—Similar to that of *asperifrons,* but aggregations of melanophores, rather than chevrons, are associated with the lateral line pores on the anterior half of the body. Below the lateral line, some scattered dark spots may occur but normally do not extend ventrally more than a distance of one scale. *N. roseus.*—More intense in front than in *asperifrons* and *xaenocephalus;* dorsal and ventral aspects almost parallel and nearly entire; as wide or wider than pupil. A blotch above and below each lateral line pore anteriorly; these become larger and more intense on posterior half of band. Scales of the lateral line row and the first row below with melanophores on the border, except in some specimens in the southern part of range, in which melanophores may be

found further ventrally. Lateral line coincides with ventral edge of the band anteriorly but is included within it posteriorly. Light band poorly developed above the dark band and crossed regularly, especially on its anterior half, by the fine dark lines that border the scales. *N. petersoni.*—Much like that of *roseus,* but more uniform throughout its length. The amount of dark pigment found below the lateral line anteriorly is geographically variable but usually limited to the border of the lateral line scale and the upper half of the scale below. Light band above weak and broken by the dark edges of the scales. *N. chalybaeus.*—Sharply delimited, as wide or slightly wider than the pupil, and uniformly dark except for the light lateral line which is included within the band for its entire length. The parallel light band above is narrow, uniform, in width and dusky, although not as dark as the dorsum.

Caudal spot and adjacent pigment.—N. asperifrons.—Continuous with but darker and wider than the dark lateral band on the caudal peduncle; subquadrate, but narrows posteriorly, and extends only a short distance beyond the flesh covered base of the caudal rays. *N. xaenocephalus.*—The subcircular spot has about the same intensity as the lateral band; it narrows posteriorly and scarcely extends beyond the flesh overlying the base of the caudal rays. *N. roseus.*—Continuous, or has only a slight constriction anteriorly; of about the same width and only slightly more intense than the band; subquadrate; continues only a short distance beyond the base of the caudal rays. *N. petersoni.*—Not continuous with band. Spot roughly V-shaped, with apex pointed anteriorly; slightly more intense but narrower than the band. *N. chalybaeus.*—Continuous with, but narrower and more intense than the band; width limited to the base of six median caudal rays and extends posteriorly about half the distance from the base of the rays to the caudal fork.

Dark band on side of head behind eye.—N. asperifrons.—A few scattered melanophores on the postorbital region, and a moderately strong band on the opercle, with a few scattered melanophores below and above. No pigment on the fleshy margin of the opercle. *N. xaenocephalus.*—Similar to that of *asperifrons,* but with more melanophores scattered over the area above the opercle. *N. roseus.*—Similar to that of *asperifrons,* but less sharply defined on the dorsal part of the opercle. *N. petersoni.*—Like that of *roseus,* but with an occasional melanophore on the fleshy margin of the opercle. *N. chalybaeus.*—An intense, continuous band extends behind the eye; reduced slightly on the posterior fleshy margin of the opercle; scattered melanophores above the band on the opercle.

Dark band on side and front of snout.—N. asperifrons.—A prominent dark band fades anterior to the nostril, interrupted by a light oval area immediately in front of eye; continues around snout tip, best developed on the lower edge and on the upper lip. A light band extends from eye to nostril. *N. xaenocephalus.*—A few superficial melanophores scattered in front of the eye; anteriorly the band rings

the snout and the upper lip. A light triangular area extends from the eye to nostril. *N. roseus.*—A band of scattered melanophores; fades somewhat at the anterior nostril but is well developed on the upper lip. Light area in front of eye has scattered melanophores. *N. petersoni.*—Like that of *roseus,* but band strongly developed in front as well as laterally. *N. chalybaeus.*—A strong band encircles the snout, lips and chin. Melanophores scattered on the preorbital area.

Lower lip, chin, inside of mouth and underside of head.—*N. asperifrons.*—Lower lip has a few melanophores; these almost absent at the symphysis. Chin and inside of mouth and underside of head light. *N. xaenocephalus.*—As in *asperifrons;* both may have a few melanophores on the oral valves. *N. roseus.*—Anterior part of lower lip and chin black. Scattered melanophores prominent on oral valves. Underside of head white. *N. petersoni.*—Lower lip dusky anteriorly; chin dusky with a medial extension of melanophores, but otherwise white below. Scattered melanophores present on oral valves and on the roof of the mouth. *N. chalybaeus.*—Lower lip black except posteriorly; chin black, darkish on inside of mouth. Scattered melanophores present on the isthmus and the gular region.

Pigmentation on temporal area of head.—*N. asperifrons.*—Temporal canal bordered on either side, but especially posteriorly, by a dark line which forms a prominent biconcave occipital bar; this continues obliquely downward as a moderately developed bar on the shoulder girdle which is not continuous to the pectoral fin base in this or in any of the three other species. *N. xaenocephalus.*—Temporal canal not outlined in black. No occipital bar. A weak oblique bar on shoulder girdle. *N. roseus.*—Temporal area with scattered melanophores. No occipital bar. A well developed, oblique, girdle bar present but mostly limited to the width of the lateral band. *N. petersoni.*—Temporal canal with a line of melanophores posteriorly forming a thin occipital bar and continued obliquely downward along the anterior lateral line to form a diffuse bar on the shoulder girdle. *N. chalybaeus.*—Temporal area darkish; an occipital bar continues downward as a short bar on the shoulder girdle.

Middorsal streak before dorsal fin.—*N. asperifrons.*—Obsolescent; a thin line developed part way in some. *N. xaenocephalus.*—Moderately developed; widest at occiput and at a point just anterior to the dorsal origin. *N. roseus.*—Prominent; about half a scale row wide and developed about equally throughout. *N. petersoni.*—Diffuse but well developed except at the occiput; not as wide as in *roseus. N. chalybaeus.*—Prominent; about 1/3 scale row wide.

Pigmentation on body at dorsal fin base.—*N. asperifrons.*—None beyond normal scale pigmentation except for a slight concentration at the base of each ray. *N. xaenocephalus.*—Expanded dark area immediately before the dorsal origin and a well-defined dark line at and between the bases of the last six dorsal rays. *N. roseus.*—A definite and diffuse widening of band before the dorsal fin; several

rows of melanophores continue posteriorly on either side of the dorsal fin base. The posterior half of the dorsal base dark. *N. petersoni.*—No, or very little, expansion of middorsal band. A small dark concentration at the base of dorsal fin rays. *N. chalybaeus.*—Only a slight concentration before the dorsal fin. Dorsal base dusky.

Middorsal streak posterior to dorsal fin base.—N. asperifrons.—Absent, or a row of melanophores extends for only a few scale rows behind the dorsal fin base. No concentration anterior to the base of the procurrent caudal rays, although the dark scale margins appear as a series of crescents when viewed from above. *N. xaenocephalus.*—A narrow stripe; consists of 2 or 3 rows of melanophores and less intense than the predorsal stripe. A slight dark concentration present at the base of the procurrent caudal rays. *N. roseus.*—A definite but narrow streak, one to three rows of melanophores wide, present; narrower than the predorsal stripe. Only a slight dark concentration at the base of the procurrent caudal rays. *N. petersoni.*—Somewhat better developed than in *roseus.* No concentration present at procurrent caudal rays. *N. chalybaeus.*—An ill-defined streak present. No concentration located posteriorly.

Coloration of dorsolateral scales.—N. asperifrons.—Anterior half light, occasionally with a few scattered melanophores; lighter than in *xaenocephalus.* Posterior edge lined by one or two rows of macromelanophores, preceded by a well defined dark crescent. Appear diamond-shaped in contrast with next species. Row of scales above dark lateral band light colored. *N. xaenocephalus.*—As in *asperifrons,* but the large dark spots on the posterior scale margin lacking; more chromatophores scattered over the anterior half of the scale, so that the clear area is less obvious than in *asperifrons.* The scale row above the dark lateral band light. *N roseus.*—As in *xaenocephalus,* but with darker dorsal scales; the row above the dark lateral band crossed by the dark scale margin but to a lesser extent posteriorly. *N. petersoni.*—As in *roseus. N. chalybaeus.*—Scales darkish with a somewhat darker border outlining the posterior margin.

Pigment on belly and area between the pelvic fin base and the urinogenital orifice.—N. asperifrons, xaenocephalus and *petersoni.*—Scattered melanophores show through body wall. *N. roseus.*—White with an occasional melanophore just anterior to the orifice. *N. chalybaeus.*—Darkish.

Pigment on body from anus to area about the anal fin base.—N. asperifrons.—Scattered melanophores just behind anus connect laterally and anteriorly with those from postpelvic region to outline the urinogenital papilla; dark continued posteriorly and darker immediately laterad and at the anal base. *N. xaenocephalus.*—A row of melanophores laterad of the urinogenital papilla; the area immediately behind the anus and in front of the anal fin light. Prominent melanophores laterad and at the anal fin base. *N. roseus.*—Melanophores laterad of the urinogenital papilla, behind the anus, and before, lateral and at the anal fin. *N. petersoni.*—As in *roseus,* but with more and

smaller melanophores. Those laterad of the anal fin base extend farther dorsad on the body. *N. chalybaeus.*—Dark except for the urinogenital papilla.

Pigment on lower median area of caudal peduncle.—N. asperifrons.—A band of two rows with an incomplete median row of melanophores arranged in three loops; the anteriormost loop lies above the last anal fin ray; the hindmost loop small and located at the base of the procurrent caudal rays. *N. xaenocephalus.*—As in asperifrons, but with the posterior loop little or not developed. *N. roseus.*—A band of three rows of melanophores present on the anterior half only. *N. petersoni.*—A band of three rows of melanophores present; often reduced to two rows on the posterior third. *N. chalybaeus.*—A prominent band of two or three rows of melanophores developed with an occasional additional stellate macromelanophore lying immediately laterad of the band.

Pigmentation of peritoneum.—Large scattered melanophores ventrally and somewhat darker dorsolaterally; *petersoni* and *chalybaeus* darker than the other three species.

Pigmentation of pectoral fin.—All five species have a row of melanophores along each of the outermost five or six rays; darkest in *chalybaeus.*

Pigmentation on pelvic fin.—N. asperifrons, xaenocephalus and *roseus.*—A few or no melanophores scattered on the outermost three rays. *N. petersoni.*—A row of widely spaced melanophores present along the rays of the outer half of the fin. *N. chalybaeus.*—A row of melanophores on either edge of the rays of the outer two-thirds of the fin.

Pigment on anal fin.—N. asperifrons.—A line of small melanophores borders the outer two-thirds of the rays. *N. xaenocephalus.*—Clear except in an occasional specimen which may have a few melanophores near the margin of the last two rays. *N. roseus.*—Anterior rays clear, posterior four rays outlined by melanophores. *N. petersoni.*—All rays uniformly margined by melanophores, except near their base. *N. chalybaeus.*—All rays uniformly margined except near the base of the anteriormost three or four rays.

Pigment on caudal rays.—N. asperifrons and *xaenocephalus.*—Fine lines of melanophores border each ray. *N. roseus* and *petersoni.*—Similar, but with central and outer rays darker than intermediate rays. *N. chalybaeus.*—As in *petersoni,* but generally darker and with an extended basicaudal spot.

Pigment on dorsal fin rays.—All five species have the rays bordered by melanophores; blacker in *roseus, petersoni,* and *chalybaeus.*

Additional items on coloration of *asperifrons* follow: Melanophores are irregularly scattered on top of the head in front of the eyes. Anterior to the nostrils the fewer melanophores give the effect of a lightish bar. Deep-seated melanophores form two lunate bars above each nostril. Between the eyes are two elongate dark blotches, which narrow gradually anteriorly; the intermediate area is clear. A promi-

nent heart-shaped mark is found on the top of the head posteriorly. Anterior to it is a light oval area which bears scattered melanophores. On the posterolateral margin of the heart-shaped mark is a relatively light area, disrupted laterally by a crescent-shaped dark bar that opens ventrally.

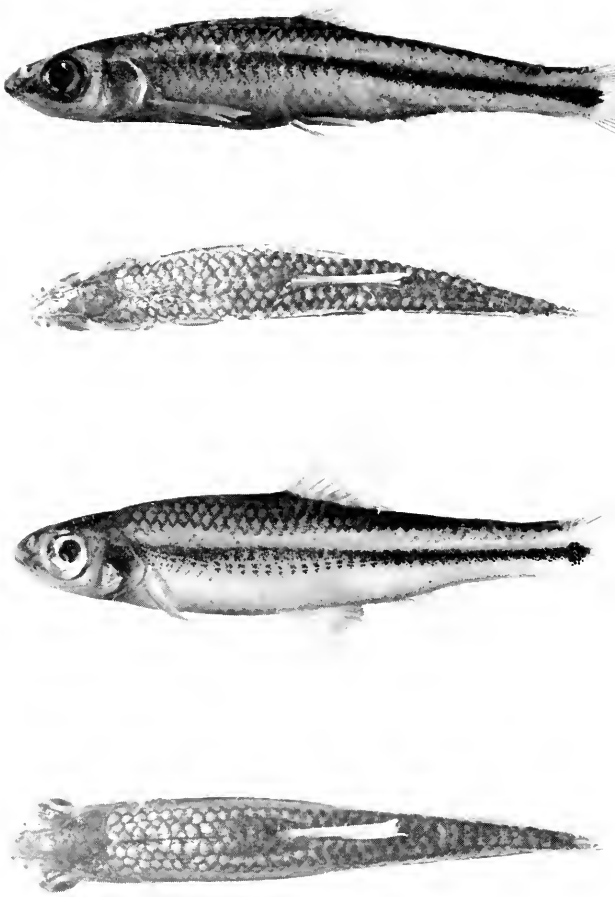
Nuptial Tubercles and Sexual Dimorphism

The anterior part of the snout of the male is densely covered by small white tubercles, which are larger than those on the body or fins. The tubercles are less numerous in the area between and below the nostrils; only an occasional tubercle of the type found on the snout is seen behind the nostril, except for a prominent row that begins behind the posterior nostril and continues upward to a point above and close to the eye. Tubercles of the same type form a patch on the chin and two or three irregular rows on the mandible and gular region. Finer light-colored tubercles are present on the lips, and to a lesser extent on the rest of the head; few or none are present on the opercles. One or occasionally two vertical rows of small tubercles are present on the anterior exposed edge of each scale of the anterior two-thirds of the lateral line, but are absent on other scales. The dorsal aspect of the first seven or eight pectoral fin rays is covered by dense bands of fine tubercles. None was observed on other fins. No large tubercles were found on the many females present in the series taken June 15, 1952 (TU 4251) but small ones, visible only under magnification, were scattered over the head and in a vertical row on the anterior lateral line scales.

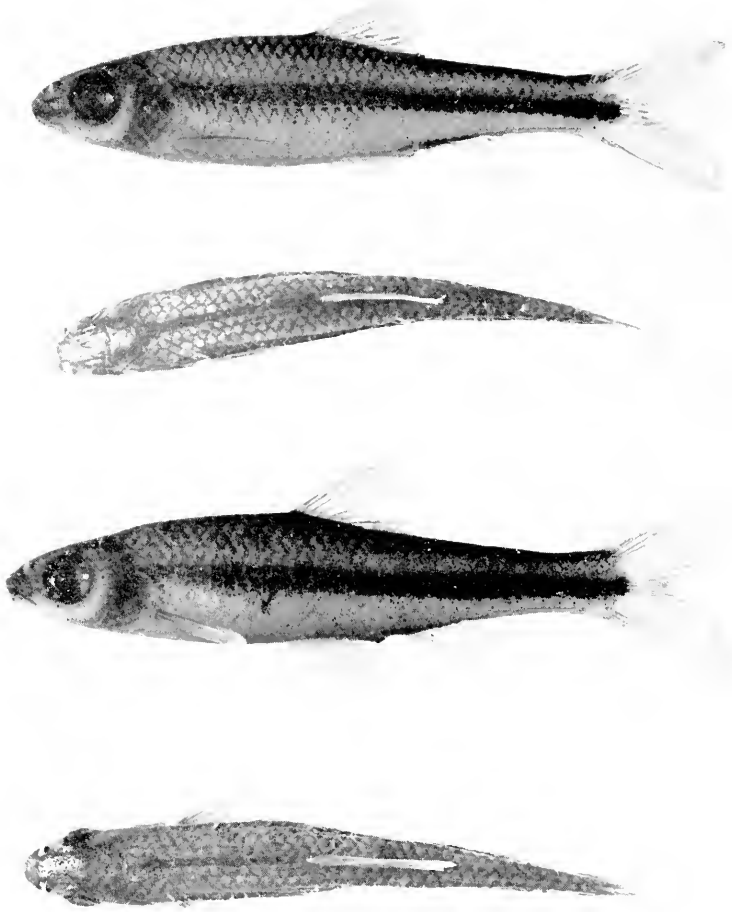
The nuptial tubercles on the snout are larger and more prominent than in *xaenocephalus*. The entire head is covered with fine scattered tubercles but there are fewer on the opercle. They are absent on the scales except for a nearly vertical row of small tubercles on the anterior lateral line scales. The largest tubercles are those on the upper surface of the pectoral fin of the male; here they are arranged in two dense rows on the anterior eight or nine rays and may be useful in holding the female during the spawning act. None is present on the other fins. The females of *xaenocephalus* have only a few small tubercles including the row on the anterior lateral line scales. None is present on the pectoral fin.

Bailey et al. (1954) have pointed out the salient differences in the development of nuptial tubercles in adult males of *roseus, petersoni* and *chalybaeus*. The large pointed tubercles present on the snout of *roseus* and *petersoni* are lacking in *chalybaeus* and *asperifrons*. In *roseus*, the tubercles on the snout are numerous and large; in *petersoni* the snout lacks tubercles except for a single or double row of large ones which overhang the upper lip. In *chalybaeus* a single or partly double row of moderately large tubercles on the edge of the snout point downward; their light color contrasts with the dark of the rest of the head.

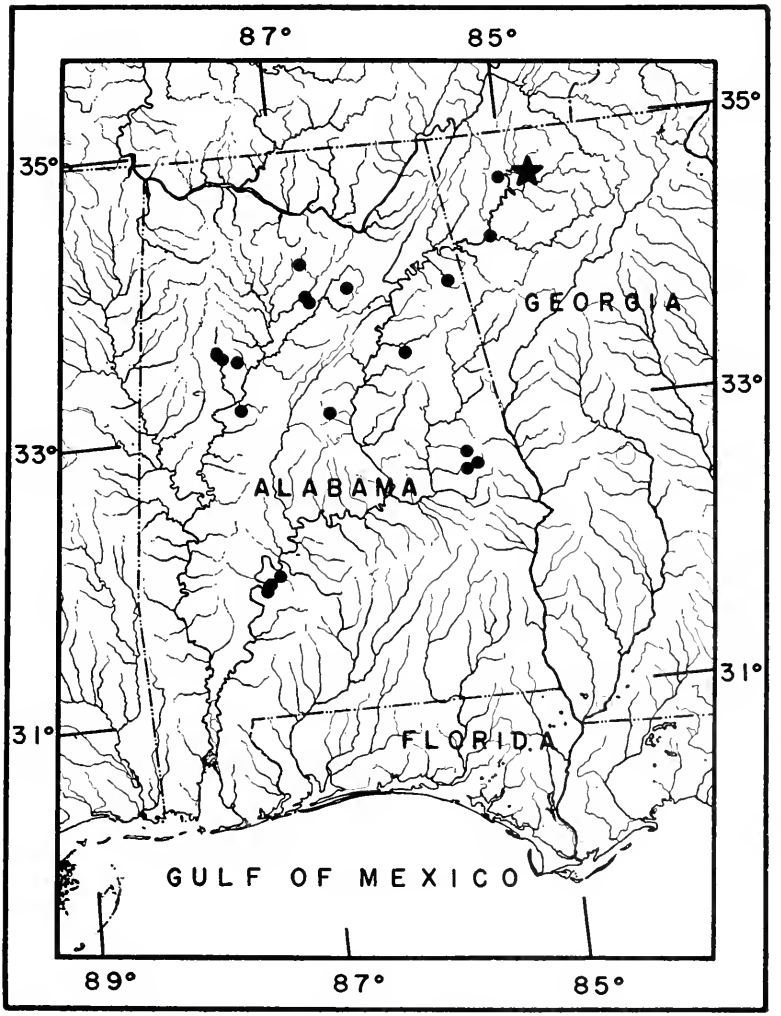
In *asperifrons* the pectoral and anal fins are longer in males than in females. When the fin is depressed the tip of the pectoral reaches



Figures 1-4. **1** (top) *Notropis asperifrons:* side view of the holotype, an adult female, 50 mm in standard length, from Holly Cr., 8 mi. N. Murray Co. line at Ramhurst, Murray Co., Georgia. **2** (second) *Notropis asperifrons:* top view of the holotype. **3** (third) *Notropis xaenocephalus:* side view of an adult male, 49 mm in standard length, from Etowah R., 5.4 mi. S. W. Dahlonega, Lumpkin Co., Georgia. **4** (bottom) *Notropis xaenocephalus:* top view of the same specimen illustrated in fig. 3 above. (Photographs by Douglass M. Payne.)



Figures 5-8. **5** (top) *Notropis roseus:* side view of an adult female, 50 mm in standard length, from Chipola River, Apalachicola River system, 1 mi. N.W. Grangeburg, Houston Co., Alabama. **6** (second) *Notropis roseus:* top view of the same specimen illustrated in fig. 5 above. **7** (third) *Notropis petersoni:* side view of an adult female, 49 mm in standard length, from Kiokee Cr., trib. Chickasawhatchee Cr., Apalachicola R. system, 3.2 mi. W. Pretoria, Dougherty Co., Georgia. **8** (bottom) *Notropis petersoni:* top view of same specimen illustrated in fig. 7 above. (Photographs by Douglass M. Payne.)



Map 1. Distribution of *Notropis asperifrons*. Star indicates type locality.

a point within two or three scale rows of the pelvic insertion, rather than being five scale rows distant in the female. The tip of the pelvic reaches beyond the anus in the male, rather than ending in front of the anus. Females appear to reach a greater length than males.

Compared with *asperifrons* the pectoral and pelvic fins of *xaenocephalus* are much longer in adults. When depressed the posterior

tip of the pectoral fin of the male nearly reaches the pelvic insertion and is about three to four scale rows distant in the female. In the male the posterior tip of the pelvic fin falls behind the anus but ends well ahead of this structure in the female. The females seem to reach a larger size than the males.

The name *asperifrons,* derived from *asper,* rough, and *frons,* forehead, refers to the tuberculate snout.

Range and Ecology

Apparently *asperifrons* is limited to the Mobile Bay drainage. In the Alabama River system it is known from stations on the upper Coastal Plain, the Piedmont, and from mountain type streams in the headwater tributaries of the Coosa River. The available collections from the Black Warrior River system were taken in the Piedmont area in the vicinity of Tuscaloosa, Cullman, and Oneonta, Alabama. It has been taken in clear streams of small and moderate size, usually 4 to 50 feet in width. Most of these streams have rubble, bed rock and sand bottom and flow through wooded areas. At one or several places it was taken with *Notropis xaenocephalus, roseus, chrosomus* or *baileyi.*

Key to the Species of *Notropis* which Inhabit the Eastern Tributaries of the Gulf of Mexico from the Mobile Bay to the Apalachicola Bay Drainage and which are Characterized by the Typical Count (2, 4—4, 2 Teeth, 7 or 8 Anal Rays) and a Dark Lateral Band (Except for *hypsilepis*).

Bailey et al. (1954) have recently cleared up some of the confusion which clouded the status of *Notropis roseus, petersoni* and *xaenocephalus* in southeastern United States and have given some characters to separate these species as well as the related *chalybaeus.* To summarize the salient differences and to assist in identification we have constructed the following key to the nine species of *Notropis* under discussion.

1. Anal rays 7. 2
   Anal rays 8. 7
2. Mouth inferior. Anterior lateral line scales elevated. Predorsal dark streak absent or obsolescent. 3
   Mouth terminal. Anterior lateral line scales little or not elevated. Predorsal dark streak well developed. 4
3. Muzzle bluntly rounded. Head subquadrate. Gape only slightly oblique, rising to lower level of eye anteriorly. Body deep. Light colored. Dark lateral band little or not developed anteriorly. Caudal spot small, wedge-shaped and separated from the dark lateral band. Lacks dark pigment below the lateral line on anterior side except for a dark spot just be-

low each pore. Lower jaw light colored. Lacks dark bar on shoulder girdle. Occipital bar absent or obsolescent. Light area present behind anus. Suborbital wide, its least width 31-41 (35); Interorbital wider, its least fleshy width 85-95 (89); dorsal, anal and caudal fins longer, 225-246 (232), 169-193 (181), and 270-304 (282), respectively (measurements in thousandths of standard length). Circumferential body scales 22 to 26. Preoperculomandibular pores 12 or 13. Range: Apalachicola Bay drainage in the Chattahoochee and Flint rivers.....*Notropis hypsilepis* Suttkus and Raney

Muzzle acute. Head subtriangular. Gape more oblique, rising to the lower level of the pupil. Body elongate. Moderately dark colored. Dark lateral band well developed anteriorly. Caudal spot large, quadrate, connected with and wider than the lateral band. The dark marks below and above the anterior lateral line pores form chevrons. Lower jaw with scattered melanophores. Dark bar present on shoulder girdle. Occipital bar well developed. Dark area behind anus. Suborbital narrower, its least width 16-27 (23); interorbital narrower, its least fleshy width 79-85 (81); dorsal, anal and caudal fins shorter, 198-223 (210), 140-151 (146), and 213-245 (236), respectively. Circumferential scales 19 to 21. Preoperculomandibular pores 10. Range: Mobile Bay drainage in the Black Warrior and Alabama rivers (Map 1).....*Notropis asperifrons* sp. nov.

4. Middorsal stripe variously developed but not solidly encircling dorsal fin base. Mouth small; upper jaw as long as or shorter than eye. Dark lateral band broken immediately behind eye; represented by scattered melanophores. Lateral band on body not uniform; varies in density especially on the anterior half; spots and/or short bars are associated with the lateral line pores..... 5

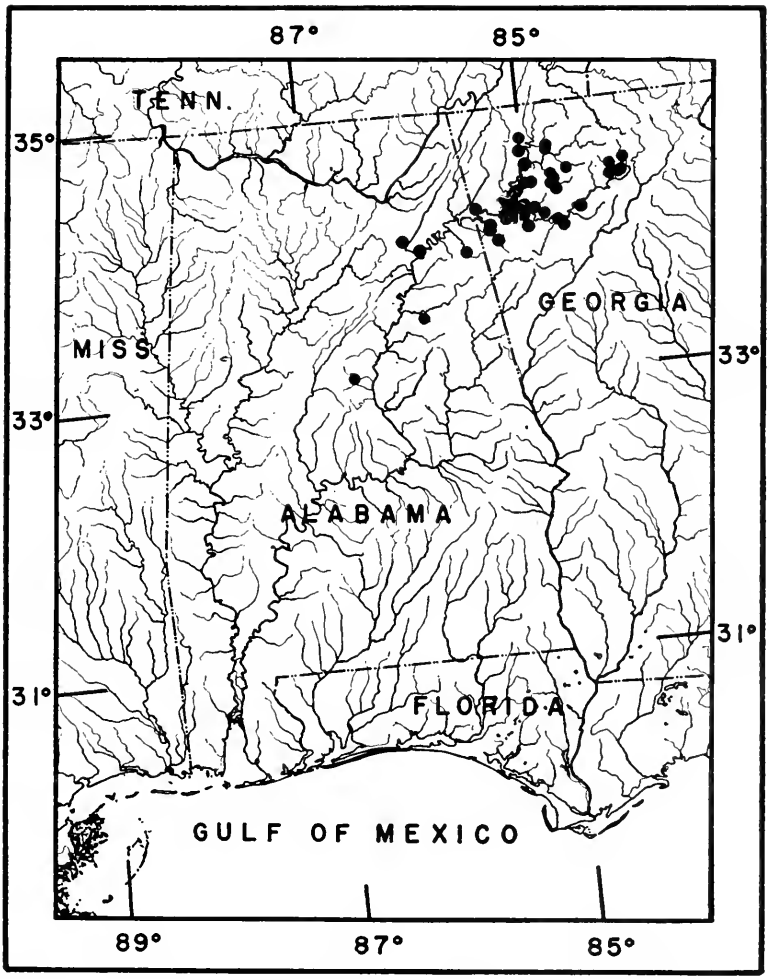
Middorsal dark stripe solidly encircles the dorsal fin base and continues to the procurrent caudal rays. Mouth large; upper jaw much longer than eye. Dark lateral band continuous immediately behind eye and of same intensity and width as that on the opercle. Lateral band on side of body fairly uniform in density

throughout; lower margin entire. More closely related to *chrosomus* and *lutipinnis*. Range: Leaf and Chickasawhay rivers of the Pascagoula Bay drainage eastward to the Tombigbee, Black Warrior and Alabama rivers of the Mobile Bay drainage.....*Notropis baileyi* Suttkus and Raney

5. Posteriormost four or fewer anal rays outlined in black, in contrast to the light anterior rays. Basicaudal spot quadrate or somewhat rounded; continuous with the dark lateral band on the caudal peduncle; wider than lateral band on peduncle. Median dorsal stripe expanded laterally immediately before the origin of the dorsal fin to form a conspicuous dark blotch. Transverse occipital bar obsolescent or absent. Melanophores are scattered in the internarial area or form diffuse blotches. Tubercles on snout of males fine or if large (*roseus*) are scattered over the entire snout..... 6

All anal fin rays edged with scattered melanophores. Basicaudal spot wedge-shaped and separated somewhat by a light area from the posterior end of the lateral band on the caudal peduncle; basicaudal spot as wide as or narrower than band on peduncle. Median dorsal stripe not expanded laterally immediately before dorsal origin. Transverse occipital bar strongly developed and expanded midlaterally. Two large dark crescents in the internarial area. Large nuptial tubercles on snout of male limited to one or two rows circling the anterior edge of the snout. Range: Coastal Plain from the Escambia River eastward to peninsular Florida and northward to the Cape Fear River system, North Carolina.....*Notropis petersoni* Fowler

6. Anal fin rays usually clear except for a narrow dark border on the last anal ray; some specimens have a few scattered melanophores on other rays. Basicaudal spot rounded. Anterior half of dark lateral band diffuse. Upper margin of dark lateral band clearly delimited anteriorly; clear stripe above not obscured by dark edges of scales. In the male, fine breeding tubercles are present on the head, snout and lower jaw; tubercles present on anterior scales only. Range: Mobile Bay drainage



Map 2. Distribution of *Notropis xaenocephalus*. Star indicates type locality.

where it is limited to the upper Alabama River system (Map 2).....*Notropis xaenocephalus* (Jordan)

Last 3 or 4 anal rays have a narrow dark border. Basicaudal spot quadrate. Anterior half of dark lateral band is dark and is about the same density throughout. Upper margin of dark lateral band not clearly demarked at anterior end; area immediately above obscured by dark color on the scale margins. Coarse breed-

ing tubercles are scattered over top of head and snout; the latter are large and sharp pointed; large tubercles on lower jaw; anterior scales, extending medially along the back and onto the first dorsal ray, are tuberculate. Range (in part from Bailey et al, 1954): From the Ochlockonee River drainage west along the Gulf Coastal Plain to eastern Texas, and north in the Central Lowland to eastern Iowa, southern Wisconsin, and southwestern Michigan.....*Notropis roseus* (Jordan)

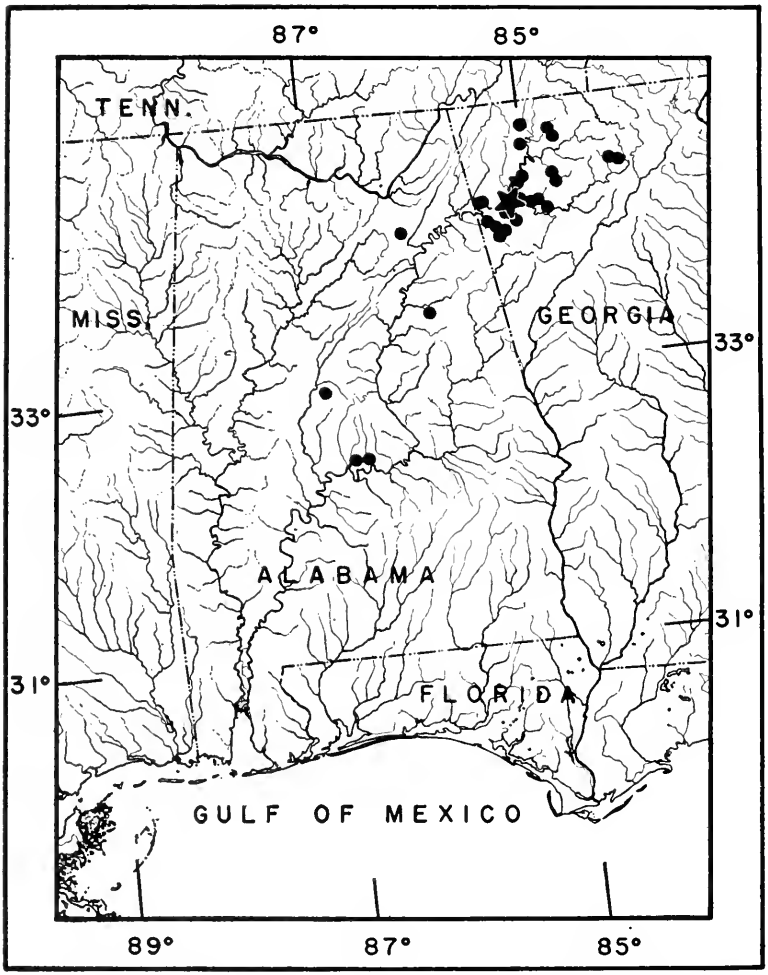
7. Eye moderate; shorter than snout. Peritoneum white ventrally; with some melanophores on lateral wall. Lining of mouth white, with few small scattered melanophores on upper oral valve. Light colored on the midline of breast, belly, area behind the pelvis and on the area before and around the anus; body at base of anal fin and on lower edge of caudal peduncle is white or has a few deep seated melanophores. Band on snout lacking or diffuse; chin not black, although it may be finely peppered with small dots; dark lateral band on front of body weak to moderately developed. Only the anterior anal rays have a dark margin. Nuptial tubercles extend the length of body on dorsal scales..... 8

Eye very large; much longer than snout. Peritoneum black ventrally. Lining of mouth black, above and below. Black on midline of breast, belly, area behind pelvis, area before and around anus, body at base of anal fin and the lower edge of caudal peduncle. Black band is intense on snout and chin, and extends posteriorly to the caudal base. Anal rays delicately but evenly dark margined throughout. Nuptial tubercles on scales restricted to anterior half of body. Range (in part from Hubbs and Lagler, 1947: 66): Coastal Plain from southeastern New York to Texas; northward, in the Mississippi Valley to Iowa, northern Indiana and the St. Joseph River system of the Lake Michigan basin. .....*Notropis chalybaeus* (Cope)

8. Dark lateral band deeper but less intense in front; narrow and darker posteriorly; bordered above by prominent wide light stripe which the darkish scale margins do not cross.

Basicaudal spot present. Strong oblique dark bar on shoulder girdle reaches to pectoral fin base. Black blotch on dorsum located below the posterior half of the dorsal fin base. Postorbital dark band diffuse; spreads ventrally on opercle. Caudal peduncle scales 12. Circumferential body scales 22-24, usually 22 or 23. Posterior tip of jaw barely reaches a vertical from the front of the eye. Upper jaw shorter than snout. Head shorter; into standard length more than 4 times. Body terete. Snout bluntish. Anal fin shorter; into standard length more than 5 times. Fleshy margin of opercle is light colored in projected region of dark lateral band. In the male nuptial tubercles on the body are limited to those on and dorsad of the row of scales below the lateral line; lacks tubercles on pelvic, dorsal, anal and caudal fins. Range: Mobile Bay drainage where it is limited to the upper Alabama River system (Map 3)..... *Notropis chrosomus* (Jordan)

Dark lateral band about the same intensity and diameter throughout; no light stripe above. Lacks a basicaudal spot. Faint, oblique bar on shoulder girdle not reaching pectoral base. Faint blotch on the dorsum below posterior part of the dorsal fin base. Postorbital dark band restricted to the upper part of the opercle. Caudal peduncle scales 14 to 17. Circumferential body scales 26-31, usually 27. Posterior tip of jaw extends behind a vertical from the front of the eye. Upper jaw longer than snout. Head longer; into standard length less than 4 times. Body compressed. Snout sharp. Anal fin longer; into standard length less than 4.5 times. Fleshy margin of opercle is dark in projected region of dark lateral band. In the male nuptial tubercles are present on all body scales; tubercles are present on pelvic, dorsal, anal and caudal fins. Range: Apalachicola Bay drainage in the Chattahoochee River, northeastward to the Santee River system, South Carolina..... *Notropis lutipinnis* (Jordan and Brayton)



Map 3. Distribution of *Notropis chrosomus*. Star indicates type locality.

Relationships

The writers realize that an attempt to fix the locality at which, and the time when, differentiation occurred, is tentative at best, especially when only the present day evidence is available. However, the following hypothesis of mode, time and place of origin appears to be most consistent with the facts of variation and distribution as worked out in this paper.

Although *N. chalybaeus* is related to *N. roseus* and *N. petersoni*,

TABLE 4.

FREQUENCY DISTRIBUTIONS OF THE CEPHALIC LATERAL LINE PORE COUNTS OF NINE SPECIES OF *Notropis*

Canal	Supratemporal					Supraorbital				Infraorbital								Preoperculomandibular					
Species	2	3	4	5	6	7	8	9	10	10	11	12	13	14	15	16	17	8	9	10	11	12	13
hypsilepis	—	3	—	2	—	—	2	1	2	—	—	—	—	1	1	1	2	—	—	—	—	1	4
asperifrons	—	—	5	—	—	—	3	2	—	—	—	—	2	3	—	—	—	—	—	5	—	—	—
xaenocephalus	—	1	6	—	—	—	7	—	—	—	1	1	1	3	1	—	—	—	2	3	2	—	—
roseus	1	—	3	—	1	—	3	2	—	—	—	1	1	1	2	—	—	—	1	3	—	1	—
petersoni	3	2	2	—	—	1	5	1	—	1	2	3	—	1	—	—	—	3	2	2	—	—	—
chalybaeus	—	—	1	3	2	—	4	2	—	—	—	—	—	3	2	1	—	—	—	—	6	—	—
baileyi	—	—	7	1	—	—	6	2	—	—	—	—	1	3	4	—	—	—	2	4	2	—	—
chrosomus	—	—	6	1	—	—	2	4	1	—	—	—	3	1	1	2	—	—	—	4	1	2	—
lutipinnis	—	4	1	—	—	—	3	2	—	—	—	—	1	4	—	—	—	1	3	1	—	—	—

it has long been speciated and differs in many characters, including a typical anal ray count of eight. The range of the lowland *chalybaeus* includes and is greater than that of both *roseus* and *petersoni* and the three species have been taken in the same collection on the eastern Gulf lowland where the ranges of *roseus* and *petersoni* overlap. We postulate that *chalybaeus* and *roseus* were evolved from the same stock, and probably they were isolated early; *roseus* in the Gulf and Mississippi lowlands and *chalybaeus* in the Atlantic Coastal Plain area. Subsequently *chalybaeus* reinvaded the western lowlands where it is now sympatric with *roseus*.

Apparently *N. roseus* and *N. petersoni* are closely related and the latter probably evolved from a Pleistocene invasion of the Atlantic Coastal Plain by *roseus* stock. This eastern component (*petersoni*) evolved to the species level and has reinvaded the Gulf Coastal Plain where it has advanced at least as far as the lower Escambia River. Its subsequent coastwise dispersal to the west and into peninsular Florida, where it is now widely distributed as far southward as the Caloosahatchee River system (Lee Co.) seems to be favored by its tolerance of saline water, a fact recently pointed out by Bailey et al. (1954).

The populations of *petersoni* in peninsular Florida, especially those in the lower west coast drainages, seem to have differentiated and are now characterized by a short (Table 5), slim body, a large eye, bluntish snout, and dark coloration.

While *N. roseus* is primarily a Coastal Plain and lowland species it is presumably physiologically preadapted to permit invasions of upstream habitats. For example it is now known from tributaries of the Black Warrior River, Green and Tuscaloosa counties, Alabama, where it lives sympatrically with *asperifrons*. While *asperifrons, hypsilepis* and *xaenocephalus* probably arose from such invasions by *roseus* stock, the time and mode of isolation are not clear. The common characters and the range of *asperifrons* and *hypsilepis* seem to point to a common ancestry (*roseus* or *roseus*-like stock), with subsequent differentiation. Besides sharing the basic characters of 2, 4—4, 2 teeth and 7 anal rays the three are similar to *roseus* in many details of coloration, counts, and proportions as may be seen in the descriptions above and in Tables 1-4. Notwithstanding the close relationships, these forms are differentiated on the species level. *N. roseus* and *asperifrons* are sympatric in the Black Warrior and Alabama River systems of Alabama; *asperifrons* was taken with *xaenocephalus* several times in the Alabama River system; *hypsilepis* and *roseus* occur together in a tributary of Lazier Cr., Flint R. drainage, Talbot Co., Georgia.

An invasion of *roseus* in the Flint River section of the Apalachicola Bay drainage, which is very close to the extreme of its range, has evolved into a population of *roseus* which we believe may prove worthy of subspecific recognition. It is not now designated as such since we believe that *roseus* should be studied throughout its range

TABLE 5.

FREQUENCY DISTRIBUTION OF LARGEST SPECIMEN IN EACH COLLECTION OF FIVE SPECIES OF *Notropis*

Species	Standard Length in mm										No. of Collections	No. of Specimens
	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69		
hypsilepis	—	1	—	—	1	—	4	—	—	—	6	47
asperifrons	—	—	—	2	8	1	1	1	—	—	11	120
xaenocephalus	—	—	—	—	4	8	9	4	3	—	28	677
roseus	—	2	1	5	11	19	27	30	6	1	102	2462
petersoni	2	—	4	13	20	20	26	7	5	1	108	2819
St. Marys R., Fla. to Cape Fear R., N. C.	—	—	2	2	1	9	19	5	3	1	42	1384
Peninsular Fla.	2	—	2	11	16	9	7	2	1	—	50	1308
Econfina R., Fla. to Apalachicola R., Ala. & Ga.	—	—	—	—	3	2	—	—	1	—	6	127

before adding additional names (see Bailey et al., 1954). The trend toward a reduction of tooth number in some samples of *asperifrons,* a *roseus* derivative, also occurs in the northern part of the range of *roseus.* The Flint River population of *roseus* shows a notable difference in body depth. In fifteen specimens from 43-59 mm in standard length, the body depth expressed in thousandths of standard length ranges from 215 to 286, mean 255; eight females averaged 266 and seven males averaged 243 (see Table 2 for measurements of other samples of *roseus*). There is also a greater number of circumferential scales, the count usually being 26 in Flint River specimens and 24 in those taken in lowland situations.

We postulate that *xaenocephalus* evolved from *roseus* stock which invaded the Mobile Bay drainage. It now seems to be limited to the Alabama River system while the related *asperifrons* occurs in both the Alabama and Black Warrior river systems. Many of the salient differences between the two are to be seen in the key, the description given above, in Tables 1-4, and in Figures 1-4. In summary, *asperifrons* differs from *xaenocephalus* in having an inferior mouth; more elevated anterior lateral line scales; a longer slimmer body, with less arched dorsal and ventral contours; a more acute muzzle; smaller, more fragile fins; a more elongate caudal spot; obsolescent or absent predorsal dark mark and middorsal dark streak; the dorsal origin is slightly behind the pelvic insertion rather than the reverse; a lower pectoral ray count; and a much lower circumferential scale count. In practically all characters mentioned in this comparison *xaenocephalus, roseus* and *petersoni* are very much alike. Other differences between *asperifrons* and *roseus* may be seen in the key.

A detailed reading of *Jordan's* (1877: 355) original description of *N. xaenocephalus* with specimens of related species at hand shows clearly that he described the form recognized herein under that name. However, a re-examination of the two types, USNM 20116, which were designated as such in Jordan and Evermann (1896: 289), proves that Jordan had both *N. xaenocephalus* and *N. asperifrons* in his original material. We hereby designate as lectotype of *N. xaenocephalus* the specimen which measures 50.1 mm in standard length and retains the number USNM 20116. The single specimen of *N. asperifrons* has been recataloged as USNM 164969 and is designated as a paratype. Also examined was another series of three specimens originally bearing the number USNM 17886 collected by Jordan near Rome, Georgia and which were probably used at least in part in the original description of *N. xaenocephalus.* Two specimens 48.3 and 38.1 mm in standard length may be considered syntypes of *xaenocephalus.* The third specimen in this series is *N. asperifrons,* an adult 45.5 mm in standard length. It has been removed, designated as a paratype and recataloged as USNM 164968.

The original description of *N. xaenocephalus by* Jordan (1877: 335) stated that "Two varieties or forms may be appreciated, the one larger, stouter, and with a larger mouth and much larger eye.

They seem, however, to shade into each other. They occur together in about equal abundance." Our study of adequate series of *N. xaenocephalus* (28 collections numbering 677 specimens) indicates that he was dealing with characters which represented the extremes in size, and also probably in age, and our observations of the characters of large specimens are similar to his. That these ontogenetic changes may be of considerable degree was demonstrated early in our study since in preliminary sorting of specimens, we believed that two species (not including *asperifrons*) were present.

Gilbert (1891: 154) also overlooked *N. asperifrons* and misidentified both *roseus* and *asperifrons* from the Black Warrior River system as *xaenocephalus.* In addition, he misidentified *N. baileyi* as *chrosomus.* Two series of *N. baileyi* housed in the United States National Museum were the basis for Gilbert's (1891: 154), records of *N. chrosomus* from a tributary of the Black Warrior River near Tuscaloosa, Alabama. The data for the two series are as follows: USNM 125079 (1, 43), Black Warrior R., Tuscaloosa, Ala., May 21, 1889, collected by P. H. Kirsch and USNM 36690 (10, 39-47) North R., Tuscaloosa, Ala., collected by C. H. Gilbert and Joseph Swain (presumably in 1884).

Since the description of *Notropis baileyi* appeared, two additional lots have been discovered in the University of Michigan, Museum of Zoology, by Reeve M. Bailey. The data for these two series, furnished by him, are as follows: UMMZ 111121 (24, 33-55), 6 mi. W. Auburn, Wire Road, Alabama, June 29, 1930; UMMZ 111124 (2 adults), Willmore Dam, September 13, 1930.

Notropis asperifrons and *N. xaenocephalus* have also been taken together in three collections now housed at Cornell. The collections were made by Robert H. Gibbs and Philip P. Caswell in mid-June 1952. Both were found at the type locality of *asperifrons* in Murray Co., Georgia and at two places in Alabama: a tributary of Terrapin Cr. at the Cherokee-Calhoun county line on Alabama Hwy. 74 and in Cheaha Cr., 3.3 mi. S.W. Mumford on U.S. Hwy. 421. Although their ranges overlap, *asperifrons* was taken downstream in the Coosa River system, where *xaenocephalus* was not captured. We also have 27 collections of the latter, without *asperifrons,* from the tributaries of Coosa and Etowah rivers in Bartow, Cobb, Gordon, Dawson, Floyd, Lumpkin, Murray, Pickens, and Whitfield counties in north Georgia.

The types of Jordan's (1877: 61) *"Luxilus roseus,"* taken in Natalbany R. near Tickfaw, La., were examined. Nineteen specimens representing two genera and four species were present in the series, USNM 17831. Eight specimens of *Notropis roseus* which measured from 36.5 to 53.5 mm in standard length were included. The largest specimen is hereby designated as lectotype. Although the teeth are missing from the left side, those on the right are 4,2 and in other respects it is a typical example of *roseus.* The other eleven specimens in the "type" series were identified and recataloged as follows: *Notropis venustus* (Girard), 1 spec., 26.5 mm recataloged as USNM

163569; *Notropis cornutus* (Mitchill), 9 spec., 23.7-38.4 mm recataloged as USNM 163570; *Hybopsis amblops* (Rafinesque), 1 spec., 47.7 mm recataloged as USNM 163571.

The relationships of *N. hypsilepis* and the allopatric *asperifrons,* both of which were probably derived from *roseus,* are close. The development of an inferior mouth seems to be an adaptation for life on or near the bottom. These two forms may be separated easily by reference to the many characters used in the key; *asperifrons* is dark and elongate whereas *hypsilepis* is light-colored and relatively deep bodied; the back at the dorsal fin base is light posteriorly in *hypsilepis* whereas it is dark in *asperifrons.* Their relationships are indicated by the presence in each of a vertical row of nuptial tubercles on the anterior lateral line scales and elevated anterior lateral line scales.

The following combinations of characters will serve to separate *hypsilepis* from the other species of *Notropis,* (*asperifrons, xaenocephalus, roseus,* and *petersoni*) in the same general geographical area, with 7 anal rays and 2, 4—4, 2 teeth: Body light colored rather than darkish. Contrasting dark patches on the body at the dorsal and anal fin bases limited to the base of the first 4 or 5 rays and thus appear as blotches rather than being distributed along the entire base. Melanophores absent immediately behind or beside the anus. The dark lateral band weak anteriorly but present posteriorly, rather than being strongly developed throughout its length. The basicaudal spot definitely separated from the lateral band, rather than being continuous or only slightly separated (*petersoni*); wedge-shaped and narrow, being no wider than three caudal rays at its posterior and rather than being quadrate, or, if wedge-shaped, as wide as five or six caudal rays. The upper lip light on its posterior two-thirds, and the lower lip white rather than dusky or black in whole or part.

The characters given in the key will suffice for separating *asperifrons* from *baileyi,* which also has 2, 4—4, 2 teeth and 7 anal rays. As Suttkus and Raney (1955a) have pointed out, the relationships of *baileyi* are with *lutipinnis* and *chrosomus.*

References Cited

Bailey, Reeve M., Howard Elliott Winn and C. Lavett Smith 1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes. *Proc. Acad Nat. Sci., Phila.,* 106: 109-164, 1 fig.

Gilbert, Charles H. 1891. Report of explorations made in Alabama during 1889 with notes on the fishes of the Tennessee, Alabama and Escambia rivers. *Bull. U. S. Fish Comm.,* 9 (1889): 143-159, 2 figs.

Hubbs, Carl L. and Karl F. Lagler 1947 (and second printing, 1949). Fishes of the Great Lakes region. *Bull. Cranbrook Inst. Sci.,* 26: i-xi, 1-186, many figs.

Jordan, David Starr 1877. A partial synopsis of the fishes of upper Georgia. *Ann. N. Y. Lyceum Nat. Hist.,* 11: 307-377.

---------- 1877. Contributions to North American ichthy-

ology. A. Notes on Cottidae, Etheostomidae, Percidae, Centrarchidae, Aphredoderidae, Dorysomatidae and Cyprinidae, with revisions of the genera and descriptions of new or little known species. *Bull. U. S. Nat. Mus.*, 10: 1-68.

JORDAN, DAVID STARR and BARTON WARREN EVERMANN 1896. The fishes of North and Middle America. . . . *Bull. U. S. Nat. Mus.*, 47, Pt. 1: i-ix, 1-1240.

SUTTKUS, ROYAL D. and EDWARD C. RANEY 1955a. *Notropis baileyi*, a new cyprinid fish from the Pascagoula and Mobile Bay drainages of Mississippi and Alabama. *Tulane Stud. Zool.*, 2 (5): 69-86, 4 figs., 1 map.

---------- 1955b. *Notropis hypsilepis*, a new cyprinid fish from the Apalachicola River system of Georgia and Alabama. *Tulane Stud. Zool.*, 2 (7): 159-170, 2 figs., 1 map.

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A NEW LOUISIANA COPEPOD RELATED TO *DIAPTOMUS* (*AGLAODIAPTOMUS*) *CLAVIPES* SCHACHT

(COPEPODA, CALANOIDA)

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A NEW LOUISIANA COPEPOD RELATED TO *DIAPTOMUS* (*AGLAODIAPTOMUS*) *CLAVIPES* SCHACHT (COPEPODA, CALANOIDA)

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Study of new collections from small bodies of fresh water in Louisiana continues to reveal species of copepods new to science as well as species as yet unrecorded for the state. The present report describes the fourth new Louisiana species to be added recently to the list of North American diaptomid copepods. Others are *Diaptomus louisianensis* M. S. Wilson and Moore (1953a), *D. bogalusensis* M. S. Wilson and Moore (1953b) and *D. moorei* M. S. Wilson (1954).

It is also of interest to note that the type localities of two other diaptomid copepods are in Louisiana. Of these, *D. conipedatus* Marsh (1907) has not yet been reported from outside the state. *D. dorsalis* Marsh (1907) is now known to be fairly common in the southeastern states and also to occur in the West Indies. Kiefer (1936) recorded it from Haiti as a new species, *D. proximus.* Kiefer's description is more detailed than that of Marsh and comparison of it with type material of *dorsalis* in the United States National Museum shows that differences noted by Kiefer were omitted from the original description. The species also occurs in Puerto Rico having been identified by myself in a U. S. National Museum collection from Guanica Lake. *D. dampfi* Brehm (1932, 1939) from Lake Peten, Guatemala, is closely allied to *dorsalis* and may or may not be synonymous. Brehm's descriptions are too incomplete to allow for a satisfactory decision on the basis of his papers alone.

The occurrence of *dorsalis* throughout the southeastern United States and the West Indies, and its possible presence in Central America, suggests that these new species should be looked for throughout this relatively little known area. Neither the recently discovered species nor the older *conipedatus* should be considered endemic to Louisiana on the basis of present knowledge. Although there may well be extreme localization of some species in the southeastern part of the continent, recent studies have extended the range of species that for many years were considered localized or rare, and no conclusions should be drawn until an intensive survey of the region has been made. One of the new species (*moorei*) is already known from eastern Texas.

Anyone studying Louisiana diaptomids, should also note the new species recently found in neighboring areas: *D. sinuatus* Kincaid (1953), a form closely allied to *bogalusensis*, from Panama City, Florida; *D. marshianus* M. S. Wilson (1953) from Lake Jackson, Florida; and *D. texensis* M. S. Wilson (1953) from Aransas County, Texas.

Kiefer (1936: 309) summarized the literature dealing with the

free-living fresh and brackish water copepods of this region (West Indies, Florida west to Texas, Mexico and Central America). Since then, records of distribution of such copepods in this general region are found in papers by C. B. Wilson (1936, 1938), Kiefer (1938), Pearse (1938), Brehm (1939), Harkness and Pierce (1940), Osorio Tafall (1941, 1942a, b, 1943), Coker (1943), Yeatman (1944), Penn (1947), Pierce (1947), Davis (1948), Dickinson (1949), King (1950), Davis and Williams (1950), Comita (1951), Hoffman and Causey (1952), Kincaid (1953), Peckham and Dineen (1953), M. S. Wilson (1941, 1953, 1954) and M. S. Wilson and Moore (1953a, b).

I am indebted to Dr. James E. Sublette of Northwestern State College, Natchitoches, Louisiana, who made the collections of the new species upon which this study is based, and to Dr. Walter G. Moore of Loyola University who referred the collections to me. Specimens of *Diaptomus clavipes* Schacht used for comparative study were from the collections of the United States National Museum and the Illinois Natural History Survey.

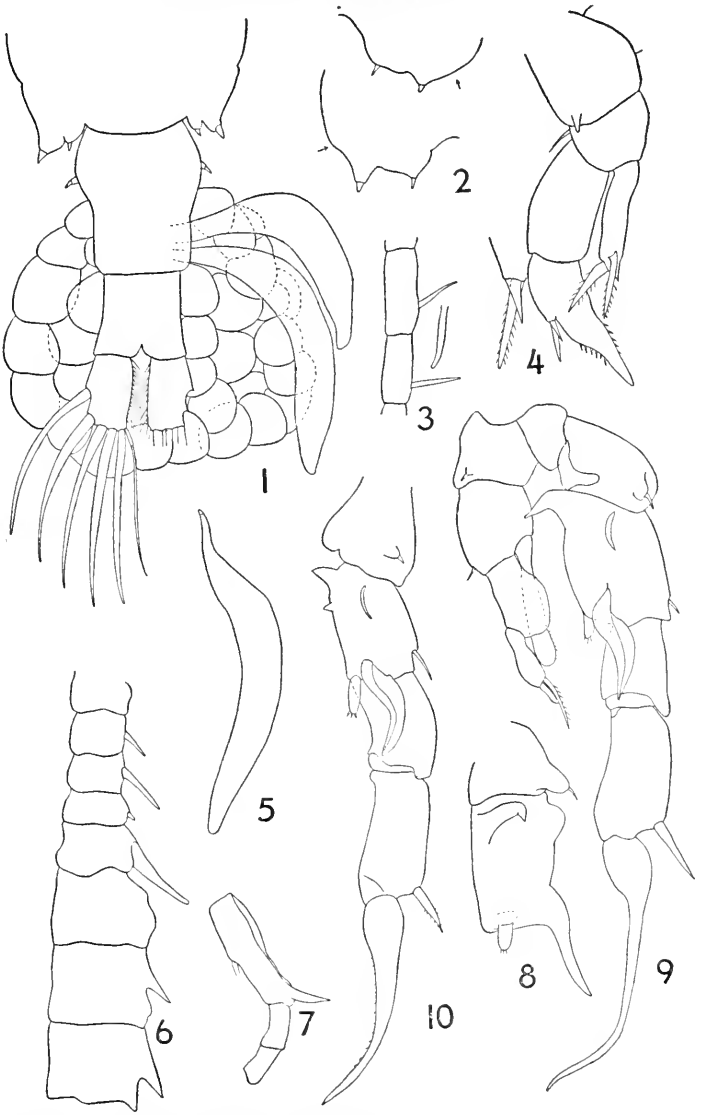
DIAPTOMUS (AGLAODIAPTOMUS) **CLAVIPOIDES,** sp. nov.

Specimens Examined.—Type lot: five hundred adults of both sexes, many females ovigerous and with attached spermatophores; seasonal pond near Grand Ecore, Natchitoches Parish, Louisiana, March 23, 1954, J. E. Sublette. Associated with *D. moorei* M. S. Wilson. Holotype ♀, United States National Museum catalog number 97230, allotype ♂, number 97231.

One hundred adults of both sexes, same locality, May 31, 1954.

Diagnosis.—With these characters of the subgenus *Aglaodiaptomus:* Two setae on segment 11 of female and left male antennules. Right antennule male, segment 14 without spinous process but with processes on segments 15 and 16. Maxilliped with three setae on distal lobe of basal segment. Leg 2, Schmeil's organ present on endopod segment 2 of both sexes. Leg 5 of female, third segment of exopod imperfectly separated; two well developed, thickly plumose setae on apex of endopod. Leg 5 of male, left exopod of the *leptopus* form with narrow distal segment and closely set, apical processes; the outer process digitiform, the inner a much longer curving seta.

Length, ♀ 2.3-2.5 mm. ♂ 2.0-2.13 mm. Greatest width of metasome in both sexes in mandibular area of cephalic segment. Metasome segments 5 and 6 separated only by short lateral suture. Metasomal wings of female not laterally expanded and with slight asymmetry; each wing with moderately developed inner lobe not reaching beyond that of the outer portion, that of the left a little larger than that of the right (fig. 2); in dorsal view, this difference is hardly noticeable (fig. 1). Urosome of female two-segmented (fig. 1); genital segment with very slight lateral symmetrical swelling; caudal rami shorter than anal segment (segments 2 + 3), hairs on inner margin only. Ova numerous, average number per ovisac 26. Urosome of male symmetrical except for backwardly produced portion



Figures 1-9. *Diaptomus clavipoides*, sp. nov., female: **1.** metasomal segments 5-6 and urosome, dorsal view, ovigerous specimen with two attached spermatophores; **2.** right (top) and left metasomal wings, lateral view (arrows indicate outer edge); **3.** setae of antennule segments 19-20, with detail of apex; **4.** leg 5, with detail exopod setae. Male: **5.** spermatophore, dissected out from body; **6.** right antennule, spines and processes of segments 10-16; **7.** same, apical segments 23-25; **8.** leg 5, right basipod 2, profile view of processes of mid-posterior face; **9.** leg 5, posterior view.
Figure 10. *Diaptomus clavipes* Schacht: male, right leg 5, posterior view (from slide in type lot, Illinois Natural History Survey collection.)

of right side of segment 4. Spermatophore somewhat angled near its proximal third and curved in the midportion (fig. 5); when attached to the female and viewed dorsally, it appears strongly curved to the right (fig. 1).

Antennules of both sexes reaching to near middle of urosome; those of the female and left side of the male with two setae on segment 11, and one on segments 13-19; setae of segments 17, 19, 20 and 22 shorter than the length of their segments, stiff, their tips not bent into a hook, though sometimes slightly curved (fig. 3). Right antennule of male (fig. 6) with spine of segment 8 not enlarged, that of 13 longer than that of 11, outcurved. Proportions of spines to the segmental width and to one another:

Segment	10	11	13
Segment width	23	23	35
Spine length	16	25	33

Strong spinous processes at midpoint of segments 15 and 16. Segment 23 (fig. 7) with short (length subequal to segment width), thick process strongly directed outward; a hyaline membrane along entire margin of segment to base of process.

Leg 5, female (fig. 4). Exopod 3 not developed. Lateral seta of segment 2 lacking. Outer seta of exopod 3 a stout, flat spine; the inner a plumose seta at least twice the length of the outer. Endopod reaching to end of first exopod segment or beyond; the terminal setae with widened bases and thickly plumose margins, their length about half that of the endopod.

Leg 5, male (fig. 9). Left leg reaching from just above middle of right exopod 2 to a little beyond. Basal sensilla of both legs short, slender spines. Midposterior face of right basipod 2 (fig. 8), with a proximal rounded lobe and a large distally placed process which reaches to near the end of the first exopod segment and consists of a curved spinous portion and an inner membrane; proximally the inner margin of the segment is produced into a prominent process bent at its middle into an obliquely directed spiniform portion. Relative proportions of outer margins of right basipod 2 and exopod segments 1 and 2, 39:32:45. Lateral spine of right exopod 2 placed near distal end, its length a little less than width of segment, 20:23. Claw longer than exopod, 85:77, enlarged basally, tapered abruptly beyond basal swelling so that it is very slender throughout, the tip usually recurved. Left basipod and exopod subequal to one another. Relative lengths of outer margins of exopods 1 and 2, 20:22. Left exopod 1 swollen medially, with extensive hairy pad. Left exopod 2 comparatively much reduced in width, its length about three times its width; processes terminally placed close together, the inner seta at least twice the length of the outer digitiform process, about 20:9. Right endopod reduced, reaching to proximal fourth or third of exopod 1. Left endopod elongate, reaching beyond middle of exopod 2.

Systematic Discussion

This new species is closely allied to *Diaptomus clavipes* Schacht (1897). The following notes comparing the characters of the two species are based upon study of a large number of specimens of both. Several collections of *clavipes* have been examined. Most of these are listed under the section "Distribution" as new records. In addition, some slides from the type lot in the Schacht collection, Illinois Natural History Survey have been studied, as well as whole specimens of *D. nebraskensis* Brewer (1898) from the type lot in the U. S. National Museum. As has been long recognized, Brewer's name is synonymous with *clavipes*.

Relationship of the two species is shown by both sexes. They do not vary widely from one another in total length range, and both have stout bodies and appendages. The females are very similar to one another, but exhibit several constant differences which are considered to be of specific value in these as well as in other diaptomids. In both species, the urosome is two-segmented and the genital segment is without noticeable lateral protrusions. Their differences are:

(1) *Metasome:* greatest width in the mandibular area of the cephalic segment in *clavipoides;* in the second segment in *clavipes.*

(2) *Metasomal wings:* with moderately developed inner lobes and of nearly same size in *clavipoides;* lacking inner lobes in *clavipes* and with the left wing more produced posteriorly than the right.

(3) *Antennule:* setae of segments 17, 19, 20 and 22 with unhooked ends in *clavipoides;* with hooked ends in *clavipes.*

(4) *Leg 5:* lateral seta of exopod 2 lacking in *clavipoides;* present in *clavipes.*

The structure of the fifth leg in the male is quite indicative of the close relationship of the two species. Each has on the posterior medial face of the right second basipod segment a proximal lobe and a large distal process. Comparable armature is found in other aglaodiaptomids (*leptopus, spatulocrenatus, conipedatus*) but the distal process is much smaller in them. *D. clavipes* and *clavipoides* are further distinguished from these species by the presence of the mesially directed process on the inner basal portion of this segment. It is in the same position in the two species, but differs in size and shape. In *clavipes,* it is comparatively small (its width about 13-15 percent of the length of the inner margin of the segment) and protrudes directly outward from the segment. In *clavipoides,* there is a stout basal portion with a nearly equally large, obliquely directed spiniform apex; its width is about 24-25 percent of the total length of the inner margin of the segment. In *clavipes* there is also a smaller process placed distad to the basal process near the middle of the segment (fig. 10). This second process is lacking in *clavipoides.* Other noticeable differences are the more reduced right endopod of *clavipoides,* and the greater length of the claw. In *clavipes,* the endopod

usually reaches to near the middle of the first segment of the exopod, and the claw is shorter than the exopod.

The left antennule of the male of *clavipoides* agrees with those of the female in having straight setae on segments 17, 19, 20 and 22; these were hooked in all the various collections of *clavipes* that were examined. The right antennule in these two species is similar in the armature and relative lengths of the spines of segments 8-16. The apical process of segment 23 was invariably present in the numerous specimens of *clavipoides,* all of which were checked for this character, but it was not found in specimens of *clavipes,* nor has it been recorded in literature for this species. In both, there is a lateral hyaline membrane along the entire margin of the segment; in *clavipes,* this membrane is very strongly developed with a well rounded apex.

The spermatophores attached to the female genital segment and also some dissected out from the body of the male, were bent near the base and curved as shown in figures 1 and 5. In the specimens of *clavipes* that were examined, the spermatophore is nearly straight and unangled as is usual in *Diaptomus.* What significance, if any, attaches to this unusual shape in *clavipoides,* is not known. On the basis of the type lot it is a character of distinction from *clavipes* and one that should be carefully checked in future studies of the species and other aglaodiaptomids.

The differences between the males of the two species may be summarized as follows:

(1) *Leg 5, right:* Second basipod segment, inner proximal process with enlarged basal portion and obliquely directed apex in *clavipoides;* without enlarged basal portion and the apex directed mesially in *clavipes;* no small process distad to proximal process in *clavipoides,* present in *clavipes.* Claw longer than exopod in *clavipoides;* shorter than exopod in *clavipes.* Endopod short in *clavipoides* (about one-fourth to one-third of length of inner margin of exopod 1); longer in *clavipes* (nearly one-half of exopod 1).

(2) *Antennule:* Left, setae of segments 17, 19, 20 and 22 with straight end in *clavipoides;* with hooked end in *clavipes.* Right, segment 23 produced into outwardly directed process and with lengthwise membrane in *clavipoides;* with membrane only in *clavipes.*

(3) *Spermatophore:* bent near base and curved in *clavipoides;* without such distinct curvature in *clavipes.*

Because of the seemingly close relationship of the new species to *clavipes,* particular attention was paid in study of specimens to the possible existence of variation in the characters by which the two forms are separated. Dissections of twenty specimens of both sexes of *clavipoides,* and of the same number of *clavipes* from a single sample (Baja California) were checked for variation in the stated diagnostic differences in the antennules and the fifth legs. In addition, these were further checked on two to five specimens of *clavipes* from each of the new collection records listed herein. No variation

was found in either species in any of the "present-absent" characters such as the lateral seta of the second exopod segment of the female fifth leg, the apical hook on certain antennular setae, the process of segment 23 of the male right antennule, and the small medial process of the right second basipod segment of the male fifth leg. In the "quantitative" characters such as the comparative size of the proximal process of the inner margin of the second basipod segment, the claw and endopod of the male right fifth leg no intermediate condition or overlap was found. Those characters for which dissection was unnecessary for observation, such as the attached spermatophore, the shape of metasome and wings, the apex of the antennular setae and the process of segment 23 of the male right antennule, were also checked on all the available whole specimens and no variation found.

Some of the structural characters of *clavipoides* are of considerable taxonomic interest. Among these is the lack of development of the third exopod segment and the absence of the lateral seta of the second exopod segment of the female fifth leg.

From species to species and also within individual species in the subgenus *Aglaodiaptomus,* there is considerable variation in the degree of development and the distinctness of separation of the third segment, but *clavipoides* is the only species in which I have observed the apparently constant combination of complete loss of both the third segment and the seta of the second segment. This is a distinctive character of three related North American subgenera, *Leptodiaptomus, Onychodiaptomus* and *Skistodiaptomus.* Between these subgenera and the common western and northern subgenus *Hesperodiaptomus,* the aglaodiaptomids are an intermediate group. This intermediate position is well emphasized in *clavipoides* in the reduction in the exopod of the female fifth leg.

The straight tips of the setae on certain segments of the female antennules and on the left antennule of the male in *clavipoides* have been particularly noted because in most of the species of the subgenus *Aglaodiaptomus* these setae have a characteristic hooked tip. Although small, this hook is distinct enough to be noticeable in undissected specimens under low power of the microscope. The variability of such a character might be questioned, but I have never found the hook lacking in large numbers of specimens of all the species concerned from a wide geographical range. The only species of the subgenus other than *clavipoides* in which this hook is not present is *D. stagnalis,* which also differs in several other details from the conditions usual in other aglaodiaptomids and has no near relative among the known species.

Most of the species of the subgenus *Aglaodiaptomus* have only 1 seta on each of segments 13-19. Those in which 2 setae are found on some segments are *stagnalis* (2 on 14, 16, 18, 19) and *lintoni* and *forbesi* (2 on 16). Occasionally, in this group as in other diaptomids having two setae on segment 11, an extra seta may be present on a segment which normally has only one. I have never observed in the

female such a seta on both antennules of a pair. This asymmetry coupled with the comparative rarity, makes this condition appear as an anomaly comparable to the occasional multiplication of other setae, claws or structures that have been noted in several appendages in all diaptomid groups. Among a large number (117) of female *clavipoides* carefully checked for antennal setation, two instances of such anomaly were found. One individual had two setae on segment 13 of the right antennule, another had two on segment 19 of the left; in each instance the corresponding segment of the opposite antennule was normal.

Distribution

D. clavipes was described from Iowa, and this is still the farthest eastern record. The summary of its distribution given by Marsh (1929) included records from only a few other states (Nebraska, Colorado, Texas). Since then, other records have extended or amplified its distribution: Oklahoma (Duck, 1937), Kansas (Leonard and Ponder, 1949; Ratzlaff, 1952); Texas and northern Mexico (Comita, 1951); Arizona, New Mexico, Montana (Kincaid, 1953); eastern Texas (M. S. Wilson, 1954).

The Light accession in the United States National Museum contains several collections of *clavipes* which further amplify its occurrence in southwestern United States and Mexico. These were all identified by Dr. Light, but have been verified in connection with the present study. The data with collections and associated calanoid species are as follows: *Arizona:* Small dammed reservoir in edge of hills, one mile south of Payson, Gila Co., May, 1935, S. F. Light, elevation 4800 feet; Coolidge Dam, San Carlos Lake, Gila Co., May, 1935, S. F. Light, elevation 2400 feet, with *D. siciloides;* Annex Lake, Coconimo National Forest, Coconimo Co., May 26, 1934, S. Wright, with *D. nudus;* About 10 miles north of Williams, Coconimo Co., May 15, 1937, A. Michelbacher, elevation 6690 feet, with *D. nudus*.

Nevada: Mead Lake, in deep water above dam, Clark Co., April, 1937, A. Michelbacher, with *D. siciloides. New Mexico:* A prairie lake near Clovis, Curry Co., July, 1941, Kathryn Buchanan, with *D. siciloides;* Another lake, same data, with *D.* (*Mastigodiaptomus*) *albuquerquensis. Texas:* Small artificial lake at Baird, Callahan Co., July, 1936, S. Wright, with *D. siciloides. Mexico:* Tank, 20 miles northeast of Cumondu, Baja California, July 21, 1938, A. Michelbacher and E. Ross, with *D. novamexicanus;* Presa de Hipolito, Coahuila, May 11, 1941, E. S. Deevey, with *D. siciloides.*

The common diaptomid association in these instances is with a species of the subgenus *Leptodiaptomus.* Such is also true in the occurrence of *clavipoides* with *D.* (*L.*) *moorei.* This latter species was also found in eastern Texas with *clavipes* (M. S. Wilson, 1954).

In present knowledge, therefore, the distribution pattern of *clavipes* includes the lower altitudes of the Rocky Mountains in the United States and neighboring areas of northern Mexico, the nearby south-

western states and those east to the Mississippi River. Its most western occurrence is in Baja California, Mexico. At present there are no known records from the state of California. The Nevada record given above is on the border of Arizona. Whether the species is generally spread in the western Mississippi Valley is still to be investigated. It can not be called a rare species, and its occurrence at widely ranging altitudes and in diverse bodies of water, such as lakes, reservoirs, ponds and roadside ditches, suggests both a much more common occurrence than now recorded and in part, at least, a fortuitous type of dispersal.

The comparative distribution patterns and associations of closely related species of diaptomids have been little considered in North America. We do not actually know what significance attaches to geographic distribution in relation to the taxonomy of diaptomid copepods. As a result of my studies, I have come to the conclusion that it may well be a very useful tool in the interpretation of taxonomy both in relation to the status of forms and the evaluation of characters. Of particular importance is the study of closely allied species (M. S. Wilson, 1953: 2). When thoroughly known, the comparative distribution patterns, associations and characters of these two aglaodiaptomid species may be of instructive value in the taxonomy of the group. Quite possibly, the two may be macrogeographically sympatric in the lower western Mississippi Valley and westward into Texas. This is already suggested by the presently known distribution of *clavipes* and the association of both species with *D. moorei* within a rather close geographic range as represented by the eastern Texas record of *clavipes* and the type locality of *clavipoides* in western Louisiana. The distribution of the latter species may be more localized or restricted than that of *clavipes,* but no conclusions on the presence or absence of either species can be reached until the region involved has been thoroughly surveyed.

References Cited

Brehm, Vincenz 1932. Notizen zur Süsswasserfauna Guatemalas und Mexikos. *Zool. Anz.,* 99: 63-66.

---------- 1939. La Fauna microscopica del Lago Peten, Guatemala. *Ann. Escuela Nac. Cienc. Biol.,* 1: 173-202.

Brewer, Albert D. 1898. A study of the Copepoda found in the vicinity of Lincoln, Nebraska. *Jour. Cincinnati Soc. Nat. Hist.,* 19: 119-138.

Coker, R. E. 1943. *Mesocyclops edax* (S. A. Forbes), *M. leuckarti* (Claus) and related species in America. *Jour. Elisha Mitchell Sci. Soc.,* 59(2): 181-200.

Comita, Gabriel W. 1951. Studies on Mexican copepods. *Trans. Amer. Micros. Soc.,* 70(4): 367-379.

Davis, Charles C. 1948. Notes on the plankton of Long Lake, Dade County, Florida, with descriptions of two new copepods. *Quart. Jour. Fla. Acad. Sci.,* 10(2-3): 79-88.

Davis, Charles C. and Robert H. Williams 1950. Brackish water plankton of mangrove areas in southern Florida. *Ecology,* 31: 519-531.

DICKINSON, J. C., JR. 1949. An ecological reconnaissance of the biota of some ponds and ditches in northern Florida. *Quart. Jour. Fla. Acad. Sci.*, 11(2-3): 1-28.

DUCK, LESTER G. 1937. Some copepods of Oklahoma. *Proc. Oklahoma Acad. Sci.*, 17: 34-35.

HARKNESS, W. J. K. and E. L. PIERCE 1940. The limnology of Lake Mize, Florida. *Proc. Fla. Acad. Sci.*, 5: 96-116.

HOFFMAN, CARL E. and DAVID CAUSEY 1952. Limnological studies in Arkansas. I. Physico-chemical and net plankton studies of Lake Fort Smith in its fourth year of impoundment. *Proc. Arkansas Acad. Sci.*, 5: 55-72.

KIEFER, FRIEDRICH 1936. Frielebende Süss- und Salzwassercopepoden von der Insel Haiti. *Archiv. Hydrobiol.*, 30: 263-317.

_____ 1938. Ruderfusskrebse (Crust. Cop.) aus Mexiko. *Zool. Anz.*, 123: 274-280.

KINCAID, TREVOR 1953. *A Contribution to the Taxonomy and Distribution of the American Fresh-water Calanoid Crustacea.* Calliostoma Co., Seattle, 73 pp. & Addendum, P. 74.

KING, JOSEPH E. 1950. A preliminary report on the plankton of the west coast of Florida. *Quart. Jour. Fla. Acad. Sci.*, 12(2): 109-137.

LEONARD, A. B. and L. H. PONDER 1949. Crustacea in eastern Kansas. *Trans. Kansas Acad. Sci.*, 52: 168-204.

MARSH, CHARLES DWIGHT 1907. A revision of the North American species of Diaptomus. *Trans. Wisc. Acad. Sci., Arts, Lttrs.*, 15(2): 381-516.

_____ 1929. Distribution and key of the North American copepods of the genus *Diaptomus*, with the description of a new species. *Proc. U. S. Nat. Mus.*, 75(14): 1-27.

PEARSE, A. S. 1938. Copepoda from Yucatan Caves. *Carnegie Inst. Wash., Publ.* 491: 153-154.

PECKHAM, RICHARD S. and CLARENCE F. DINEEN 1953. Summer plankton of Lake Amatitlan, Guatemala. *Amer. Midl. Nat.*, 50(2): 377-381.

PENN, GEORGE HENRY 1947. Branchiopoda and Copepoda of the New Orleans area as recorded by Ed Foster in the early 1900's. *Proc. Louisiana Acad. Sci.*, 10: 189-193.

PIERCE, E. L. 1947. An annual cycle of the plankton and chemistry of four aquatic habitats in northern Florida. *Univ. Fla. Studies, Biol. Sci. Ser.*, 4(3): 1-67.

SCHACHT, FREDERICK W. 1897. The North American species of *Diaptomus. Bull. Illinois State Lab. Nat. Hist.*, 5(3): 97-208.

RATZLAFF, WILLIS 1952. The limnology of some roadside ditches in Chase and Lyon Counties, Kansas. *Emporia State Res. Stud.*, 1(1): 5-32.

TAFALL, B. F. OSORIO 1941. *Diaptomus cuauhtemoci* nov. sp. de la mesa central de Mexico. *Ciencia* (Mexico), 2: 296-298.

_____ 1942a. Un nuevo "*Diaptomus*" del Mexico central (Copepoda, Diaptomidae). *Rev. Brasil Bio.*, 2(2): 147-154.

_____ 1942b. *Diaptomus (Microdiaptomus) cokeri*, nuevos subgenero y especie de Diaptomido de las cuevas de la region de Valles (San Luis Potosi, Mexico) (Copep., Calan.). *Ciencia* (Mexico), 3: 206-210.

_____ 1943. Observationes sobre la fauna acuatica de las cuevas de la region de Valles, San Luis Potosi (Mexico). *Rev. Soc. Mex. Hist. Nat.*, 4: 43-71.

WILSON, CHARLES BRANCH 1936. Copepods from the cenotes and caves of the Yucatan Peninsula, with notes on cladocerans. *Carnegie Inst. Wash., Publ.* 457: 77-88.

---------- 1938. Copepoda from Yucatan caves. *Carnegie Inst. Wash., Publ.* 491: 153-154.

WILSON, MILDRED STRATTON 1941. New species and distribution records of diaptomid copepods from the Marsh collection in the United States National Museum. *Jour. Wash. Acad. Sci.*, 31: 509-515.

---------- 1953. New and inadequately known North American species of the copepod genus *Diaptomus*. *Smithsonian Misc. Coll.*, 122(2): 1-30.

---------- 1954. A new species of *Diaptomus* from Louisiana and Texas with notes on the subgenus *Leptodiaptomus*. *Tulane Stud. Zool.*, 2(3): 49-60.

WILSON, MILDRED STRATTON and WALTER G. MOORE 1953a. New records of *Diaptomus sanguineus* and allied species from Louisiana, with the description of a new species (Crustacea: Copepoda). *Jour. Wash. Acad. Sci.*, 43(4): 121-127.

---------- 1953b. Diagnosis of a new species of diaptomid copepod from Louisiana. *Trans. Amer. Micros. Soc.*, 72(3): 292-295.

YEATMAN, HARRY CLAY 1944. American cyclopoid copepods of the *viridis-vernalis* group (including a description of *Cyclops carolinianus* n. sp.). *Amer. Midl. Nat.*, 32(1): 1-90.

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A NEW SPECIES OF *STERNOTHERUS* WITH A DISCUSSION OF THE *STERNOTHERUS CARINATUS* COMPLEX

(CHELONIA, KINOSTERNIDAE)

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Tulane University field crews under the supervision of Dr. Fred R. Cagle and supported by a grant from the National Science Foundation have done much to clarify the status of turtle populations in the rivers of the north Gulf coast (Cagle, 1952, 1953, 1954).

The collecting techniques developed, such as that described by Chaney and Smith (1950), made possible the procurement of samples of *Sternotherus* from the major rivers along the Gulf coastal plain. These samples revealed the presence of an undescribed species in the upper reaches of the Black Warrior river above the Fall Line in Alabama which is defined and named herewith.

The authors are indebted to Dr. Cagle for the opportunity provided of serving with the field crews; to Dr. Hobart M. Smith of the University of Illinois for examining selected specimens; to Dr. William B. Davis of Texas A. & M. College for making available the holotype of *Sternotherus peltifer* and other material; to Dr. Wilfred T. Neill of the Ross Allen Reptile Institute, Dr. Albert Schwartz of the Charleston Museum and Dr. Ralph L. Chermock of the University of Alabama for the loan of material; and to Mrs. Roger Conant and Mrs. Fred R. Cagle for photographs. We are grateful, also, to the many students who worked with us in the field for their contribution of time and ideas. The name for the new species was suggested by Dr. E. S. Hathaway, emeritus professor of Zoology at Tulane University.

Sizes referred to in the text are plastra lengths measured along the median longitudinal suture to the nearest tenth of a millimeter with a Vernier caliper. Sex in all Tulane (TU) specimens was determined by dissection.

STERNOTHERUS **DEPRESSUS**, sp. nov.

Holotype.—Tulane University number 16171, immature male, taken in the Mulberry Fork of the Black Warrier river, 9 miles east of Jasper, Walker County, Alabama, near the bridge crossing of U.S. highway 78, August 11-12, 1953, by Robert G. Webb and Donald W. Tinkle.

Paratypes.—Tulane University numbers 15902 (12) and 16062 (10) and Museum of Comparative Zoology number 54023, 18 females and five males collected at the type locality in June and August, 1953; University of Alabama 52-1065, 8 miles south of Carbon Hill, Walker County, Alabama, June 14, 1952, by H. Boschung and L. Cooper.

This latter paratype is the only adult specimen of the new species known to us. Twenty-five types and seven topotypes comprise the hypodigm.

Type locality.—A sluggish tributary of the Black Warrior river. All specimens taken at night, except one, by trapping or hand collecting from crevices in submerged stumps and in detritus along the shore.

Diagnosis and definition.—A species possessing a round, low carapace with flared marginals; obtuse vertebral angle; and a reticulated pattern of lines on the dorsum of the head. Adult with flat carapace, arched at the sides. Related to *Sternotherus carinatus* in having imbricate carapace shields, by absence of light stripes on the head and neck, absence of barbels on the neck, and lack of lateral keels in juveniles. There characters distinguish *S. carinatus* and *S. depressus* from *S. odoratus*. Differing from *S. c. carinatus* by lacking a high vertebral keel, absence of spots on the head, and presence of a gular scute. Differing from *S. c. peltifer* by lacking dark stripes on the sides of the head and neck, by having a flatter carapace with a larger ratio between vertebral angle and carapace height. Differing from *S. c. minor* by absence of lateral ridge, by a low carapace in adults which is flat on top, and by the presence of a reticulated pattern on the head.

Description of holotype.—Male; plastron length, 36.8 mm; maximum carapace length (straight line), 59.9 mm; carapace height from abdominals to juncture of second and third vertebrals, 18.5 mm; carapace width at juncture of sixth and seventh marginals, 52 mm; maximum head width, 12.6 mm; length of abdominal from axillary to inguinal periphery, 8.0 mm; interhumeral suture, 5.8 mm; interpectoral suture, 4.4 mm; interabdominal suture, 7.9 mm; interfemoral suture, 4.0 mm; interanal suture, 11.3 mm; length of mandibular symphysis, 6.0 mm; angle of keel at juncture of second and third vertebrals, 133°. Eleven marginals, the last two higher than any of the first nine. All vertebrals except first wider than long. Each carapace shield with dark streaks on a gray-green background. Center of each marginal with a radial light line distinct against the cloudy ground color. Plastron immaculate; gular scute single and small. Neck with seven broken, irregular thin lines on the dorsal and dorsolateral surfaces. Head pattern of fine, reticulated, and dark lines on a yellow-green ground color. The anterior surfaces of forelegs and posterior surfaces of hind legs with similar reticulate pattern. Tail with eight irregular dark lines converging distally. Horny beak of upper jaw with numerous, tangentially arranged, dark markings. Two chin barbels; no neck barbels.

Description of paratypes.—Measurements of the smallest and largest of the topotypes are: plastron length, 18.7 and 36.4 mm; maximum carapace length, 33.4 and 53.4 mm; carapace height, 9.5 and 16.8 mm; carapace width 31.3 and 50.0 mm; head width, 7.3 and 11.8 mm; abdominal length, 3.3 and 8.2 mm. Measurements other than plastra lengths do not necessarily reflect the maximum in these topotypes.

The elevation of the tenth and eleventh marginals above the preceding ones is more distinct in larger individuals. The dark markings on the carapace may be radiating lines, spots or small blotches. The markings are reduced in some turtles, but never absent. The plastra are usually covered with a brown deposit of environmental origin which must be removed to reveal the immaculate scutes. The gular is variable in size and unpaired.

Dark lines on the neck vary from five to 18, depending partially upon which are considered lines and which rows of tiny, sometimes united spots. The reticulated arrangement of dark lines on a light background gives the head a dendritic pattern, which is also present on the limbs. Dark tangential marks are universal on the beaks of both jaws. Dark lines present on the tail.

The vertebral angle was measured with aluminum wire (1.2 mm diameter) which was bent around the keel of the carapace at the juncture of the second and third vertebrals. The angle formed was traced on paper and measured with a protractor. This method is a slight modification of that reported by Mosimann (1955). The variation in this angle was 113° to 132°. The size of the angle is generally directly correlated with the size of the turtle. The inherent error for measurements of *S. c. carinatus* and *S. depressus*, the forms representing the extremes of size of the angle, was two to four (mean 2.44 degrees) for the former and four to six (mean 4.75 degrees) for the latter. The error for the other forms presumably lies between these extremes.

The adult paratype must be given special consideration. Its color pattern is identical with that of the holotype. The carapace is low, but flat and is arched at the sides, unlike any of the topotypes. Its combination of characters sets this turtle apart from adults of any other form in the *Sternotherus carinatus* complex. Measurements are as follows: plastron length, 55.8 mm; carapace length, 89.4 mm; carapace height, 26.7 mm; carapace width, 60.4 mm; interhumeral suture, 6.2 mm; interpectoral suture, 10.6 mm; interabdominal suture, 16.1 mm; interfemoral suture, 6.8 mm; interanal suture, 14.2 mm.

Little variation of the differentiating characters exists in the paratypic series. All are similar to the holotype in general appearance, pattern and proportions.

Range.—This species has been taken only from a two mile length of the Mulberry Fork of the Black Warrior river in the vicinity of the type locality, and from a stream in the Black Warrior drainage, eight miles south of Carbon Hill. Both localities are in Walker County, Alabama, above the fall line. *Sternotherus depressus* is undoubtedly more widespread, and should be expected in Tennessee, particularly in the drainage of the Tennessee River. Its known distribution presents a geographic puzzle. Collections made in the Black Warrior river in Greene and Tuscaloosa counties, Alabama, contain only *S. c. peltifer* which has not been found in the Black Warrior above the fall line where *S. depressus* occurs. In the Coosa river of

TABLE 1.

COMPARISON OF THE FORMS IN THE *Sternotherus carinatus* COMPLEX.

Character	*depressus*	*peltifer*	*minor*	*carinatus*
Gular scute	present	present	present	absent
Stripes on head and neck	If present, narrow	wide and distinct	absent in most	never present
Carapace angle	Wide in all; always greater than 100°	narrow in juveniles; increasing with age. Less than 100° in juveniles	as in *peltifer*	Narrow in all; less than 100° in all, less than 45 mm carapace height
Angle/height ratio	Mean about 9.5 in juv.	Mean about 5.0 for those with keel	as in *peltifer*	Mean about 4.0 for those with keel
Carapace shape and arching	Circular in outline; adult with arched sides but flat top	Less circular. Sides arched, but not flat on top	as in *peltifer*	Less circular; some arching in old individuals, but high keeled usually retained
Keels	None sharp; mid-dorsal present and blunt	1 distinct in juveniles, none in adult	3 in juv., none in adult	1 distinct in all
Pattern on dorsum of head	Reticulated pattern of fine lines	Usually spotted; a few reticulated posteriorly	Usually spotted; in some, spots coalesced into blotches	always small spots
Range	Northern Alabama and probably Tennessee	Alabama, Miss., and W. Florida	Fla. and Ga., possibly E. Alabama	East central Texas to eastern Miss.

eastern Alabama, *S. c. peltifer* occurs above the fall line and *S. depressus* is absent.

Comparisons (Table 1).—*Sternotherus depressus* is an unusual turtle. The low carapace with flaring marginals gives the turtle the appearance of being dorsoventrally flattened, whence the specific name (fig. 1-4). The characteristic depression of the carapace has been placed on a quantitative basis by calculation of the ratio of carapace angle to carapace height. *Sternotherus depressus,* at least the juveniles, are strikingly different in this character from other members of the *Sternotherus carinatus* complex (fig. 7).

Another distinctive feature of young *S. depressus* is the shape of the carapace in outline as seen from dorsal aspect. The shape more closely approaches the form of a circle than does that of any other members of the genus. A ratio of carapace-length/carapace-width expresses this characteristic and demonstrates the differences in this character between the members of the *Sternotherus carinatus* complex (fig. 8).

The general shape of the carapace in cross section is important in distinguishing among juveniles in the *S. carinatus* complex (fig. 9). Though distinct in some features, *Sternotherus depressus* is most closely allied to *S. c. peltifer* in general appearance and totality of characters.

Discussion.—Allopatric populations with some resemblances are usually considered to be subspecifically related. However, in this instance, the striking differences of *S. depressus* and the lack of evidence of intergradation make the elevation of this form to specific rank a more conservative procedure. *Sternotherus depressus* is almost as different in its peculiar characteristics from *S. carinatus* and *S. odoratus* as the latter two are from one another. Further knowledge

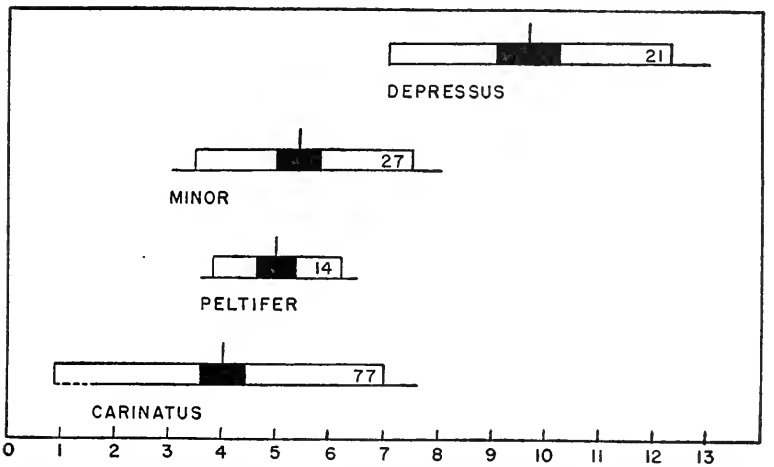


Figure 7. Comparison of carapace - angle/carapace - height ratios. Block diagram shows mean, two standard errors and two standard deviations.

of distribution and variation of *S. depressus,* as well as other members of the complex, may alter this tentative conclusion.

The turtles referred to as *Sternotherus carinatus peltifer* fit the description of that form given by Smith and Glass (1947). We have compared our specimens with the holotype in the Texas Cooperative Wildlife Collection of Texas A. & M. College. This form was described as *Sternotherus peltifer.* Carr (1952) referred it to conspecificity with *S. carinatus.*

Because *S. c. peltifer* is most closely related to *S. depressus* a redescription of the former is needed in order to evaluate its status and understand its relationships within the *Sternotherus carinatus* complex. We have available 24 specimens from which the following description was made.

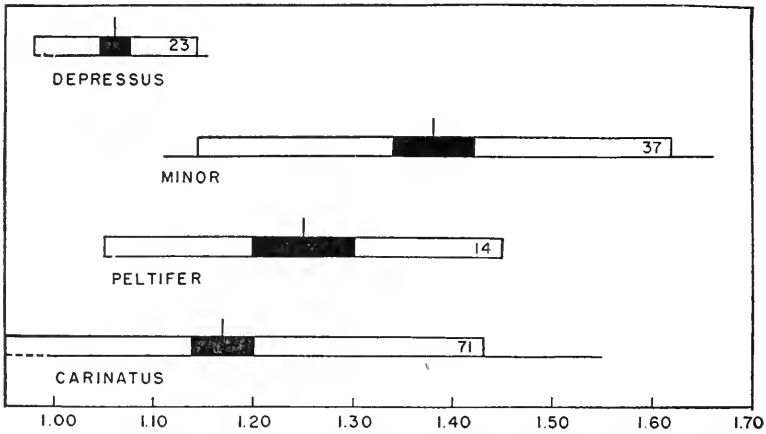


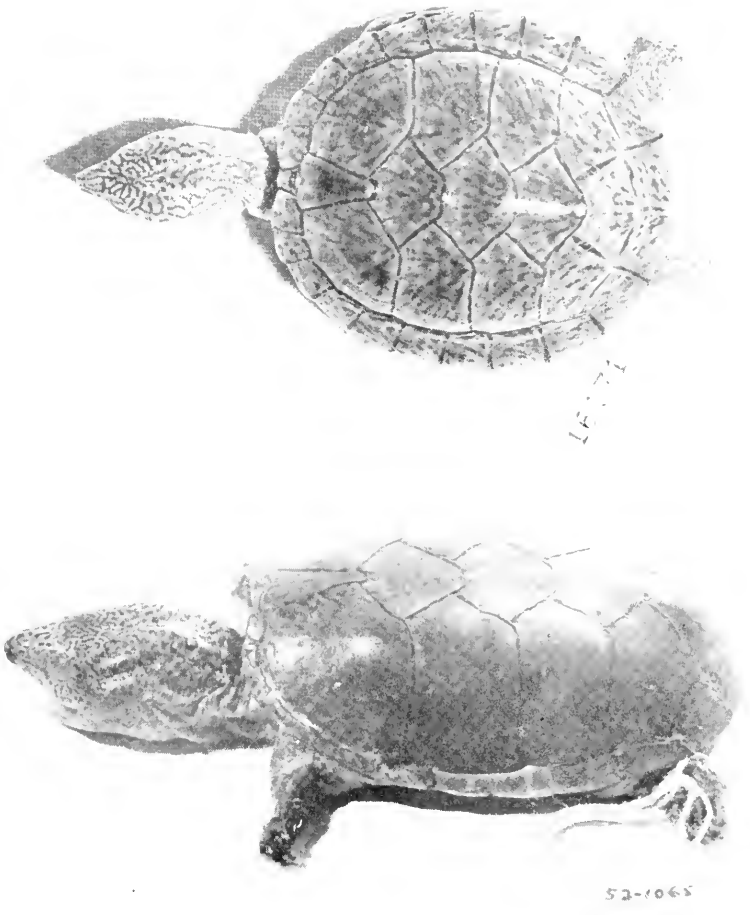
Figure 8. Comparison of carapace - length/carapace - width ratios. Block diagram shows means, two standard errors and two standard deviations.

Status of *Sternotherus c. peltifer* Smith and Glass

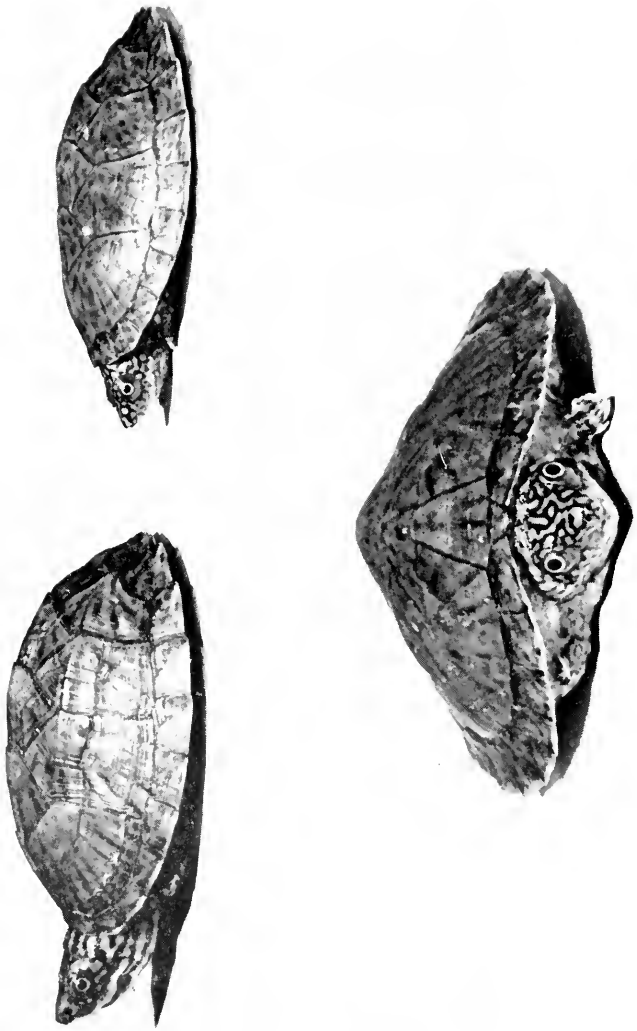
The holotype is similar in every detail to our specimens. Four of the latter are from the Coosa River above the fall line in Alabama, and the remainder from the Alabama and Black Warrior rivers below the Fall Line.

The character of size of the axillary and inguinal scutes used by Smith and Glass (1947) holds for all specimens, *i.e.* in each these scutes are small and longer than broad. This character is of no value in differentiating *S. c. peltifer* and *S. depressus.* The striping on the sides of the head and neck is the best character for distinguishing *S. c. peltifer* from the majority of individuals of other forms in the complex (fig. 5-6). This striping occurs in occasional specimens of *S. c. minor,* but not to the extent characteristic of *S. c. peltifer.*

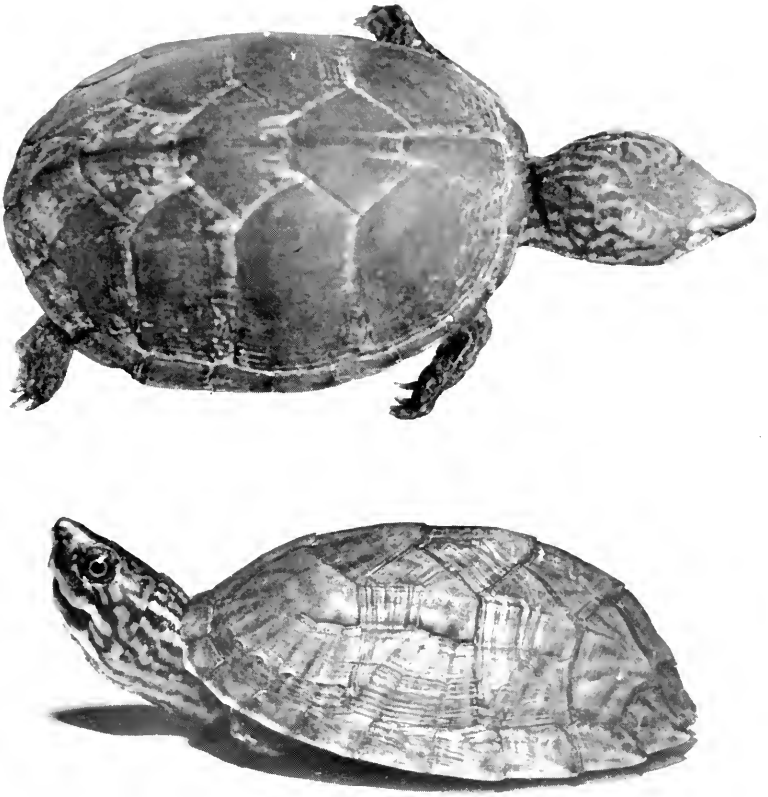
The second, third and fourth vertebrals are broader than long in all individuals. This is true generally also of *S. depressus.* The length



Figures 1-2. **1.** (top) Holotype of *Sternotherus depressus*. **2.** (bottom) Adult paratype of *Sternotherus depressus* (Photographs by Mrs. Fred R. Cagle).



Figures 3-4. **3.** (top) *Sternotherus carinatus peltifer* and *S. depressus*. Juveniles of approximately same size **4.** (bottom) Front view of *S. depressus* showing flared marginals (Photographs by Isabelle Hunt Conant).



Figures 5-6. **5.** (top) Holotype of *Sternotherus carinatus peltifer* (Photograph by R. G. Webb) **6.** (bottom) Juvenile *S. c. peltifer* from Black Warrior River, Tuscaloosa County, Alabama (Photograph by Isabelle Hunt Conant).

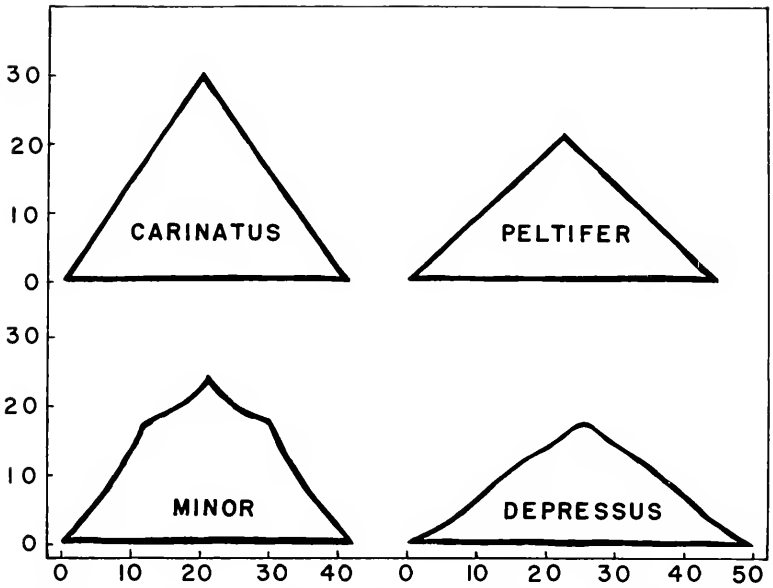


Figure 9. Relative carapace shapes of juvenile representatives of each member of the *Sternotherus carinatus* complex. Height is shown on ordinate and width on abscissa. All specimens are of the same plastron length.

of the median humeral suture is too variable to be of any diagnostic value. In general appearance, *S. c. peltifer* is most similar to *S. c. carinatus* because of the prominent median dorsal keel. This keel is never as high nor sharp as in the latter, and is completely lost in older individuals of *S. c. peltifer* which developed the arched carapace characteristic of *S. c. minor.* Lateral keels are absent, but in small individuals faint ridges are present on some of the costal shields. The carapace pattern is of dark lines on each shield radiating from the postero-dorsal corner. The plastra are immaculate.

The dorsal surface of the head in all individuals below the Black Belt (Chermock, 1952) is marked with small dark spots which are sparse or absent in the nasal region. These spots predominate also in individuals above the Black Belt, but fusion of the spots and development of a partially reticulated pattern (like *S. depressus*) occurs in a few individuals.

The gular is unpaired in all except one individual which lacks this scute. Two chin barbels are present; no barbels present on the neck. The ventral surface of the neck is well marked, but the pattern is variable from distinct longitudinal stripes to a reticulate or diffuse pattern of spots.

In summary, *S. c. peltifer* is a musk turtle with a distinct middorsal keel which becomes reduced with increasing age; with no lateral keels;

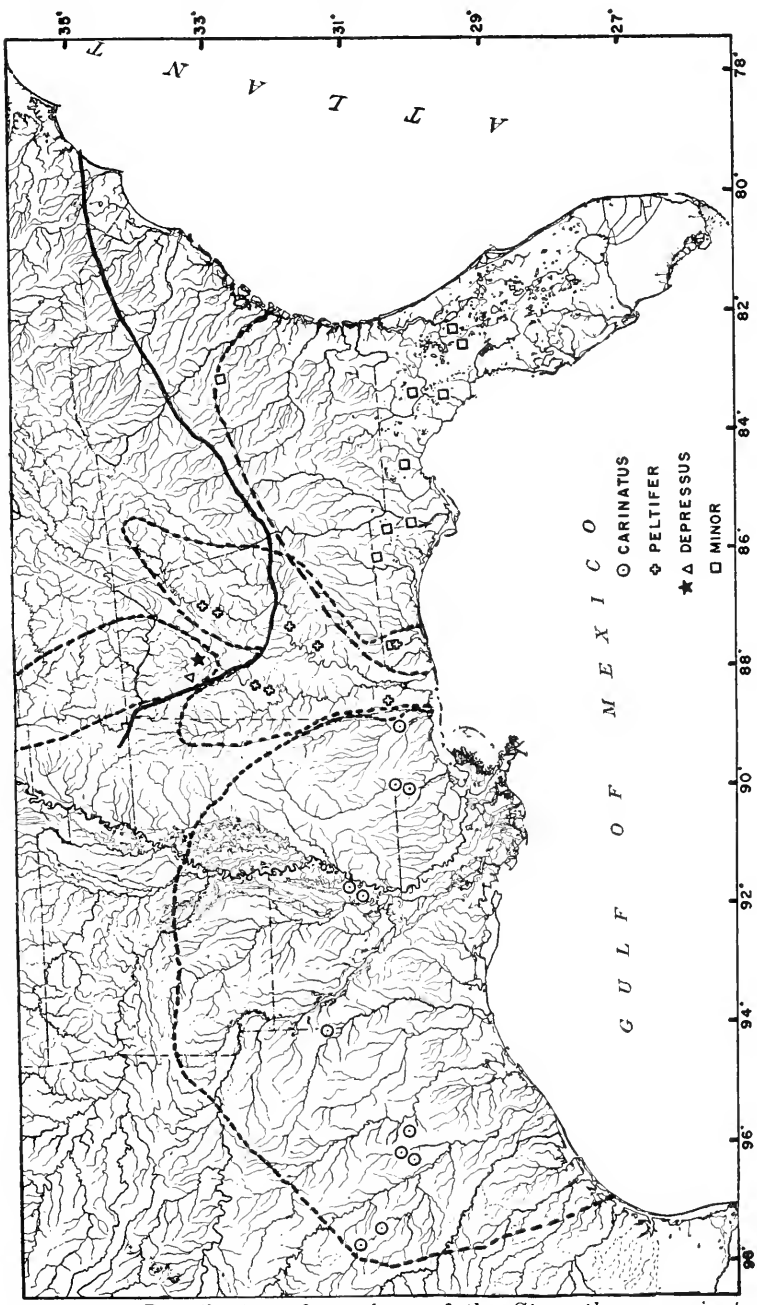


Figure 10. Distribution of members of the *Sternotherus carinatus* complex. The symbols show actual localities from which material has been examined (star symbol is type locality of *S. depressus*). Dotted line shows hypothetical distributions and solid line approximates the geographic position of the Fall Line.

with unpaired gular; and with dark stripes on the sides of the head and neck.

The range of this form cannot be definitely delimited on the basis of existing records. The holotype was taken in the Pascagoula River drainage of central Mississippi. Two trips to the type locality failed to reveal the presence of *S. c. peltifer* in the area, but numerous *S. odoratus* were collected there. Intensive work on the Pascagoula river and seining in other rivers, streams and ponds in Mississippi has not produced additional specimens. Only *S. c. carinatus* is represented in turtle samples taken from the Pascagoula river. Assuming the validity of the type locality, *S. c. carinatus* may be sympatric with *S. c. peltifer,* or the inferred distribution may reflect an interdigitation of the ranges. The probable distribution of *S. c. peltifer* is Mississippi to western Florida. The northward distribution cannot be surmised but it definitely reaches into northern Alabama. Smith and Glass (1947) allocated a specimen from Tennessee mentioned by Stejneger (1923) to this form, but did not examine it. The specimens referred to by Neill (1948) from "near the fall line" in Georgia are *Sternotherus odoratus.* Neill reached and informed us of this conclusion in recent conversation, and showed us material similar to that described in his paper.

Further collections from critical areas and examination of additional museum material must serve as a basis for defining the ranges of the various forms under consideration. A map showing the probable distribution of the *Sternotherus carinatus* complex is given in figure 10.

Indicated taxonomic arrangement of *Sternotherus carinatus* complex

Sternotherus c. carinatus is distinctive by having a pronounced, acutely keeled carapace. This keel persists in old individuals, though somewhat blunted by slight arching of the carapace. The gular scute is absent. This turtle may be sympatric in part of its range with *S. c. peltifer.* These differences are of specific value and *Sternotherus carinatus* should be recognized as a distinct species. This arrangement leaves *S. c. minor* and *S. c. peltifer* in another group which would be *Sternotherus minor minor* and *Sternotherus minor peltifer* as previously suggested by Smith and Glass (1947). This is reasonable because both of these forms: (1) have the same growth progression, *i. e.* toward development of a low, unkeeled and arched carapace in adults; (2) are allopatric; and (3) the most important differentiating characteristic of *S. m. peltifer* (the head and neck striping) is present in some individuals of *S. m. minor.* More conclusive is the existence of a population of turtles in the Escambia river which is apparently an intergrading one between these two races.

Therefore, the genus *Sternotherus* consists of two well-marked species, *S. carinatus* and *S. odoratus* with another complex of less certain relationships made up of *S. depressus* and the two races of *S. minor.* This latter group of three forms is more closely related to

S. carinatus than to *S. odoratus* and together with the former has been referred to as the *Sternotherus carinatus* complex. The senior author is continuing with a further study of the relationships in these species.

A tentative key for the identification of the majority of individuals in the various forms of *Sternotherus* follows. Although *S. odoratus* has not been considered in detail in this paper, it has been included in the key for the sake of completeness.

KEY TO MEMBERS OF THE GENUS STERNOTHERUS

1. Two distinct light stripes present on sides of head (if absent, head almost black); throat and chin barbels present; three dorsal keels (juveniles) or none; shields of carapace not overlapping; ground color of head usually dark. ..... *S. odoratus*

   Light stripes usually absent; if present they alternate with dark stripes; barbels on chin only; number of keels variable; shields of carapace overlap; ground color of head light. 2

2. Gular absent; head with dark spots on a light background; carapace with a high, sharp median keel, sloping abruptly to marginals. ..... *S. carinatus*

   Gular present; head with dark spots on a light background, or with dark stripes, or with a reticulated pattern; number of keels variable, but middorsal not as high nor as sharp as in *S. carinatus;* adult specimens with distinctly arched carapace without a sharp median keel. 3

3. Sides of head with alternating dark and light stripes or with dark stripes on a light background; middorsal keel in juveniles is distinct and moderately high; never more than one keel. ..... *S. m. peltifer*

   Sides of head without dark and light stripes (rarely present and, if so, animal usually with three keels. 4

4. Head with dark spots on a light background; carapace relatively high, the ratio of carapace angle to carapace height less than six in individuals greater than 20 mm in height; juveniles with three keels; adults with at least a partially rounded carapace in cross section, not perfectly flat dorsally. ..... *S. m. minor*

   Head with a reticulate pattern of dark lines on a light background; carapace low, the ratio of carapace angle to carapace height greater than six in individuals greater than 20 mm in height; no sharp middorsal keel;

juveniles never with lateral keels; carapace of juveniles nearly circular in dorsal view; adults with a low carapace, arched at sides, but not rounded in cross section; carapace flat dorsally. ..... *S. depressus*

Material examined.—Numbers in parentheses indicate the total number of specimens in the series. Institutions from which material was utilized are abbreviated as follows: AU = University of Alabama; CM = Charleston Museum, Charleston, S. C.; TCWC = Texas Cooperative Wildlife Collection of Texas A. & M. College; TU = Tulane University; RARI = Ross Allen Reptile Institute.

Sternotherus depressus: TU 15902 (12), TU 16062 (11), TU 16631 (5), Mulberry Fork of the Black Warrior River, 9 mi. e. Jasper, Walker Co., Ala.; AU 52-1065, 8 mi. s. Carbon Hill, Walker Co., Ala.

Sternotherus carinatus peltifer: TU 1504, 1513, 1515, 5859-62, Navco, Mobile Co., Ala.; TU 14668 (2), 14732, 16064, 16167, Black Warrior River, 17 mi. ssw. Tuscaloosa, Tuscaloosa Co., Ala.; TU 15634, 3.4 mi. sw. Camden, Wilcox Co., Ala.; TU 16168, Coosa River at Childersburg, Shelby Co., Ala; TU 16608, Alabama River, 4 mi. n. Whitehall, Lowndes Co., Ala.; TU 16623 (3), Black Warrior River, 3 mi. e. Eutaw, Greene Co., Ala.; TU 16634 (4), Coosa River, 6 mi. e. Pell City, Talladega Co., Ala.

Sternotherus carinatus carinatus: TU 1373, 1379-80, 1385, 1395, 1408-09, 1412, 1426, 1433, 1437, 1439, 1452-54, 1456, 1460, 1470, 1472-75, 1478-79, 1482, Jonesville, Catahoula Par., La.; TU 11303, 14010, Pearl River near Angie, Washington Par., La.; TU 11647-48, 11661 (5), 12011-12, 12038-41, 12058 (23), Pearl River, 7 mi. e. Varnado, Washington Par., La.; TU 14349, tributary of Sabine River, 9 mi. nw. Joaquin, Shelby Co., Texas; TU 14816 (10), 14925, 16545 (4), Pascagoula River, 13 mi. sw. Lucedale, George Co., Miss.; TU 16047 (2), Tensas River at Clayton, Concordia Par., La.; TCWC 511-13, Twin Lakes, Madison Co., Tex.; TCWC 521, 684, Wickson Lake, Brazos Co., Tex.; TCWC 4647, Navasota River, 6 mi. w. Normangee, Brazos Co., Tex.; TCWC 4689-90, Black Lake, 17 mi. nne. Bryan, Brazos Co., Tex.; TCWC 7236, Gatesville, Coryell Co., Tex.; TCWC 8978-79, Leon River, 5 mi. n. Hamilton, Hamilton Co., Tex.

Sternotherus carinatus minor: CM 57-87-2 (2), RARI 769-79, McKinneys' Pond near Midville, Emanuel Co., Ga.; CM 54-144-12 (23), RARI 700-719; 721-731, Ichtucknee Spring run between Suwannee and Columbia Cos., Fla.; RARI 732-33, 736, 743-45, 765-68, 787, 788-90, 797-99, 804, Silver Springs, Marion Co., Fla.; RARI 734-35, 742, Silver Glen Springs, Marion Co., Fla.; RARI 737, small stream near Eureka, Marion Co., Fla.; RARI 739-41, 746-53, 754-64, 780-85, 803, 786, 793-96, Chipola River, 4 mi. n. Scott's Ferry, Calhoun Co., Fla.; RARI 791-92, Oklawaha River near its junction with Fla. hwy. 40, Marion Co., Fla.; TU 13313, 13342-43, 13353, 13356, 13359,

13368-69, 13411, 13422, 13574 (2), 15244, Chipola River, 4 mi. s. Marianna, Jackson Co., Fla.; TU 15629, 6.5 mi. nw. jct. hwys. 79 and 177, Holmes Co., Fla.; TU 15829 (5), 16565 (16), Escambia River, 1.2 mi. e. Century, Escambia and Santa Rosa Cos., Fla.; TU 15848 (5), Wacissa River, 1 mi. s. Wacissa, Jefferson Co., Fla.; TU 15915 (18), Suwannee River at Fannin Springs, Gilchrist Co., Fla.

References Cited

Cagle, Fred R. 1952. The status of the turtles *Graptemys pulchra* Baur and *Graptemys barbouri* Carr and Marchand, with notes on their natural history. *Copeia*, 1952 (4): 223-234.

---------- 1953. Two new subspecies of *Graptemys pseudogeographica*. *Occ. Pap. Mus. Zool. Univ. Mich.*, No. 546: 1-17.

---------- 1954. Two new species of the genus *Graptemys*. *Tulane Stud. Zool.*, 1(11): 165-186.

Carr, Archie F. 1952. *Handbook of Turtles*. Comstock Publ. Co., Ithaca, New York. pp. 1-542.

Chaney, A. H. and C. L. Smith 1950. Methods for collecting map-turtles. *Copeia*, 1950 (4): 323-324.

Chermock, Ralph L. 1952. A key to the amphibians and reptiles of Alabama. *Geol. Surv. Ala., Mus. Pap.*, No. 33: 1-88.

Mosimann, J. 1955. Methods for measuring cross-section and volume on turtles. *Copeia*, 1955 (1): 58-61.

Neill, Wilfred T. 1948. The musk turtles of Georgia. *Herpetologica*, 4(5): 181-183.

Smith, Hobart M. and Bryan P. Glass 1947. A new musk turtle from the southeastern United States. *Jour. Wash. Acad. Sci.*, 37(1): 22-24.

Stejneger, Leonhard 1923. Rehabilitation of a hitherto overlooked species of musk turtle of the southern states. *Proc. U. S. Nat. Mus.* 62(6): 1-3.

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A NEW *CAMBARUS* OF THE *DIOGENES* SECTION FROM NORTH LOUISIANA

(DECAPODA, ASTACIDAE)

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A NEW *CAMBARUS* OF THE *DIOGENES* SECTION FROM NORTH LOUISIANA

(DECAPODA, ASTACIDAE)

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Department of Zoology, Tulane University, New Orleans, Louisiana

The *Diogenes* section of the genus *Cambarus,* to which the new species described here belongs, was defined by Ortmann (1931: 146) to include those species with an ovate, depressed cephalothorax without lateral spines; rostrum without lateral spines; chelae short and broad, depressed, and ovate; areola very narrow or obliterated in the middle, and always distinctly longer than half of the cephalic section of the cephalothorax. Up until now seven species and a subspecies have been assigned to this section: *Cambarus diogenes diogenes* Girard (1852: 88), *C. diogenes ludovicianus* Faxon (1884: 144), *C. fodiens* (Cottle, 1863: 217), *C. hedgpethi* Hobbs (1948: 224), *C. byersi* Hobbs (1941: 118), *C. uhleri* Faxon (1884: 116), *C. carolinus* (Erichson, 1846: 96), *C. monongalensis* Ortmann (1905: 395), and a species described but unnamed by Hobbs (1942: 168).

Most of the material on which the description is based was collected in the vicinity of Ruston, Louisiana by Thomas H. Nickerson to whom I am indebted for these and other lots of crawfishes.

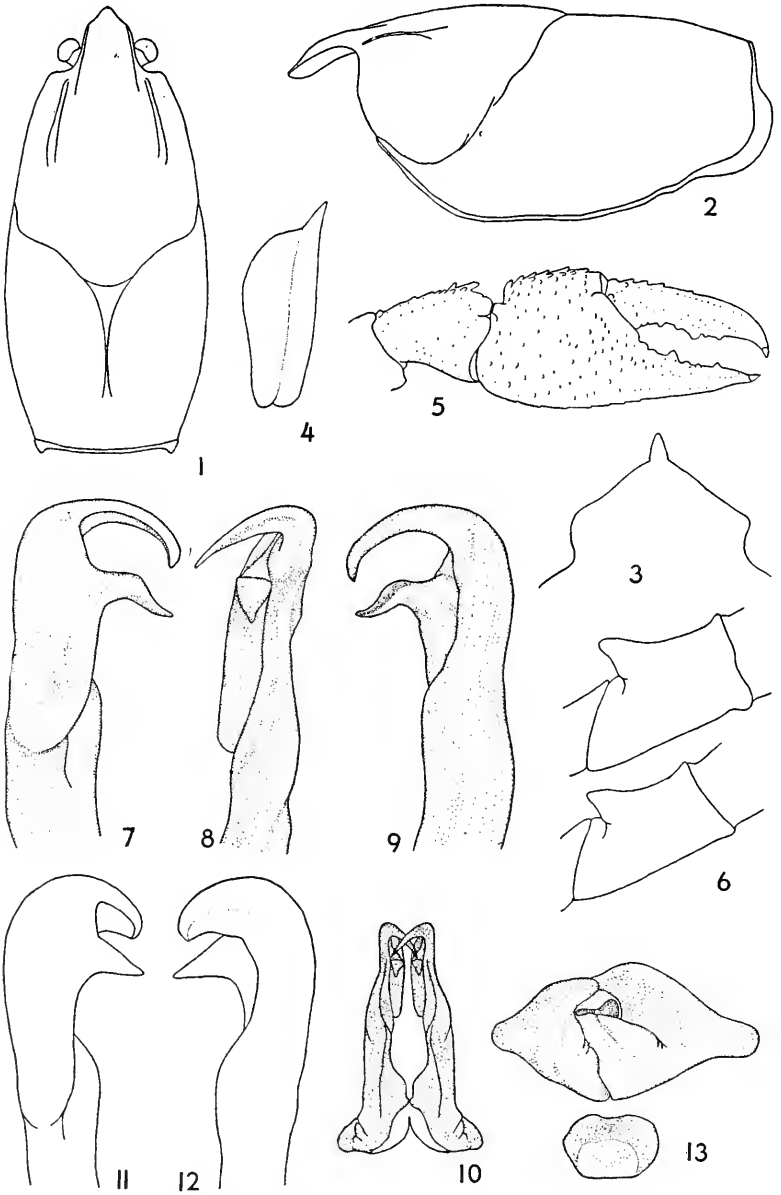
CAMBARUS **DISSITUS,** sp. nov.

Diagnosis.—Rostrum without lateral spines; antennal scale not extending beyond tip of rostrum; areola obliterated or very narrow in middle; chelae depressed apically, palm inflated; hooks on ischiopodites of third and fourth pereiopods; mesial process of first pleopod of form I male grooved so as to appear twisted; central projections of the two first pleopods recurved caudomesiad so that *in situ* they overlap in the mid-ventral line.

Holotype male, form I.—Body ovate; abdomen narrower than cephalothorax (10.0-12.5 mm in widest parts respectively). Width of cephalothorax (figs. 1, 2) equal to depth in region of caudodorsal margin of cervical groove (12.0-12.0 mm). Greatest width of cephalothorax slightly caudad of caudodorsal margin of cervical groove.

Areola obliterated in middle; cephalic section of cephalothorax 1.62 times as long as areola; length of areola about 38 percent of entire length of cephalothorax.

Rostrum directed cephaloventrad; upper surface shallowly excavate; margins converge slightly from base and turn abruptly mesiad at base of the acumen; no lateral spines, hence acumen is not distinctly set off from the rest of the rostrum. Rostrum with a few punctations at base; apical two-thirds glabrous. Rostral ridges weakly inflated. Postorbital ridges low and terminating anteriorly without spines. Branchiostegal spines minute, blunt.



Figures 1-13. *Cambarus dissitus*, sp. nov.: **1, 2,** cephalothorax of the holotype; **3,** epistome of the holotype; **4,** antennal scale of the holotype; **5,** chela and carpus of the holotype; **6,** hooks on the third and fourth pereiopods of the holotype; **7, 8, 9,** mesial, caudal and lateral views of the first pleopod of the holotype; **10,** ventral view of two first pleopods *in situ* on a paratype; **11, 12,** mesial and lateral views of the first pleopods of the morphotype; **13,** annulus ventralis of the allotype. Pubescence removed from all structures illustrated.

Surface of cephalothorax sparsely punctate dorsally and slightly granulate laterally.

Cephalic section of telson with one spine in each caudolateral corner.

Epistome (fig. 3) wider than long, terminating anteriorly in a strong median spine.

Eyes normal.

Antennules of usual form; a spine present on ventral side of basal segment.

Antennae broken (but, not extending beyond the caudal margin of the cephalothorax in any of the other specimens examined). Antennal scale (fig. 4) short, not reaching tip of rostrum; total length approximately one-fourth that of areola (2.5-10.5 mm); widest point distad of middle; lateral margin terminating in a strong spine.

Right chela (fig. 5) depressed; palm inflated; thickness of palm about 70 percent of its width (5.0-8.5 mm). Fingers curved ventrally from their bases, gaping for entire length; fingers punctate above and below; palm punctate above, sparsely granulate below. Palm with six tubercles along mesial margin. Immovable finger with six tubercles on basal two-thirds of opposable margin; third tubercle from base of finger largest. Dactyl with five tubercles on basal two-thirds of opposable margin; middle tubercle largest.

Carpus (fig. 5) longer than wide, slightly longer than mesial margin of palm (7.7-6.0 mm); with a well-defined longitudinal furrow above. Mesial margin with seven tubercles irregularly arranged, the largest one at the distal end. Under side with five small tubercles near mesial margin and two larger ones at distal end.

Hooks (fig. 6) present on ischiopodites of third and fourth pereiopods. Hooks simple; length of hook on third pereiopod about one-half the greatest width of the ischiopodite; length of hook on fourth pereiopod about one-third the greatest width of the ischiopodite.

Coxopodite of fourth pereiopod with a prominent, flattened, ventrocaudal longitudinal projection which meets anterior margin of coxopodite of fifth pereiopod.

First pleopod (figs. 7, 8, 9) reaching to middle of coxopodite of third pereiopod when abdomen is flexed; terminating in two distinct parts. Central projection corneous and bladelike, recurved caudomesiad at slightly greater than a right angle to main shaft of pleopod; fusion line of its two component elements clearly marked. Mesial process grooved so as to appear twisted; not bulbous; recurved caudolaterad at slightly more than a right angle to the main shaft of the pleopod. *In situ,* the central projections of the two pleopods overlap each other in the mid-ventral line (fig. 10). Mesial surface of the endopodite heavily bearded.

Morphotype male, form II.—Very similar to holotype in general appearance; areola slightly open (Table 1); chelae and hooks on

TABLE 1.
MEASUREMENTS (IN MILLIMETERS) OF *Cambarus dissitus* TYPES

	Holotype ♂ I	Allotype ♀	Morphotype ♂ II
Cephalothorax			
Length	27.5	29.0	25.5
Width (greatest)	12.5	14.0	11.5
Depth (greatest)	12.0	12.0	11.0
Areola			
Length	10.5	11.0	9.5
Width (at narrowest part)	0.0	0.1	0.2
Rostrum			
Length	4.7	4.5	4.2
Width at base	3.8	3.7	3.7
Antennal scale			
Length	2.5	2.2	2.5
Width (greatest)	1.0	1.1	1.0
Epistome			
Length	1.1	1.4	1.1
Width	2.4	2.6	2.3
Abdomen			
Length (including telson)	24.0	28.0	23.0
Chela			
Length of outer margin	17.0	15.0	14.0*
Length of dactyl	11.5	10.0	9.0
Width of palm	8.5	7.6	6.5
Thickness of palm (greatest)	5.0	4.5	4.0

* left chela measured on morphotype; right chela on other types.

ischiopodites of third and fourth pereiopods reduced. First pair of pleopods (figs. 11, 12) reaching to caudal margin of coxopodites of third pereiopods when abdomen is flexed; all processes reduced and non-corneous.

Allotype female.—Very similar to holotype in general appearance; areola slightly open (Table 1); chelae reduced. Caudoventral projections on coxopodites of fourth pereiopods undeveloped. Annulus ventralis (fig. 13) immovable, about 2.25 times wider than long; with a rounded depression on the anterior face, behind and ventral to which there is an irregular antero-ventrally projecting transverse ridge. The whole effect in ventral aspect resembles somewhat a baseball catcher's mitt standing on edge. The sinus originates in the right side of the anterior depression, runs ventrally and dextrad to the apex of the posterior ridge, then turns sinistrad to the midline on the posterior face of the annulus and terminates near the base. The sternites of the fourth and fifth thoracic segments are smooth and do not encroach on the annulus.

Type locality.—The holotype was dug from a shallow burrow near a stream three miles east of Choudrant, Lincoln Parish, Louisiana, on February 24, 1952 by T. H. Nickerson. The allotype and morpho-

type were dug from similar burrows two miles east of Choudrant on the same day. No other species of crawfishes was found at either locality.

Disposition of types.—The holotype, allotype and morphotype are deposited in the United States National Museum, numbers 98125, 98126, and 98127 respectively. The 31 paratypes are in the following collections: Academy of Natural Sciences of Philadelphia, American Museum of Natural History, Carnegie Museum, personal collection of Dr. Horton H. Hobbs, Jr. at the University of Virginia, and Tulane University.

Geographic distribution.—The type series of *Cambarus dissitus* were collected from four localities in northern Louisiana. These records and a summary of deposition of specimens are as follows: *Caldwell Parish:* 2 ♂♂ I, Kelly, December 24, 1953, W. E. Shell (TU 2998); *Lincoln Parish:* 2 ♂♂ I, three miles east of Choudrant, February 24, 1952, T. T. Nickerson (USNM 98125, TU 3124); 1 ♂ I, 2 ♂♂ II, 2 ♀♀, 1 ♂ juv., 2 ♀♀ juv., two miles east of Choudrant, February 24, 1952, T. H. Nickerson (USNM 98126 and 98127, TU 3123); 12 ♂♂ I, 7 ♀♀, 3 ♀♀ juv., Ruston, May 17, 1953, T. H. Nickerson (ANS, AMNH 11756, CM, HHH, USNM 98128, TU 3125).

Ecological and life history notes.—All collections have come from the upland shortleaf and longleaf pine hills of the State. The soils of this area are for the most part sand and sandy clay (longleaf pine hills) or sandy clay and silt of non-alluvial character (shortleaf pine hills) both of which are usually well drained and fairly dry (Viosca, 1933). All of the specimens were dug from shallow burrows, two along a stream, two in a hillside seepage area, the remainder in areas considerably farther removed from surface water.

Form I males were taken in February, May and December, mature females only in February and May. The smallest juvenile, a female with an 18.0 mm cephalothorax, was taken in May. The absence of smaller juveniles from all collections of *C. dissitus* is suggestive of an aquatic habitat for the immature stages, as in other species of the section, but it may represent merely the bias of the collectors.

Variation.—Body ratios from four samples (17 specimens) of form I males (Table 2) and two samples (8 specimens) of mature females (Table 3) show the greatest variability in the length of the rostrum, length of the antennal scale, and width of the areola. Although the rostrum, expressed as a proportion of cephalothoracic length, shows considerable variation in length, the length-width proportions are relatively constant in both males and females. The same appears to hold true for the antennal scale in relation to cephalothoracic length and in length-width ratios. In all except two specimens (TU 2998) the antennal scale was notably short and did not extend anteriorly to the tip of the rostrum. The only other species of the section with such a short antennal scale is *Cambarus byersi.*

The areola is obliterated in the middle in twenty (58.8 percent)

TABLE 2.

BODY PROPORTIONS OF FORM I MALE *Cambarus dissitus*

	Holo-type	Paratypes						All Combined	
	USNM 98125	TU 2998 Range	Avg.	TU 3123	TU 3124	ex-TU 3125† Range	Avg.	Range	Avg.
Number of Specimens	1	2		1	1	12		17	
Cephalothorax Length, mm	27.5	24.2 – 25.5	—	31.5	29.0	24.0 – 30.5	—	24.0 – 31.5	—
Cephalothorax: Length/Width	2.20	2.04– 2.20	2.12	2.10	2.07	2.12– 2.29	2.18	2.04– 2.29	2.16
Cephalothorax: Length/Antennal Scale	11.00	10.20– 11.00	10.60	11.25	10.35	10.20– 13.25	11.22	10.20– 13.25	11.08
Cephalothorax: Length/Rostrum	5.85	6.72– 7.08	6.90	5.94	6.44	5.91– 6.78	6.28	5.85– 7.08	6.32
Cephalothorax: Length/Areola	2.62	2.55– 2.69	2.62	2.74	2.64	2.55– 2.79	2.68	2.55– 2.79	2.67
Cephalothorax: Length/Chela	1.62	1.46 *	1.46	1.54	1.32	1.35– 1.67	1.51	1.32– 1.67	1.50
Cephalothorax: Length/First Pleopod	3.67	3.45– 3.78	3.62	3.94	3.87	3.43– 3.99	3.80	3.43– 3.99	3.78
Cephalothorax: Width/Depth	1.04	1.09– 1.10	1.10	1.07	1.08	1.00– 1.17	1.09	1.00– 1.17	1.09
Head: Length/Antennal Scale	6.80	6.20– 6.91	6.56	7.14	6.61	6.40– 8.50	7.17	6.40– 8.50	7.04
Antennal Scale: Length/Width	2.50	2.44– 2.50	2.47	2.54	2.80	2.00– 2.50	2.32	2.00– 2.50	2.39
Rostrum: Length/Width	1.24	1.08– 1.13	1.08	1.23	1.13	1.04– 1.34	1.15	1.03– 1.34	1.15
Epistome: Length/Width	0.46	0.39– 0.43	0.41	0.54	0.44	0.44– 0.60	0.51	0.39– 0.60	0.49
Areola: Length/Width	‡	90.00–100.00	95.00	57.50	‡	90.00–105.00	‡	57.5 –105.00	‡
Chela: Length/Palm Width	2.00	2.03– *	2.03	2.05	2.20	2.00– 2.40	2.10	2.00– 2.40	2.09
Chela: Length/Dactyl	1.48	1.67– *	1.67	1.58	1.69	1.52– 1.68	1.61	1.48– 1.69	1.61
Chela: Palm Width/Palm Thickness	1.70	1.56– *	1.56	1.67	1.67	1.64– 1.85	1.75	1.56– 1.85	1.73

* one specimen without chelae

‡ includes specimens with areola obliterated; no average calculated

† includes 1 ♂ I in collections of USNM, ANS, AMNH, CM, HHH.

TABLE 3.

BODY PROPORTIONS OF MATURE FEMALE *Cambarus dissitus*

	TU 3123* Range	TU 3123* Avg.	ex-TU 3125† Range	ex-TU 3125† Avg.	All Combined Range	All Combined Avg.
Number of Specimens	2		6		8	
Cephalothorax Length, mm	26.5 – **29.0**	—	29.0 – 31.0	—	26.5 – 31.0	—
Cephalothorax: Length/Width	**2.07**– 2.21	2.14	2.03– 2.32	2.21	2.03– 2.32	2.19
Cephalothorax: Length/Antennal Scale	10.60– **13.18**	11.89	10.34– 11.60	11.21	10.34– 13.18	11.38
Cephalothorax: Length/Rostrum	5.64– **6.44**	6.04	6.27– 7.38	6.67	5.64– 7.38	6.51
Cephalothorax: Length/Areola	**2.64**– 2.79	2.72	2.58– 2.86	2.74	2.58– 2.86	2.74
Cephalothorax: Length/Chela	**1.93**– 1.96	1.95	1.87– 2.07	1.95	1.87– 2.07	1.95
Cephalothorax: Width/Depth	1.00– **1.17**	1.09	1.00– 1.11	1.07	1.00– 1.17	1.08
Head: Length/Antennal Scale	6.80– **8.18**	7.49	6.72– 7.40	7.11	6.72– 8.18	7.21
Antennal Scale: Length/Width	**2.00**– 2.27	2.14	1.92– 2.45	2.23	1.92– 2.45	2.21
Rostrum: Length/Width	1.18– **1.22**	1.20	1.02– 1.27	1.12	1.02– 1.27	1.14
Epistome: Length/Width	0.48– **0.54**	0.51	0.40– 0.50	0.45	0.40– 0.54	0.47
Areola: Length/Width	47.50–**110.00**	78.75	35.00– 60.00	‡	35.00–110.00	‡
Chela: Length/Palm Width	**1.97**– 2.14	2.06	2.00– 2.46	2.15	1.97– 2.46	2.13
Chela: Length/Dactyl	**1.50**– 1.52	1.51	1.49– 1.65	1.58	1.49– 1.65	1.56
Chela: Palm Width/Palm Thickness	1.66– **1.69**	1.68	1.63– 1.75	1.69	1.63– 1.75	1.69

* includes allotype (ratios in bold face), USNM 98126.

‡ includes specimens with areola obliterated; no average calculated

† includes 1 ♀ in collections of USNM, ANS, AMNH, CM, HHH and TU.

of the specimens examined, but there is considerable variation with respect to sex and age, *e.g.,* obliterated in 64.7 percent of form I males, 33.3 percent of mature females, 50.0 percent of form II males, and 83.3 percent of the juveniles. However, where the areola is open it is only slightly so and is never less than 35 times longer than its narrowest width.

Relationships.—With the exception of having hooks on the ischiopodites of its third and fourth pereiopods as opposed to hooks on only the third pereiopods of other species in the *Diogenes* section, *Cambarus dissitus* appears to be more closely related to *C. fodiens, hedgpethi* and *byersi* than any others. The twisted appearance of the mesial process of the first pleopod of form I males and general bodily proportions place it nearest to *hedgpethi.*

The first pleopods of *Cambarus dissitus* show a superficial similarity in structure to those of *Procambarus tenuis* Hobbs (1950: 194). In *P. tenuis* the cephalic process is reduced and inconspicuous and the caudal element is lacking, leaving the central projection and the mesial process as the most conspicuous parts. These are produced in a manner very similar to those of the genus *Cambarus* in general, but resemble the arrangement in *C. dissitus* most closely in the midventrally crossed-over central projections. Thus, *P. tenuis,* a disjunct member of the *Blandingii* section of *Procambarus,* and *C. dissitus* perhaps show a closer approach in pleopod structure than any other two species of their respective genera.

Only two other crawfishes are known with crossed-over pleopods: *Orconectes clypeatus* (Hay, 1899: 122) and *O. beyeri* Penn (1950: 166).

Derivation of name.—The species name is derived from the Latin word *dissitus,* meaning "lying apart", in allusion to the unique position of the species in the *Diogenes* section.

References Cited

Cottle, T. J. 1863. On the two species of *Astacus* found in upper Canada. *Canad. Jour. Industry, Sci. & Arts,* (n.s.) 8: 216-219.

Erichson, W. F. 1846. Uebersicht der Arten der Gattung *Astacus. Archiv. f. Naturgeschichte,* 12 (1): 86-103.

Faxon, Walter 1884. Description of new species of *Cambarus;* to which is added a synonymical list of the known species of *Cambarus* and *Astacus. Proc. Amer. Acad. Arts & Sci.,* 20: 107-158.

Girard, Charles 1852. A revision of the North American Astaci, with observations on their habits and geographical distribution. *Proc. Acad. Nat. Sci. Phila.,* 6: 87-91.

Hay, W. P. 1899. Description of two new species of crayfish. *Proc. U.S. Nat. Mus.,* 22: 121-123.

Hobbs, Horton H., Jr. 1941. Three new Florida crayfishes of the subgenus *Cambarus. Amer. Midl. Nat.,* 26 (1): 110-121.

——— 1942. The crayfishes of Florida. *Univ. Fla. Publ., Biol. Sci. Ser.,* 3 (2): 1-179.

——— 1948. A new crayfish of the genus *Cambarus* from

Texas, with notes on the distribution of *Cambarus fodiens* (Cottle). *Proc. U. S. Nat. Mus.*, 98: 223-231.

---------- 1950. A new crayfish of the genus *Procambarus* from Oklahoma and Arkansas. *Jour. Wash. Acad. Sci.*, 40 (6): 194-198.

ORTMANN, A. E. 1905. The crawfishes of western Pennsylvania. *Ann. Carnegie Mus.*, 3 (2): 387-406.

---------- 1931. Crawfishes of the southern Appalachians and the Cumberland plateau. *Ibid.*, 20 (2): 61-160.

PENN, GEORGE HENRY 1950. A new crawfish of the genus *Orconectes* from Louisiana. *Jour. Wash. Acad. Sci.*, 40 (5): 166-169.

VIOSCA, PERCY, JR. 1933. *Louisiana Out-of-Doors, A Handbook and Guide.* New Orleans, publ. by author, pp. 1-187.

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NOTROPIS EURYZONUS, A NEW CYPRINID FISH FROM THE CHATTAHOOCHEE RIVER SYSTEM OF GEORGIA AND ALABAMA

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NOTROPIS EURYZONUS, A NEW CYPRINID FISH FROM THE CHATTAHOOCHEE RIVER SYSTEM OF GEORGIA AND ALABAMA[1]

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New Orleans, Louisiana

The species here described is a colorful minnow which apparently occurs only in the tributaries of the lower part of the Chattahoochee River. The author wishes to thank the following persons who aided in the collection of specimens or loaned specimens under their care: Richard H. Backus, Reeve M. Bailey, Charles F. Cole, Robert H. Gibbs, F. E. Guyton, Charles D. Hancock, L. James Kezer, Edward C. Raney, and C. Richard Robins. Additional thanks are due Edward C. Raney for his encouragement and interest shown throughout the initial study done by the writer while a graduate student.

NOTROPIS **EURYZONUS**, sp. nov.

Figs. 1, 2, Map 1

Materials.—The type material consists of 163 specimens from 21 to 53 mm in standard length taken at eight localities in Uchee Creek, a tributary to the Chattahoochee River. Other material examined consists of 301 specimens, 21 to 55 mm, from 11 localities in other tributaries of the Chattahoochee River. Below in parentheses are indicated the number of specimens and the range of standard length in millimeters, *e.g.* (5, 25-42). In addition to standard abbreviations for compass directions, with the following "of" deleted, the following are used: Co. = County, Cr. = Creek, mi. = mile or miles, R. = River, trib. = tributary (of), Hwy. = Highway, CU = Cornell University, TU = Tulane University, UMMZ = University of Michigan, Museum of Zoology.

Holotype, CU 28346, an adult male, 49 mm in standard length, from Uchee Cr., trib. Chattahoochee R., 0.7 mi. E. Marvyn, Lee Co., Alabama, on June 12, 1949, by Royal D. Suttkus, Robert H. Gibbs, and Charles F. Cole. Thirty-six paratypes, CU 15990 (28-47), bear the same data as the holotype.

Other paratypes, listed below, are all from Uchee Creek, Alabama: CU 13983 (5, 25-42), trib. Uchee Cr., 3.1 mi. E. Marvyn, Hwy. 80, Russell Co., March 24, 1948; UMMZ 123951 (1, 37), Uchee Cr. at Marvyn, August 4, 1937; UMMZ 128744 (6, 22-38), Brush Cr., trib. Uchee Cr., Russell Co., May 10, 1939; UMMZ 128745 (1, 37), Brush Cr., trib. Uchee Cr., Russell Co., May 10, 1939; CU 16194 (2, 34-36),

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[1] This paper is based in part on a manuscript submitted as a partial fulfillment of a doctoral dissertation at Cornell University, Ithaca, New York. The study was aided in part by a loan from the Revolving Research Fund of the Society of Ichthyologists and Herpetologists, and in part by a grant from the University Council on Research at Tulane University.

Uchee Cr., 9.2 mi. S. Phoenix City, Russell Co., June 12, 1949; CU 14316 (43, 21-53), Little Uchee Cr., 0.9 mi. E. Crawford, Hwy. 80, Russell Co., March 24, 1948; TU 10700 (8, 32-47), trib. Little Uchee Cr., 1.1 mi. E. Crawford, Hwy. 80, Russell Co., September 17, 1955; TU 10718 (60, 22-53), trib. Uchee Cr., 3.2 mi. W. Crawford, Hwy. 80, Russell Co., September 17, 1955.

Other material examined from tributaries of the Chattahoochee R. is listed below by state. **Alabama:** CU 15826 (5, 35-50), Hatchechubbee Cr., 4 mi. S.W. Seale, Russell Co., June 12, 1949; CU 17491 (18, 33-55), Owens Branch, trib. Abbie Cr., 1.2 mi. E. Abbieville, Hwy. 10, Henry Co., March 28, 1950; CU 17760 (44, 23-46), trib. Abbie Cr., 2.6 mi. S. Abbieville, Hwy. 241, Henry Co., March 28, 1950; CU 17665 (25, 26-43), Omussee Cr., 5.8 mi. N.E. Dothan, Hwy. 241, Houston Co., March 28, 1950; CU 16108 (68, 21-49), trib. 9.8 mi. S.W. Eufaula, Barbour Co., June 13, 1949; TU 2564 (66, 21-50), trib. 3.9 mi. N. Columbia, Hwy. 95, Henry Co., June 1, 1951; TU 2550 (27, 26-43), trib. 6.5 mi. N. Gordon, Hwy. 95, May 31, 1951. **Georgia:** CU 17455 (16, 27-53), Hodchodkee Cr., 1.1 mi. E. Lumpkin, Hwy. 27, Stewart Co., March 28, 1950; CU 15878 (8, 24-54), Hodchodkee Cr., 1.4 mi. S. Lumpkin, Hwy. 27, Stewart Co., June 11, 1949; CU 17773 (9, 26-53), Hannahatchee Cr., 8.1 mi. N. Lumpkin, Hwy. 27, Stewart Co., March 28, 1950; CU 17157 (14, 26-47), Hichitee Cr., 4.1 mi. S. Cusseta, Chattahoochee Co., March 28, 1950; CU 15813 (1, 43), Upatoi Cr., 6.7 mi. S. Talbotton, Hwy. 80, Talbot Co., June 11, 1949; TU 7649 (14, 26-40), Upatoi Cr., 6.7 mi. S. Talbotton, Hwy. 80, Talbot Co., October 11, 1953.

Methods.—Counts and measurements were made following the methods described by Hubbs and Lagler (1947: 8-15), except for those listed below.

1. Dorsal to opercle count; the number of scale rows crossing a diagonal between the origin of the dorsal fin and the first lateral line scale at the margin of the opercle. Single isolated scales along the diagonal, were not included.
2. Dorsal fin, origin to tip of posterior lobe or last ray; when the posterior lobe was not developed the tip of the longest element of the last (split) ray was used.
3. Anal fin, origin to tip of posterior lobe or last ray; the procedure was the same as described for number 2 above.

Diagnosis.—A species of *Notropis* with 2, 4—4, 2 teeth and anal rays modally 10, often 9 or 11, rarely 8 or 12. Other fin rays: dorsal 8, sometimes 7, occasionally 9; pectoral 13 to 16, rarely 12 or 17; pelvic 8, rarely 7; caudal 19, occasionally 18. Scales: dorsal to opercle rows 17 to 22, rarely 16 or 23; lateral line scales 35 to 40, rarely 34, 41 or 42; around the body before dorsal fin 27 to 30, occasionally 26, 31 or 32, rarely 25 or 34; around caudal peduncle 12 or 13, occasionally 14 or 15, rarely 16. Body very deep and compressed. Origin of dorsal fin closer to base of caudal than to tip of snout and farther

TABLE 1.

PROPORTIONAL MEASUREMENTS OF ELEVEN ADULT *Notropis euryzonus*.
ALL PROPORTIONS ARE EXPRESSED IN THOUSANDTHS OF THE STANDARD LENGTH.

Measurement	Holotype CU 28346	Paratypes CU 15990			
	Male	5 Males		5 Females	
		Range	Mean	Range	Mean
Standard length	48.7	44.3–46.8	46.1	39.1–40.8	40.2
Dorsal origin to snout	553	540–561	554	537–574	561
Dorsal origin to caudal base	502	484–510	500	472–505	486
Dorsal origin to occiput	365	359–376	369	361–385	372
Pelvic insertion to snout	489	474–487	482	491–505	498
Anal origin to caudal base	382	374–399	386	369–388	379
Body, greatest depth	292	238–300	292	278–292	284
Greatest width	132	126–133	130	131–145	139
Dorsal origin to 1. 1.	212	198–210	207	181–197	187
Pelvic insertion to 1. 1.	095	086–098	093	099–109	103
Caudal penduncle, length	217	208–224	216	215–227	219
Least depth	114	110–119	113	104–113	109
Head, length	232	238–245	240	239–252	246
Depth	160	168–175	169	167–174	171
Width	125	127–133	128	128–135	131
Interorbital, least fleshy width	098	092–102	098	092–100	095
Snout length	077	076–079	077	075–082	078
Dorsal fin, origin to tip of posterior lobe or of last ray	299	270–303	291	220–238	232
Eye length	065	066–068	067	067–074	069
Upper jaw length	080	080–083	081	081–088	084
Anal fin, origin to tip of posterior lobe or last ray	283	268–296	284	243–275	253
Suborbital, least width	027	022–028	025	025–028	026
Dorsal fin, depressed length	318	298–320	313	253–282	268
Dorsal fin height	317	298–320	313	253–282	268
Anal fin, depressed length	284	268–296	284	243–275	253
Anal fin height	284	253–283	274	222–237	229
Caudal fin, base to tip	303	295–306	300	283–304	292
Pectoral fin length	192	183–195	191	180–197	187
Pelvic fin length	204	200–208	204	165–181	173

TABLE 2.

COMPARISON OF SCALE COUNTS IN TWO RACES OF *Notropis euryzonus*.

	Circumferential scales											
Race	25	26	27	28	29	30	31	32	33	34	Number	Mean
Uchee Creek	—	2	4	26	21	21	9	1	—	1	85	29.08
Lower Chattahoochee River	2	6	25	59	51	19	5	3	—	1	171	28.46

	Lateral line scales										
Race	34	35	36	37	38	39	40	41	42	Number	Mean
Uchee Creek	—	3	13	33	15	9	9	2	—	84	37.58
Lower Chattahoochee River	1	13	34	48	43	18	12	1	1	171	37.35

TABLE 3.

COMPARISON OF SCALE COUNTS IN TWO RACES OF *Notropis euryzonus*.

	Dorsal to opercle scale rows									
Race	16	17	18	19	20	21	22	23	Number	Mean
Uchee Creek	—	1	9	27	27	11	5	—	80	19.66
Lower Chattahoochee River	1	13	32	62	53	10	3	1	175	19.14

	Circumferential scales above lateral line								
Race	13	14	15	16	17	18		Number	Mean
Uchee Creek	1	7	49	20	8	—		85	15.31
Lower Chattahoochee River	4	15	108	35	8	1		171	15.18

TABLE 4.

COMPARISON OF SCALE COUNTS IN TWO RACES OF *Notropis euryzonus*.

	Circumferential scales below lateral line								
Race	9	10	11	12	13	14	15	Number	Mean
Uchee Creek	—	3	35	28	18	—	1	85	11.76
Lower Chattahoochee River	3	25	80	49	12	2	—	171	11.28

	Total circumference of the peduncle scales						
Race	12	13	14	15	16	Number	Mean
Uchee Creek	14	13	7	4	1	39	13.10
Lower Chattahoochee River	121	27	5	—	—	153	12.24

TABLE 5.

COMPARISON OF SCALE COUNTS IN TWO RACES OF *Notropis euryzonus*.

	Circumference of peduncle scales above lateral line				
Race	5	6	7	Number	Mean
Uchee Creek	18	14	7	39	5.71
Lower Chattahoochee River	123	26	4	153	5.22

	Circumference of peduncle scales below lateral line				
Race	5	6	7	Number	Mean
Uchee Creek	26	11	2	39	5.38
Lower Chattahoochee River	152	1	—	153	5.00

posterior than insertion of pelvic fins. Mouth terminal, inclined; upper jaw longer than eye. Lateral line complete, much decurved, its vertical distance below the origin of the dorsal fin exceeds two-thirds the body depth in the male and approximates two-thirds the body depth in the female. Dorsal and anal fins of the male greatly elevated; anterior rays of dorsal fin extend beyond posterior rays when fin is depressed. Melanophores on the membranous portion of dorsal fin do not form a crescent patch across the fin as is typical in *Notropis hypselopterus* but instead are evenly distributed over the entire fin except for extreme anterior distal tip. A wide lateral band on body. The chevron or lunate-shaped basicaudal spot usually separated from end of lateral band. Size small, to 55 mm in standard length.

Description.—Proportional measurements for the holotype and 10 paratypes are given in Table 1. Tables 2-7 give frequency tabulations of selected meristic characters. These tables give comparisons of meristic characters for specimens from Uchee Creek and from the following streams: Hatchechubbee Cr., Hichitee Cr., Hannahatchee Cr., Hodchodkee Cr., Sandy Cr., and Abbie Cr. The specimens from Uchee Creek are considered to represent one race (a category below the sub-species level) and those from all other tributaries to represent a second race which is referred to as the Lower Chattahoochee River race. Table 8 gives a detailed tabulation of the number of anal fin rays. Table 9 is a tabulation of total vertebral counts. Additional characteristics are shown in Figure 1.

The body is compressed and is deepest at the origin of the dorsal fin. Body depth enters (step-measurement) standard length 3.1 to 3.8 times in the male and 3.6 to 3.7 in the female. The predorsal profile is convex whereas the postdorsal is slightly concave. The caudal peduncle is deep and when stepped into the standard length it goes 7.7 to 9.5 times. The head is subtriangular and goes into the standard length 3.8 to 4.2 times. The snout is blunt, broadly rounded as viewed from above. The premaxillary is proctractile; the upper lip protrudes slightly. The mouth is terminal, oblique and the gape reaches posteriorly nearly to a vertical in front of the eye.

In both sexes, the height of the dorsal fin is equal to its depressed length and the distal margin of the fin is nearly truncate. The height of the anal fin averages less than its depressed length in the male but is considerably less than the depressed length in the female. The distal margin of the anal fin, in both sexes, is slightly falcate.

Scales are cycloid; radii number 8 to 13 with an average of 9.8 for the ten paratypes sampled. These scales were removed from the first row above the lateral line and at a point below the origin of the dorsal fin. The scales are deeper than long, moderately rounded on their posterior margins, and are nearly truncate on their anterior margins.

The exposed surface of the lateral body scales is evenly covered with melanophores, but the margins of the several middorsal scale rows

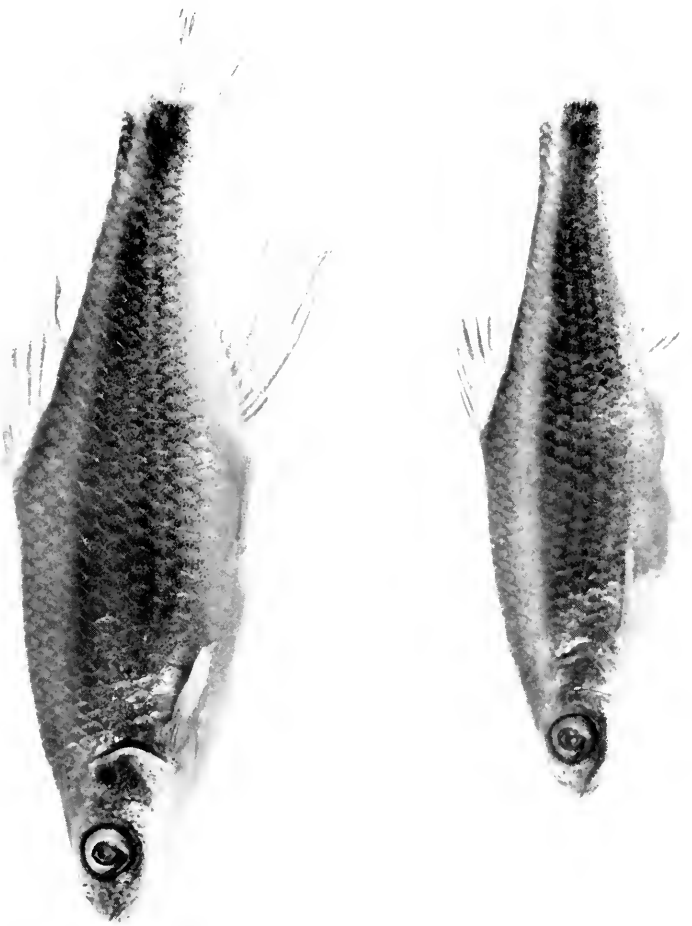


Figure 1. (top) *Notropis euryzonus*, paratype, male, 47 mm in standard length, (bottom) paratype, female, 39 mm in standard length, from Uchee Cr., trib. Chattahoochee R., 0.7 mi. E. Marvyn, Lee Co., Alabama. (Photograph by D. M. Payne.)

TABLE 6.

COMPARISON OF FIN RAY COUNTS IN TWO RACES OF *Notropis euryzonus*.

Race	Total pectoral rays										Number	Mean
	24	25	26	27	28	29	30	31	32	33		
Uchee Creek	—	—	9	7	33	13	3	—	—	—	65	27.90
Lower Chattahoochee River	1	1	13	10	56	26	35	7	9	1	159	28.72

Race	Pectoral rays						Number	Mean
	12	13	14	15	16	17		
Uchee Creek	—	26	83	21	—	—	130	13.96
Lower Chattahoochee River	3	37	148	103	26	1	318	14.36

TABLE 7.

COMPARISON OF FIN RAY COUNTS IN TWO RACES OF *Notropis euryzonus*.

Race	Anal rays					Number	Mean
	8	9	10	11	12		
Uchee Creek	1	40	53	1	—	95	9.56
Lower Chattahoochee River	—	11	141	52	2	206	10.21

Race	Dorsal rays			Number	Mean
	7	8	9		
Uchee Creek	11	84	—	95	7.88
Lower Chattahoochee River	6	206	2	214	7.98

TABLE 8.

FREQUENCY DISTRIBUTION OF THE NUMBER OF PRINCIPAL ANAL FIN RAYS IN *Notropis euryzonus*. THE STREAMS ARE ARRANGED IN THE ORDER IN WHICH THEY ENTER THE CHATTAHOOCHEE RIVER (Upatoi Cr. = most northern)

Stream	Anal rays					Number	Mean
	8	9	10	11	12		
Upatoi Cr.	—	1	9	4	—	14	10.36
Uchee Cr.	1	40	53	1	—	95	9.57
Hichitee Cr.	—	1	8	4	1	14	10.36
Hannahatchee Cr.	—	4	5	—	—	9	9.55
Hatchechubbee Cr.	—	—	5	—	—	5	10.00
Sandy Cr.	—	1	46	20	1	68	10.31
Hodchodkee Cr.	—	1	19	4	—	24	10.12
Abbie Cr.	—	4	58	24	—	86	10.23
Trib. (TU 2564)	—	5	48	13	—	66	10.12
Omussee Cr.	—	—	18	7	—	25	10.28
Trib. (TU 2550)	—	3	18	6	—	27	10.11

TABLE 9.

FREQUENCY DISTRIBUTION OF THE NUMBER OF VERTEBRAE IN *Notropis euryzonus*. THE STREAMS ARE ARRANGED IN THE ORDER IN WHICH THEY ENTER THE CHATTAHOOCHEE RIVER

Creek	Number of vertebrae					Number	Mean
	34	35	36	37	38		
Uchee	1	1	16	4	—	22	36.0
Hichitee	—	1	8	4	—	13	36.2
Hodchodkee	—	—	4	3	—	7	36.4
Abbie	—	1	26	9	1	37	36.3
Trib. (TU 2564)	—	—	7	12	1	20	36.7

are noticeably outlined by heavy concentrations of melanophores. Scales on the ventral lateral area of the body, especially at the lower edge of the lateral band, show a chain-like pattern of pigmentation due to a concentration of melanophores in a central band on each scale. Specimens in alcohol, have a broad, dark-brown, lateral band which begins at the tip of the snout and passes along the side posteriorly to the base of the caudal fin. The name *euryzonus,* descriptive of this broad lateral band, was suggested by Reeve M. Bailey. The termination of the lateral band forms an indistinct spot on the base of the caudal fin. A lightly pigmented area separates the indistinct spot from a chevron or lunate-shaped patch of melanophores on the scales overlying the basal portion of the central caudal rays. A light brown stripe parallels the dark lateral band on the side, and in turn is sharply separated from the dark brown dorsal surface of the caudal peduncle. However, on the forward part of the body the light brown shades into the more intense color of the back. An even darker median dorsal stripe is clearly defined. The top of the head is dark. The lateral light stripe passes around the end of the snout just above the upper lip. The lips and chin are dark and some pigment extends on to the anterior gular region; posteriorly this area is devoid of pigment in both sexes. The female lacks melanophores on the breast and a wide median part of the belly. The male has scattered melanophores extending ventrad along the pectoral girdle, but the right and left extensions never meet to make a band across the ventral median line. The female paratypes lack melanophores on the belly but some other females have the lateral pigmentation extending down the sides of the belly, although a wide clear median ventral area is always present. There are some melanophores around the urogenital and anal openings, but none on the rest of the area between the pelvic fins and the origin of the anal fin. The sexes are similar with respect to pigmentation of the caudal and pectoral fins. The anterior portion of the pectoral fins are dusky. The edges of the caudal fin rays are dark throughout; the outer and central rays being darkest. Other details of pigmentation are given in the section titled *Sexual Dimorphism.*

Color in life.—The most striking color feature is the bright orange caudal fin. The broad bluish-gray lateral band is bordered above by a narrow stripe of orange. A small amount of orange is present at the base of the dorsal fin and diffuse orange appears in the darkish anal fin of large males. The belly and lower part of the sides are pale and the anterior tip of the dorsal fin is bright yellow-green. Specimens taken from Omussee Creek, Houston Co., Alabama, in March 1950 had a dull red line above the dark lateral band; some of these also had a thin line of green above the red. A small clear area was noted in the center of the bright orange caudal fin of the larger males. Specimens taken from Hodchodkee Creek, Steward Co., Georgia, on June 11, 1949 exhibited a similar clear "window" in the

caudal fin. Specimens taken from Uchee Creek in September, 1955 did not show this character.

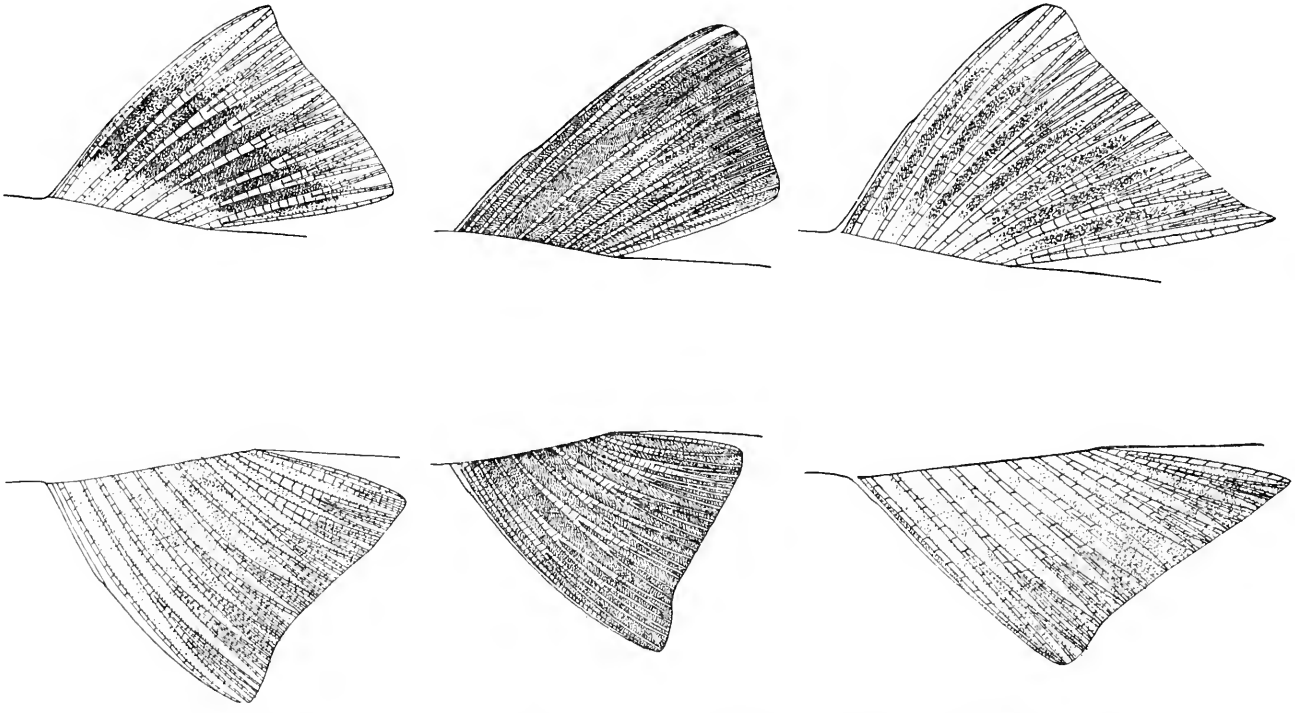
Sexual Dimorphism.—Comparisons were made between adult specimens; the most obvious differences between sexes were the color pattern and the intensity of pigmentation in the dorsal fin. The male is decidedly brighter in life and has a heavily pigmented dorsal fin (fig. 1) in which most of the interradial membranes are dark for their entire lengths. The only part of this fin lacking melanophores is a narrow area on the anterior lobe. The interradial membranes of the pelvic and anal fins in the male are moderately to densely pigmented throughout. The female usually has less pigment in the dorsal fin and this pigment is somewhat concentrated in the center of the fin which approximates the pigmentary pattern of the dorsal fin of *Notropis hypselopterus*. There is a light area at the base and a larger clear area at the tip of the fin. The female also exhibits less pigment in the anal and pelvic fins.

The sexes differ in the pigmentation about the anal and urogenital openings. The female has a large square patch of melanophores immediately behind the anal orifice whereas the male has a small crescent of dense pigmentation around the anterior base of the urogenital elevation.

In the male one row of large breeding tubercles project laterally from the lower jaws and the tip of each tubercle is curved upward. Below this main row there may be one to three additional rows of tubercles on either side; those tubercles nearest the main rows are more curved than those in the medial rows. Medium-sized tubercles are present in a group on the preorbital area. Small tubercles are scattered on the suborbital, preopercle and subopercle and a few form a ring around the eye. The scales in several of the rows behind the opercle are margined with small tubercles. The female has a single row of medium-sized tubercles on the lateral edge of the dentary and a few scattered ones along the medial margin of each dentary. There are a few minute tubercles on the suborbital and preorbital regions. The remaining surface of the head and scales behind the opercle lack tubercles. In addition to the above characteristics, the sexes can readily be separated by differences in the size of the dorsal, anal and pelvic fins (Table 1).

Infraspecific variation.—Two races of *Notropis euryzonus* are recognized mainly on the basis of the number of anal rays. The Uchee Creek race has an anal ray count which averages 9.6, and the Lower Chattahoochee River race averages slightly higher with 10.2 (Table 7). Apparently this character is not clinal (Table 8). A possible cline is illustrated by the frequency distributions of the number of vertebrae (Table 9).

In addition to the above, the Uchee Creek race has a lower pectoral ray count (Table 6), a higher circumferential body scale count (Table 2), more rows of scales between the origin of the dorsal fin and the



Figures 2-4. **2.** (middle) Dorsal and anal fins of an adult male, paratype of *Notropis euryzonus* (CU 15990), 46 mm in standard length from Uchee Cr.; **3.** (left) Dorsal and anal fins of an adult male *Notropis hypselopterus* (CU 16114), 47 mm in standard length from Choctawhatchee R. drainage; **4.** (right) Dorsal and anal fins of an adult male *Notropis hypselopterus* (CU 15803), 49 mm in standard length from Flint R. system. (William C. Dilger, delineator.)

margin of the opercle (Table 3), and a higher circumferential peduncle scale count (Table 4). The specimens from Hannahatchee Cr. have a low anal ray count as shown in Table 8 and are like the Uchee Creek specimens in this respect but have a higher pectoral ray count and thus were not included with the latter.

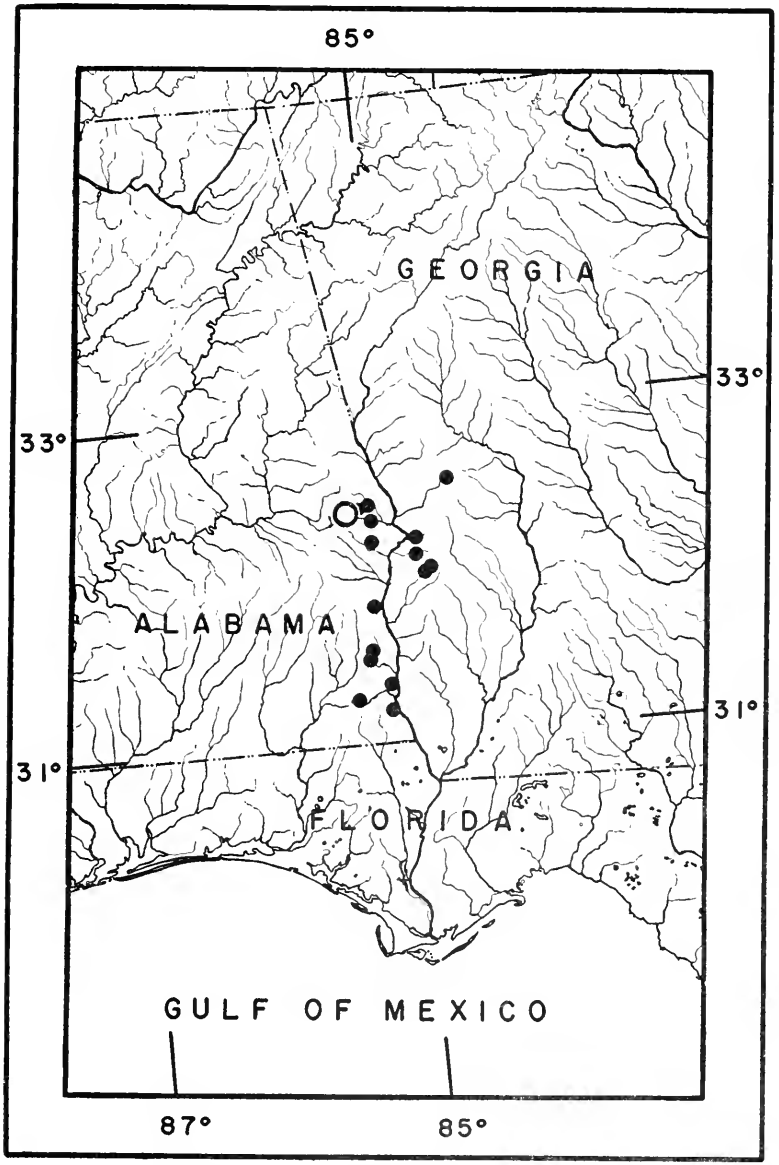
Relationships.—Notropis euryzonus is most closely related to *Notropis hypselopterus* (Gunther) and *Notropis stonei* Fowler and less so to *Notropis signipinnis* Bailey and Suttkus. *N. euryzonus* has not been taken together with either *N. hypselopterus* or *N. signipinnis* both of which occur in the same drainage. In 1951, the writer and Charles D. Hancock collected *N. hypselopterus* in a tributary of Chattahoochee River only two miles distant from a population of *N. euryzonus*. There were no apparent differences between the two streams with regards to habitats. Additional collecting may reveal cohabitation of a stream by the two forms.

Notropis euryzonus is apparently an endemic of the Apalachicola River system as is *Notropis hypsilepis* Suttkus and Raney. The most southern locality given for *N. hypsilepis* by Suttkus and Raney (1955: 162) was Hodchodkee Creek, 1.4 mi. S. Lumpkin, Georgia. *N. euryzonus* was taken from this same locality on a different date by the author. The two species have been taken from other streams in the area of overlap which extends from Hodchodkee Creek to Uchee and Upatoi Creek.

In many respects, including meristic characters, *N. euryzonus* is similar to *N. hypselopterus,* but prominent differentiating characters exist in the shape and pigmentation of the dorsal fin of the male. Figures 2-4 illustrate the shape and pigmentation of dorsal and anal fins of *N. euryzonus* (Chattahoochee River system), *N. hypselopterus* (Choctawhatchee River drainage) and *N. hypselopterus* (Flint River system). The general outline of the dorsal fin of *N. euryzonus* is rectangular and that of *N. hypselopterus* is triangular. The posterior elements are greatly extended in *N. hypselopterus,* especially so in the Flint and lower Apalachicola River specimens (males). *N. hypselopterus* in the Choctawhatchee River drainage has the fins and posterior part of the body colored with brilliant orange. The burnt orange color and the heavy concentration of melanophores in the dorsal and anal fins of *N. euryzonus* cause the fins to appear less brilliant or gaudy than in *N. hypselopterus* of the Choctawhatchee. *N. hypselopterus* in the Apalachicola drainage lack the brilliant orange but have instead some rose and dull red-orange areas on the posterior fins and body. The lateral band of *N. euryzonus* is gray with a tinge of blue.

The clear "window" found in the caudal fin of *N. euryzonus* is not present in the forms of *hypselopterus.*

Notropis euryzonus most likely evolved from a *hypselopterus* stock which moved up the Apalachicola River system during Pleistocene time. Possibly the Flint and Choctawhatchee River system were popu-



Map 1. Distribution of *Notropis euryzonus*. Circle indicates type locality.

lated later than the Chattahoochee part of the Apalachiocola or if all three (Chattahoochee, Choctawhatchee and Flint) were populated at the same time speciation was not as rapid in the latter two streams because the forms in these systems have not reached a specific level of differentiation. Isolation was probably effected by one of the periods of coastal inundations during the Pleistocene.

Ecology.—The type locality, Uchee Creek, is a shallow stream about 10 feet wide with a sand bottom. The water was brown and clear on June 12, 1949. The estimated flow was eight cubic feet per second.

Most streams in which *N. euryzonus* was seined have colorless water. The tributaries of Uchee Cr. and the tributary of the Chattahoochee River, 9.8 mi. S.W. Eufaula, Barbour Co., Alabama, have brown water.

The tributaries of the Chattahoochee River from which *N. euryzonus* was collected have various bottom types. Hodchodkee Cr., Stewart Co., Georgia has mud and clay; Abbie Cr., Henry Co., Alabama, Omussee Cr., Houston Co., Alabama, and Hichitee Cr., Chattahoochee Co., Georgia have shifting sand and silt and Hatchechubbee Cr. and one tributary of Uchee Cr., Russell Co., Alabama have exposed bedrock and drifting sand.

The specimens of *N. euryzonus* usually were taken near shelter either in the form of logs or aquatic vegetation. These minnows seldom moved from their niche and could be seined with little difficulty. The collecting of this species was difficult only when the shelter was thick and entangled with debris. *Orontium aquaticum* and *Sparganium* sp. were the most common aquatic plants recorded for the collection localities. The incidence of *Notropis euryzonus* with golden club, *Orontium aquaticum,* was not as consistent as that noted by Bailey and Suttkus (1952: 14) for *Notropis signipinnis.*

The name *euryzonus,* derived from *eury,* broad, and *zona,* zone, refers to the broad lateral band. *Notropis* is treated as masculine and the adjectival form is used in the formation of the specific name.

References Cited

Bailey, Reeve M. and Royal D. Suttkus 1952. *Notropis signipinnis,* a new cyprinid fish from southeastern United States. *Occ. Pap. Mus. Zool. Univ. Mich.,* No. 542: 1-15.

Hubbs, Carl L. and Karl F. Lagler 1947 (and 2nd printing, 1949). Fishes of the Great Lakes Region. *Bull. Cranbrook Instit. Sci.,* 26: I-XI, 1-186, many figs.

Suttkus, Royal D. and Edward C. Raney 1955. *Notropis hypsilepis,* a new cyprinid fish from the Apalachicola River system of Georgia and Alabama. *Tulane Stud. Zool.* 2 (7): 159-170, 2 figs., 1 map.

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FACTORS INFLUENCING THE RATE OF OXYGEN CONSUMPTION OF THE DWARF CRAWFISH, *CAMBARELLUS SHUFELDTII* (DECAPODA, ASTACIDAE)

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FACTORS INFLUENCING THE RATE OF OXYGEN CONSUMPTION OF THE DWARF CRAWFISH, *CAMBARELLUS SHUFELDTII*[1]

(DECAPODA, ASTACIDAE)

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The comparative physiology of respiration has been reviewed recently by Zeuthen (1955). Sex, weight, endocrines, and a daily rhythmicity are among several factors which may influence the rate of oxygen consumption of an arthropod.

Edwards (1946) demonstrated that the male imago of the housefly, *Musca domestica,* had a higher rate of metabolism than the adult female. The higher rate of the male was due to the sexual difference and not to a weight difference. In 1950 Edwards found no sexual difference in the metabolic rate of the fiddler crab *Uca pugilator.*

In general, within a single species on a unit weight basis small animals have a higher rate of oxygen consumption than large animals. Edwards (1946) found that this relationship held for the mole crab, *Emerita talpoida,* and the amphipod *Talorchestia megalopthalma.*

The role that endocrines play in the control of the metabolic rate of crustaceans has been investigated by several workers. Scudamore (1947) demonstrated that removal of the sinus glands from within the eyestalks of the crawfish *Orconectes immunis* led to an increase in the rate of oxygen consumption. Sinus gland extracts decreased the rate of oxygen consumption and central-nervous-tissue extracts increased the rate. Bauchau (1948) observed that the increase in the metabolic rate of the crab *Eriocheir sinensis* with a rise in temperature was greater following eyestalk removal. He concluded that the sinus glands of this poikilotherm normally operate in the control of metabolic rate as a partial temperature compensator. Edwards (1950), working with *Uca pugilator,* and Bliss (1953), working with the land crab *Gecarcinus lateralis,* showed an increase in the metabolic rate following eyestalk removal. Scheer and Scheer (1954) showed that ablation of the eyestalks from the prawn *Leander serratus* is not followed by a rise in the rate of oxygen consumption. *Leander* was the first crustacean investigated for which no change in metabolic rate following eyestalk removal has been reported.

Edwards (1950) demonstrated a daily rhythm of oxygen consumption in the fiddler crab *Uca pugilator.* This 24 hour cycle of oxygen consumption corresponded to the daily activity rhythm of the species. More recently, Brown, Bennett, and Webb (1954) confirmed the daily rhythm of oxygen consumption in normal *Uca pugilator.* The rate is maximal at 6-8 a.m., minimal about noon and midnight; and,

[1] This investigation was supported by Grant No. B838 from the National Institutes of Health.

a secondary maximum occurs about 10-11 p.m. The latter investigators also described a daily rhythm of the rate of oxygen consumption in eyestalkless individuals of this species. The daily form of the latter rhythm differed slightly from the rhythm of normal animals.

The current investigation was initiated to determine (1) the effect of eyestalk removal upon the rate of oxygen consumption of the dwarf crawfish, *Cambarellus shufeldtii,* (2) the influence of sex and size upon the rate of oxygen consumption, and (3) the rate of oxygen consumption throughout a 24 hour period.

Materials and Methods

Adult specimens of the dwarf crawfish, *Cambarellus shufeldtii* (Faxon), identified by Dr. George H. Penn, were collected in the vicinity of New Orleans, Louisiana, for use in the experiments. The total length of these crawfish is 15 to 25 mm, the female being larger than the male. This species, whose physiology has not been investigated previously, is one of the more common crawfish in this vicinity.

The rate of oxygen consumption of the crawfish was measured by means of (1) a continuously recording respirometer designed by Brown (1954) and (2) a Warburg respirometer. The former instrument was used for measuring the metabolic rate over 24 hour periods, the latter for intervals up to three and a half hours.

The respirometer designed by Brown consists of a collapsible plastic bag attached to 100 ml Soxhlet flask via a capillary connection. The plastic bag contained sufficient oxygen for at least 72 hours. Weights were affixed to the exterior of the flask so that the respirometer would sink just below the surface of the water in a constant temperature bath maintained at 29°C. As oxygen was consumed by an animal in the flask the specific gravity of the respirometer increased and the buoyancy decreased. The respirometer, therefore, sank deeper. Increase in specific gravity was recorded by means of a lever system attached to ink pens recording on a drum moving at the rate of 0.29 cm per hour. The decrease of the oxygen volume in the respirometer caused the observational pen to trace a line which continuously approached closer to a fixed base line. The respirometer increased one gram in weight for every milliliter of oxygen consumed. Therefore, the lever system could be calibrated and the volume of oxygen consumed per hour calculated. Data for three hour intervals were lumped. The method of analysis and presentation of the data was the same as described in detail by Brown, Bennett, and Webb (1954).

For each determination the following were placed into each of eight flasks: a vial of 20 percent potassium hydroxide (carbon dioxide absorbent), a vial of saturated cupric sulfate (ammonia absorbent), and a volume of aerated tap water sufficient to allow the crawfish to swim. Seven of the respirometers had one crawfish in each of them, the eighth served as a control. Throughout the periods of observation only one-third of the records for the 24 hour periods could be used because the animals in some of the flasks died and

some of the pens did not record between midnight and 6 a.m. The respirometers were maintained in a laboratory in which the blinds were drawn. The light intensity of the surface of the water in the bath never exceeded two ft.-c. The small changes in light intensity could not have accounted for the results to be described because the changes in light intensity that occurred in the laboratory were arrhythmic. On several evenings the laboratory lights were on until midnight with no apparent effect upon the results.

The Warburg respirometer was used in the conventional manner. Each flask contained 20 percent potassium hydroxide (carbon dioxide absorbent) and a filter paper wick in the center well, 50 percent sulphuric acid (ammonia absorbent) in the side-arm, and one ml of aerated tap water plus a crawfish. The water bath was maintained at 28.5°C.

Following removal from either respirometer, each crawfish was weighed and sexed. Total wet weight was determined by blotting each crawfish in paper towelling to remove as much of the external liquid as possible and weighing the animal to the nearest one-hundredth of a gram by means of a chainomatic analytical balance. The rates of oxygen consumption were expressed as milliliters of oxygen consumed per gram of tissue per hour (ml/g/hr).

Statistical analysis of the data which established (1) the nature of the daily rhythm and (2) the effect of eyestalk extracts on the metabolic rate was not necessary because the metabolic rates of individual crawfish were not compared with one another, but each crawfish served as its own control. Individual crawfish were considered over 24 hour intervals. Individual variation influenced only the amplitude of the daily rhythm curve but not the shape of the curve, *i.e.* the character of the daily rhythm, which was the primary object under investigation. The character of the daily rhythm was the same in all the crawfish, but the amplitude of the rhythm varied because of sex and size differences which are discussed later. The metabolic rate of each crawfish was determined before it received the extract of eyestalk. The effect of the extract upon the previously determined metabolic rate was then determined.

Experiments and Results

Daily rhythm of oxygen consumption of normal Cambarellus.— Normal animals, of which 75 percent were males, were placed in the respirometers and the rate of oxygen consumption over 24 hour intervals was determined. One crawfish was in each respirometer so that the metabolic rate of any one crawfish could be followed, rather than compare the rate of oxygen consumption of different crawfish from different times of day. These observations were made from midnight to midnight on nine days between March 30 and May 12, 1955. The data for the individual crawfish for the nine days were averaged (fig. 1). Data obtained on three other days within this period were similar to the data for the nine days but did

not include a midnight to midnight 24 hour interval and, therefore, could not be averaged with the data of the nine days. As is evident from Figure 1, the metabolic rate of the individual crawfish was continuously changing throughout the 24 hour period. The respiratory rate was maximal about 6 a.m. with a secondary peak in the

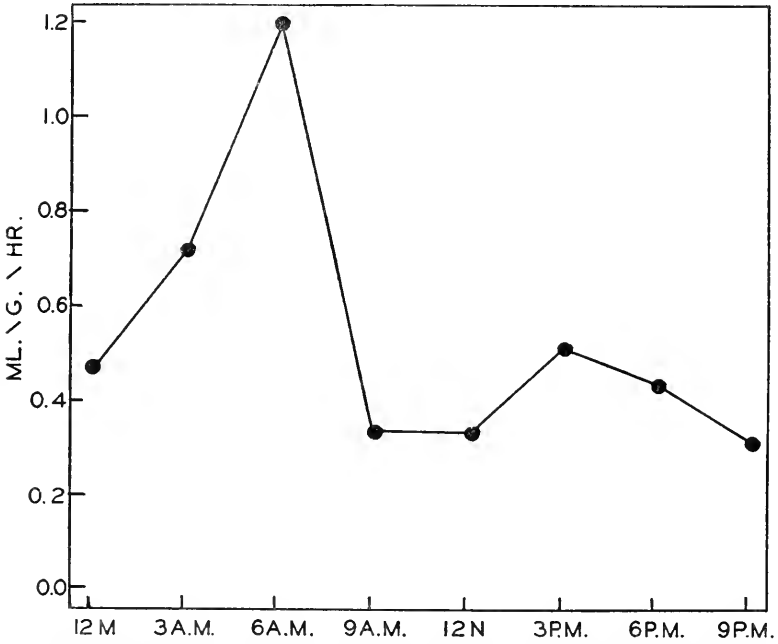

Figure 1. The daily rhythm in rate of oxygen consumption of normal *C. shufeldtii.*

afternoon (3-6 p.m.). Minima occurred between 9 a.m. and noon and 9 p.m. and midnight. No sexual difference in the character of the daily rhythm was observed.

The maximal rate of oxygen consumption was three times the minimal rate. Normal variations of this sort can explain the diverse rates of oxygen consumption in the literature for any one species. This rhythmic variation of the metabolic rate of individual crawfish is in all probability due to an endogenous activity rhythm. Mildred E. Lowe, a graduate student, observed that this species is most active in the laboratory about 7 a.m.

Daily rhythm of oxygen consumption of eyestalkless Cambarellus.— Both eyestalks were removed by transection at their bases and the wounds cauterized to minimize bleeding. Females whose eyestalks had been removed at least 24 hours previously were placed in the respirometers and the rate of oxygen consumption of these eyestalk-

less crawfish was determined. Data were obtained from midnight to midnight on three days between April 14 and May 9, 1955 and averaged (fig. 2). Results obtained on three additional days were rhythmically similar but did not include a midnight to midnight period. A daily rhythm of oxygen consumption in eyestalkless *Cambarellus* is evident from this figure. The daily pattern of the eyestalkless crawfish differs only slightly in form from the pattern of normal animals. The maximal and minimal metabolic rates occurred at approximately the same times in both normal and eyestalkless crawfish.

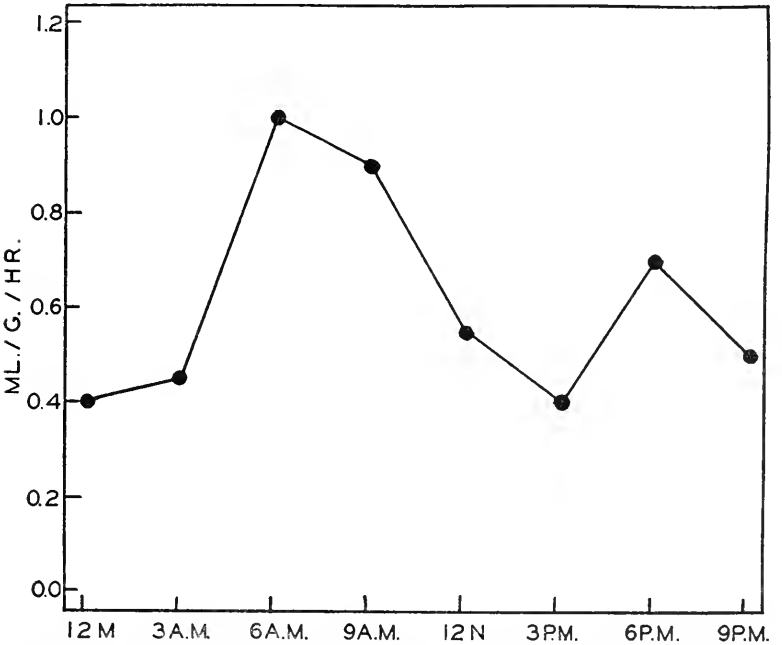

Figure 2. The daily rhythm in rate of oxygen consumption of eyestalkless *C. shufeldtii.*

Brown, Bennett, and Webb (1954) found the same is true for the daily metabolic rhythms of normal and eyestalkless *Uca pugilator.* The amplitude of the curve for eyestalkless animals is 16 percent greater than for normal crawfish.

Influence of sex and weight upon the rate of oxygen consumption in normal Cambarellus.—The rate of oxygen consumption of normal male and female *Cambarellus* was determined for one hour intervals by means of the Warburg respirometer. The data are presented in Table 1. *Cambarellus* possibly has a metabolic rhythm with a tidal frequency as found in *Uca* (Brown, Bennett, and Webb, 1954). If true, then one could not be certain that the crawfish would be rhyth-

mically similar at the same hour each day. The decision was made therefore to randomize the data with respect to time of day. Data for both sexes were collected at several times of day and night to randomize the effects of the daily rhythm. The metabolic rates of males and females could be compared with one another because the metabolic rates of individuals from both sexes were determined at

TABLE 1.
OXYGEN CONSUMPTION OF NORMAL *C. shufeldtii*

Males		Females	
Weight (g)	Oxygen Consumption (ml/g/h)	Weight (g)	Oxygen Consumption (ml/g/h)
0.12	0.140	0.10	0.280
0.12	0.197	0.11	0.279
0.13	0.277	0.11	0.293
0.13	0.300	0.11	0.331
0.13	0.323	0.12	0.179
0.13	0.654	0.14	0.161
0.15	0.238	0.14	0.182
0.15	0.264	0.15	0.286
0.15	0.268	0.16	0.210
0.15	0.480	0.26	0.307
0.17	0.205	0.28	0.196
0.17	0.307	0.28	0.261
0.17	0.312	0.29	0.238
0.18	0.339	0.30	0.267
0.19	0.203	0.30	0.280
0.19	0.221	0.31	0.164
0.19	0.313	0.31	0.222
0.20	0.369	0.31	0.229
0.21	0.472	0.33	0.152
0.22	0.245	0.33	0.165
0.22	0.427	0.33	0.170
0.23	0.330	0.33	0.245
0.24	0.278	0.35	0.211
0.24	0.279	0.35	0.214
0.24	0.307	0.35	0.342
0.31	0.171	0.36	0.292
		0.38	0.121
		0.38	0.203
Average 0.18	0.305	0.26	0.230

all times of day. Twenty-six males had an average wet weight of 0.18 grams and an average metabolic rate of 0.305 ml/g/hr. Twenty-eight females had an average wet weight of 0.26 grams and an average metabolic rate of 0.230 ml/g/hr.

The males weighed less and had a higher metabolic rate than the females. The difference in metabolic rate was probably due in part to the inverse relationship between metabolic rate and weight. This relationship also seems to hold if the sexes are considered separately. There was probably also a sexual component to the difference in

metabolic rate between the males and females. A comparison of males and females of similar weight suggested that males had the higher metabolic rate.

Effect of eyestalk removal upon the rate of oxygen consumption of Cambarellus.—The metabolic rate of male and female specimens of *Cambarellus* was determined for one hour by means of the Warburg respirometer. The animals were then weighed and their eyestalks

TABLE 2.
INFLUENCE OF EYESTALK REMOVAL ON OXYGEN CONSUMPTION

Weight (g)	Oxygen Consumption After Eyestalk Removal (ml/g/hr)				
	0 Days	1 Day	2 Days	3 Days	4 Days
		Males			
0.18	0.339	0.367			
0.19	0.221	0.289			
0.21	0.472	0.299			
0.22	0.427	0.518			
0.23	0.330	0.369			
0.13	0.323	0.446	0.867		
0.19	0.313	0.242	0.248		
0.31	0.171	0.236	0.220		
0.13	0.277	0.408	0.215	0.277	
0.13	0.300	0.553	0.492	0.423	
0.15	0.264	0.438	0.402	0.264	
0.24	0.278	0.395	0.373	0.410	
		Females			
0.30	0.276	0.311			
0.33	0.165	0.246			
0.33	0.170	0.224			
0.33	0.245	0.251			
0.35	0.214	0.286			
0.36	0.292	0.288			
0.38	0.203	0.224			
0.10	0.280	0.254	0.230		
0.28	0.261	0.225	0.268		
0.29	0.238	0.286	0.249		
0.35	0.211	0.091	0.191		
0.28	0.196	0.197	0.243	0.247	
0.31	0.164	0.187	0.155	0.139	
0.31	0.229	0.239	0.206	0.231	
0.33	0.152	0.182	0.206	0.215	
0.38	0.121	0.131	0.198	0.198	0.195

removed. The metabolic rate of these animals was subsequently determined at 24 hour intervals until death occurred. The observed data are presented in Table 2. To prepare Table 3, the data of Table 2 were averaged according to the number of days the animals of each sex survived. The values were then converted to the percentage of the metabolic rate determined prior to eyestalk removal. For example, the inital value for the animals in the "Destalked 72 hours" category

TABLE 3.

OXYGEN CONSUMPTION OF *C. shufeldtii* BEFORE AND AFTER EYESTALK REMOVAL IN TERMS OF ML/G/HR AND PERCENTAGE OF THE ORIGINAL VALUE

Sex	Number Specimens	Normal Values *	Values after Destalking *			
			24 hrs	48 hrs	72 hrs	96 hrs
			Destalked 24 hrs			
♂	12	0.310	0.380	.....	.....	.....
		100	122.5			
♀	16	0.214	0.226	.....	.....	.....
		100	105.6			
			Destalked 48 hrs			
♂	7	0.275	0.388	0.402	.....	.....
		100	141.1	146.2		
♀	9	0.206	0.199	0.216	.....	.....
		100	96.7	104.9		
			Destalked 72 hrs			
♂	4	0.280	0.449	0.371	0.344	.....
		100	160.4	132.5	122.9	
♀	5	0.172	0.187	0.202	0.206	.....
		100	108.8	117.4	119.8	
			Destalked 96 hrs			
♀	1	0.121	0.131	0.198	0.198	0.195
		100	108.2	163.6	163.6	161.2

* upper figure = ml/g/hr; lower figure = percent of original value.

was based upon the initial metabolic rate of animals which survived the operation at least 72 hours. As is evident from these averages, the metabolic rate increased following eyestalk removal. In every case where a comparison could be made, the males showed the greater percentage increase. This fact supports the contention of a basic sexual difference in metabolic rate. The percentage increase of the rate of oxygen consumption for both sexes was combined in Figure 3. There was a general trend for the animals surviving longer to have the larger increase in metabolic rate.

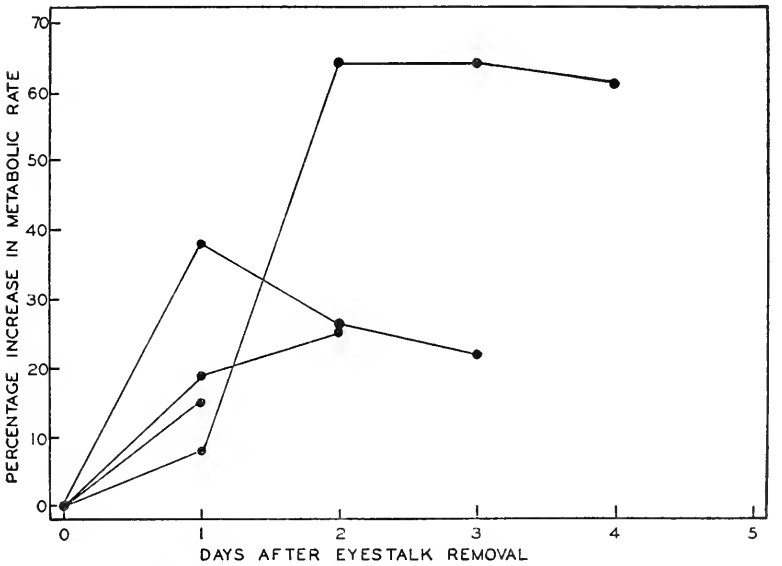

Figure 3. The effect of eyestalk removal upon the rate of oxygen consumption. The rate of oxygen consumption is expressed as the percentage increase over the rate determined prior to eyestalk removal. The results have been plotted according to the number of days the eyestalkless crawfish survived.

Effect of eyestalk extract upon the metabolic rate of Cambarellus.—Two experiments involving 11 animals were performed. The metabolic rates of six control and five experimental animals whose eyestalks had been removed at least 24 hours previously were determined for one hour by means of the Warburg respirometer. The experimental group received immediately after the initial determination of the metabolic rate an injection of the equivalent of one eyestalk in 0.025 ml of extract which was prepared in the following fashion. The eyestalks were removed from several *Cambarellus,* triturated, and resuspended in a sufficient volume of van Harreveld's solution, which is isotonic with crawfish blood, so that each 0.025 ml of

TABLE 4.

METABOLIC RATES OF EYESTALKLESS CRAWFISH INJECTED WITH EYESTALK EXTRACT (EXPERIMENTALS) AND SALINE (CONTROLS)

Minutes	Controls (ml/g)						Ave.	Experimentals (ml/g)					Ave.
10	0.027	0.030	0.046	0.032	0.035	0.043	0.036	0.048	0.030	0.031	0.034	0.048	0.038
20	0.058	0.070	0.080	0.082	0.084	0.097	0.078	0.092	0.067	0.064	0.072	0.107	0.080
30	0.067	0.097	0.114	0.129	0.119	0.140	0.111	0.130	0.100	0.092	0.107	0.159	0.118
40	0.097	0.145	0.157	0.179	0.157	0.170	0.153	0.168	0.140	0.128	0.141	0.200	0.155
50	0.127	0.190	0.197	0.227	0.208	0.220	0.195	0.200	0.187	0.168	0.175	0.245	0.195
60	0.148	0.227	0.240	0.271	0.251	0.271	0.244	0.241	0.232	0.200	0.220	0.252	0.231
30	Injected with Saline							Injected with Eyestalk Extract					
10	0.033	0.043	0.054	0.038	0.041	0.046	0.043	0.048	0.039	0.036	0.026	0.024	0.035
20	0.061	0.080	0.094	0.080	0.078	0.103	0.083	0.085	0.065	0.050	0.076	0.052	0.066
30	0.088	0.120	0.140	0.132	0.113	0.149	0.124	0.122	0.097	0.069	0.118	0.086	0.098
40	0.109	0.150	0.172	0.170	0.162	0.203	0.161	0.152	0.112	0.075	0.153	0.172	0.124
50	0.140	0.195	0.220	0.206	0.192	0.249	0.200	0.197	0.148	0.103	0.186	0.162	0.159
60	0.172	0.235	0.254	0.238	0.241	0.294	0.239	0.241	0.177	0.117	0.225	0.206	0.193
70	0.176	0.280	0.300	0.290	0.294	0.344	0.280	0.259	0.203	0.141	0.251	0.248	0.220
80	0.212	0.315	0.334	0.325	0.330	0.374	0.315	0.289	0.229	0.156	0.286	0.303	0.253
90	0.249	0.387	0.374	0.368	0.373	0.428	0.363	0.313	0.249	0.170	0.319	0.331	0.277
100	0.285	0.420	0.408	0.402	0.392	0.480	0.398	0.344	0.274	0.189	0.350	0.365	0.304
110	0.321	0.455	0.443	0.449	0.443	0.534	0.441	0.368	0.300	0.205	0.399	0.410	0.336
120	0.357	0.492	0.486	0.474	0.478	0.572	0.477	0.403	0.338	0.239	0.413	0.442	0.367

extract contained the equivalent of one eyestalk. The control group immediately received 0.025 ml of van Harreveld's solution.

The averaged results of the two experiments were used to prepare Figure 4. The oxygen consumption of each crawfish used in this

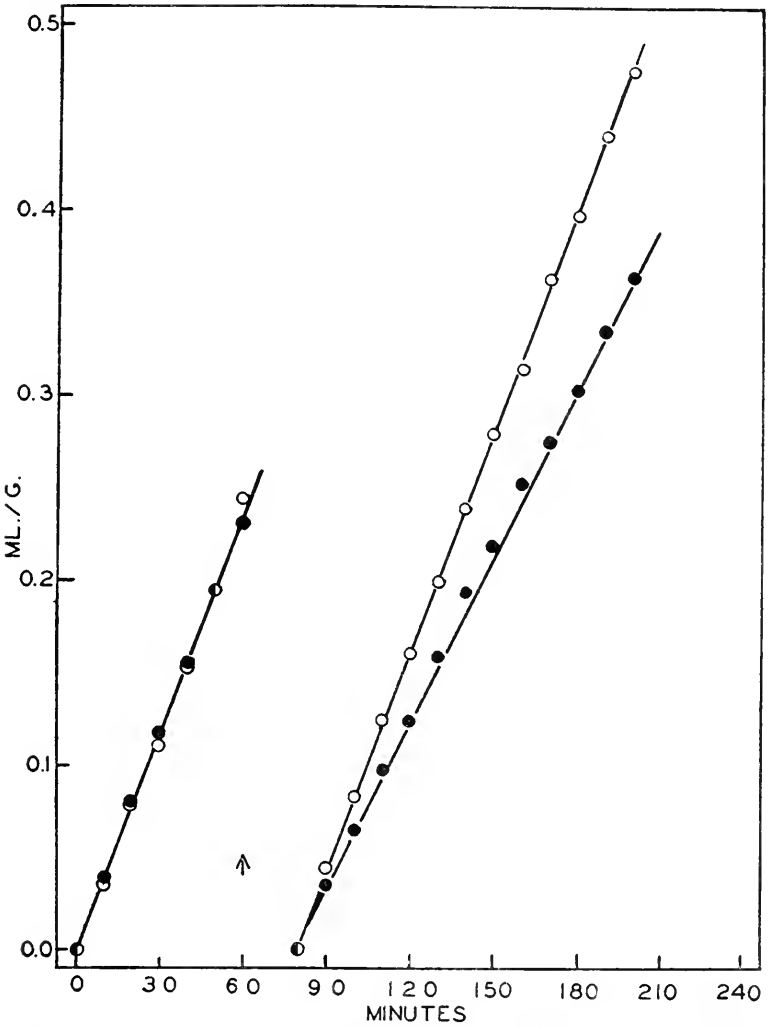

Figure 4. The influence of eyestalk extract upon the rate of oxygen consumption of eyestalkless *C. shufeldtii*. Circles=control animals which received injections of saline; dots=animals which received an injection of eyestalk extract; arrow indicates when the injections were administered; ordinate shows the milliliters of oxygen consumed per gram of body weight.

series of experiments is presented in Table 4. In this experiment comparison was made of the metabolic rate of the same crawfish before and after injection, rather than a comparison of the metabolic rates of different crawfish. The metabolic rates of the controls and experimentals were identical prior to the injections. Following the injections the controls showed no change in metabolic rate. The line representing the rate of the control animals paralleled the line drawn with the data obtained prior to the injection.

The experimental group showed a decrease in metabolic rate as evidenced by the decrease in slope. One hundred fifty minutes following the injections the metabolic rate of the experimental group was 23 percent less than the rate of the controls.

Lack of effect of stimulation of the eyestalk stubs.—The metabolic rates of six eyestalkless animals were determined for one hour by means of the Warburg respirometer. The eyestalk stubs were then stimulated by means of an electric cautery and the metabolic rates again determined. The results are presented in Table 5.

TABLE 5.
INFLUENCE OF CAUTERY OF EYESTALK STUBS UPON RATE OF OXYGEN CONSUMPTION

Animal	Oxygen Consumption Before Cautery (ml/g/hr)	Oxygen Consumption After Cautery (ml/g/hr)	Percentage Change
1	0.246	0.261	+ 6
2	0.191	0.137	—28
3	0.248	0.279	+12
4	0.224	0.276	+23
5	0.251	0.224	—12
6	0.239	0.312	+31

There was no constant effect. Four of the animals showed an increase in rate, two a decrease. The average change was a 6.4 percent increase. Scudamore (1947) found a 56.8 percent increase in metabolic rate following cauterization of the eyestalk stubs of *Orconectes immunis*. Experiments designed to test the effects of extracts of the supraesophageal ganglia with the circumesophageal connectives attached were equally inconclusive.

DISCUSSION

The existence of a daily rhythm of oxygen consumption in eyestalkless *Cambarellus* demonstrated that the sinus gland and x-organ of the eyestalk are not the centers of rhythmical activity in this species. The slight difference in the daily patterns of normal and eyestalkless *Cambarellus* might have been a modification of the basic metabolic rhythm due to the loss of the endocrine sources in the eyestalks.

The higher metabolic rate of eyestalkless crawfish is evident from (1) the greater amplitude of the daily rhythm of eyestalkless indi-

viduals and (2) the observations of the effect of eyestalk removal upon the metabolic rate of the same individual from day to day. The crawfish used in the determination of the daily rhythm of eyestalkless animals were females which were shown to have a lower metabolic rate than males. Seventy-five percent of the animals used in the studies of the daily rhythm of normal crawfish were males. The observed increase in amplitude of the daily rhythm of eyestalkless crawfish would probably have been greater than the observed 16 percent if animals of the same sex had been compared. The observed effect of eyestalk extract upon the metabolic rate confirmed the earlier observations of Scudamore (1947) who used a different genus of crawfish.

Summary

1. The rate of oxygen consumption of the dwarf crawfish, *Cambarellus shufeldtii,* has been continuously recorded for 24 hour periods.

2. Analysis of the data revealed a daily rhythm of rate of oxygen consumption. The rate was maximal around 6 a.m. with a secondary maximum at 3-6 p.m. Minima occurred from 9 a.m. to noon and from 9 p.m. to midnight.

3. Eyestalkless *Cambarellus shufeldtii* also had a persistent daily rhythm of metabolic rate. The daily rhythm of eyestalkless individuals differed slightly in pattern from that of normal crawfish.

4. Males weighed less and appeared to have a higher metabolic rate than females. The higher rate was probably due to both the sexual and weight differences.

5. Removal of the eyestalks resulted in an increase in the metabolic rate.

6. Extracts of eyestalks decreased the metabolic rate.

7. The metabolic rate of males increased more than the metabolic rate of females after eyestalk removal. This fact is further evidence in favor of a sexual difference in metabolic rate in *Cambarellus.*

References Cited

Bauchau, A. G. 1948. Intensite du metabolisme et gland sinusaire chez *Eriocheir sinensis.* H. M. Edw. *Ann. Soc. Roy. Zool. Belgique,* 79: 73-86.

Bliss, Dorothy E. 1953. Neurosecretion and crab metabolism. *Anat. Rec.,* 117: 599.

Brown, Frank A., Jr. 1954. A simple, automatic, continuous-recording respirometer. *Rev. Sci. Instruments,* 25: 415-417.

Brown, Frank A., Jr., Miriam F. Bennett, and H. Marguerite Webb 1954. Persistent daily and tidal rhythms of oxygen consumption in fiddler crabs. *J. Cell. and Comp. Physiol.,* 44: 477-506.

Edwards, George A. 1946. The influence of temperature upon the oxygen consumption of several arthropods. *Ibid.,* 27: 53-64.

---------- 1950. The influence of eyestalk removal on the

metabolism of the fiddler crab. *Physiol. Comp. et Oecol.*, 2: 34-50.

SCHEER, BRADLEY T. and MARLIN A. R. SCHEER 1954. The hormonal control of metabolism in crustaceans. VIII. Oxygen consumption in *Leander serratus*. *Pubbl. Staz. Zool. Napoli*, 25: 419-426.

SCUDAMORE, HAROLD H. 1947. The influence of the sinus glands upon molting and associated changes in the crayfish. *Physiol. Zool.*, 20: 187-208.

ZEUTHEN, ERIK 1955. Comparative physiology (respiration). *Ann. Rev. Physiol.*, 17: 459-482.

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IDENTIFICATION AND GEOGRAPHICAL VARIATION OF THE CYPRINODONT FISHES *FUNDULUS OLIVACEUS* (STORER) AND *FUNDULUS NOTATUS* (RAFINESQUE)

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In recent years it has been recognized by some ichthyologists that *Fundulus olivaceus* is worthy of recognition as a species distinct from the closely related *Fundulus notatus.* Some observations which partially clarify the morphological relationships between these two species are reported here. The author is indebted to Dr. Edward C. Raney under whom the work was done as part of a review of the genus *Fundulus* which was completed and submitted as a Master of Science thesis at Cornell University in 1954. All of the specimens examined are in the Cornell University fish collection.

That *Fundulus olivaceus* should be recognized as a good species has not been agreed upon by most ichthyologists in the past. Garman (1895: 117) placed *notatus* in the synonymy of *olivaceus.* Jordan and Evermann (1896: 659) recognized that southern specimens are larger and darker but did not separate *olivaceus* from *notatus.* Although both species occur commonly in Illinois, Forbes and Richardson (1920: 213) treated *notatus* with no mention of *olivaceus.* Hubbs and Ortenburger (1927: 98), who obviously were dealing with specimens of both species, summarized their opinions on the matter as follows: "The specks on the body vary from being diffuse or even indistinct to being sharp, round, and black. We are, however, unable to attach any racial importance to this variation, for it shows no clear-cut geographical relation, and is not always consistent at a single locality." Kuhne (1939: 77) stated, "Two subspecies occur in Tennessee, the northern (and more upland) *F. n. notatus* and the southern lowland *F. n. olivaceus* (Putnam). The latter has a flatter head and the body is marked by strong blackish spots." Moore and Paden (1950: 88) stated that "*F. notatus* and *F. olivaceus* occupy the same habitat (overflow pools, oxbow lakes, and to some extent backwaters) without any apparent interbreeding. A special effort was made to collect pairs in order to determine their characters. Both sexes of each pair proved to be either one or the other of the two forms, thus in some measure, confirming their specific identity. . . . " Jurgens and Hubbs (1953) also listed *olivaceus* and *notatus* as separate species. Knapp (1953: 89) wrote of *F. olivaceus* in Texas, "Where its range overlaps with *F. notatus* the two are usually ecologically separated, *F. olivaceus* being typically a quiet water form. Near the coastal plain this species inhabits swifter waters." He also stated, "In Texas *F. notatus* is to be expected in headwaters and fast streams." Bailey, Winn, and Smith (1954: 133) pointed out the striking resemblance of the two species and stated, "it is possible that a more thorough

TABLE 1.

NUMBER OF DORSAL RAYS IN *Fundulus olivaceus* AND *Fundulus notatus*

Populations	*Fundulus olivaceus* Number of Dorsal Rays						
	9	10	11	N	M	s	$2s_M$
Mo. R., Mo.	–	7	–	7	10.0	–	–
Southern Ill.	6	23	2	31	9.9	.50	.18
Clinch R., Tenn.	1	–	–	1	9.0	–	–
Western Tenn.	2	4	1	7	9.9	–	–
White R., Mo.	–	4	–	4	10.0	–	–
Ark. R., Ark.	2	20	3	25	10.0	.45	.18
Eastern La.	7	20	2	29	9.8	.54	.20
Total Miss. Valley	18	78	8	104	9.9	.50	.10
Biloxi R., Miss.	6	6	–	12	9.5	.52	.30
Ala. R.	34	4	–	38	9.1	.31	.10
Pensacola Bay Dr.	14	6	–	20	9.3	.47	.21
Choctawhatchee R.	7	3	–	10	9.3	.48	.31
Chattahoochee R.	2	–	–	2	9.0	–	–
Total Ala. and Fla.	57	13	–	70	9.2	.39	.09

Populations	*Fundulus notatus* Number of Dorsal Rays								
	8	9	10	11	12	N	M	s	$2s_M$
Northern Ill.	2	44	16	–	–	62	9.2	.49	.13
Marion Co., Ill.	–	5	3	–	–	8	9.4	–	–
Meramec R., Mo.	–	2	–	–	–	2	9.0	–	–
Western Tenn.	–	8	1	–	–	9	9.1	–	–
Tombigbee R., Ala.	–	3	1	–	–	4	9.3	–	–
Total	2	62	21	–	–	85	9.2	.47	.10
Galveston Bay Dr.	1	1	8	7	1	18	10.3	1.03	.49

study may prove them to be the genetic variants of a single species." They recognized that evidence from Moore and Paden (1950: 88) suggests that these are two full species sympatric in some parts of their ranges. The evidence from my studies supports the recognition of *olivaceus* as a valid species.

Methods

Dorsal and anal rays were counted at their bases, the last two rays never being counted as one, as is the custom in counting for certain groups. Standard length, caudal peduncle depth, depressed dorsal and anal fins, bases of dorsal and anal fins, and lateral-line scales were measured or counted according to the methods of Hubbs and Lagler (1947: 8-15), except that the most anterior scale counted was the one in which the center of the exposed field of the scale lay exactly on, or just posterior to, a vertical line through the upper extremity of the gill slit. Scales around the caudal peduncle (usually, but not necessarily, the least count) were counted vertically at a point half way between the posterior bases of the dorsal and anal fins and the upper and lower procurrent caudal rays. For methods of calculation and interpretation of the coefficient of divergence see Mayr, Linsley and Usinger (1953: 146).

Explanation of Figures

In the figures the range is shown as a single, heavy, horizontal line; the mean by a short, pointed, vertical line; one standard deviation on either side of the mean by a hollow bar; and two standard errors on either side of the mean by a solid black bar. Regardless of sample size the denominator used in calculating the standard deviation was always "N — 1". In general, for normal distributions, when the black bars for two samples do not overlap it is safe to conclude that the difference between the two means is probably not due to chance. When the hollow bars do not overlap, approximately 84% or more of the specimens are separable. Hubbs and Hubbs (1953) gave details for interpreting this type of diagram. Because the distributions only approach normal, statistical interpretations should be made on the conservative side.

Variation in *Fundulus olivaceus*

In *olivaceus* the dorsal and anal rays (Tables 1, 2; figs. 1, 2) are fewer in specimens from eastern Gulf Coast drainages than in those from the Mississippi Valley. With respect to these characters the specimens from eastern Louisiana clearly fit with those from the Mississippi Valley. There is probably a clinal intergradation between the Alabama-Florida and Louisiana populations since the sample from the Biloxi River of Mississippi is intermediate; additional material may show that this trend is continued in Texas populations.

A line drawn between 9 and 10 dorsal rays separates 83% of 104 Mississippi Valley specimens from 81% of 70 Alabama-Florida specimens; average separation 82%; coefficient of divergence 0.80. A

TABLE 2.

NUMBER OF ANAL RAYS IN *Fundulus olivaceus* AND *Fundulus notatus*

Populations	*Fundulus olivaceus* Number of Anal Rays						
	11	12	13	N	M	s	$2s_M$
Mo. R., Mo.	–	5	2	7	12.3	–	–
Southern Ill.	9	17	5	31	11.9	.67	.45
Clinch R., Tenn.	–	1	–	1	12.0	–	–
Western Tenn.	1	5	1	7	12.0	–	–
White R., Mo.	1	3	–	4	11.8	–	–
Ark. R., Ark.	–	15	10	25	12.4	.50	.20
Eastern La.	–	23	6	29	12.2	.41	.15
Total Miss. Valley	11	69	24	104	12.1	.57	.11
Biloxi R., Miss.	3	7	2	12	11.9	.67	.39
Ala. R.	21	17	–	38	11.5	.50	.16
Pensacola Bay Dr.	8	12	–	20	11.6	.50	.22
Choctawhatchee R.	7	3	–	10	11.3	.48	.31
Chattahoochee R.	1	1	–	2	11.5	–	–
Total Fla. and Ala.	37	33	–	70	11.5	.63	.15

Populations	*Fundulus notatus* Number of Anal Rays							
	11	12	13	14	N	M	s	$2s_M$
Northern Ill.	7	51	4	–	62	11.9	.41	.11
Marion Co., Ill.	1	6	1	–	8	12.0	–	–
Meramec R., Mo.	–	2	–	–	2	12.0	–	–
Western Tenn.	1	5	3	–	9	12.2	–	–
Tombigbee R., Ala.	–	2	2	–	4	12.5	–	–
Total	9	66	10	–	85	12.0	.48	.10
Galveston Bay Dr.	–	3	15	1	19	12.9	.46	.21

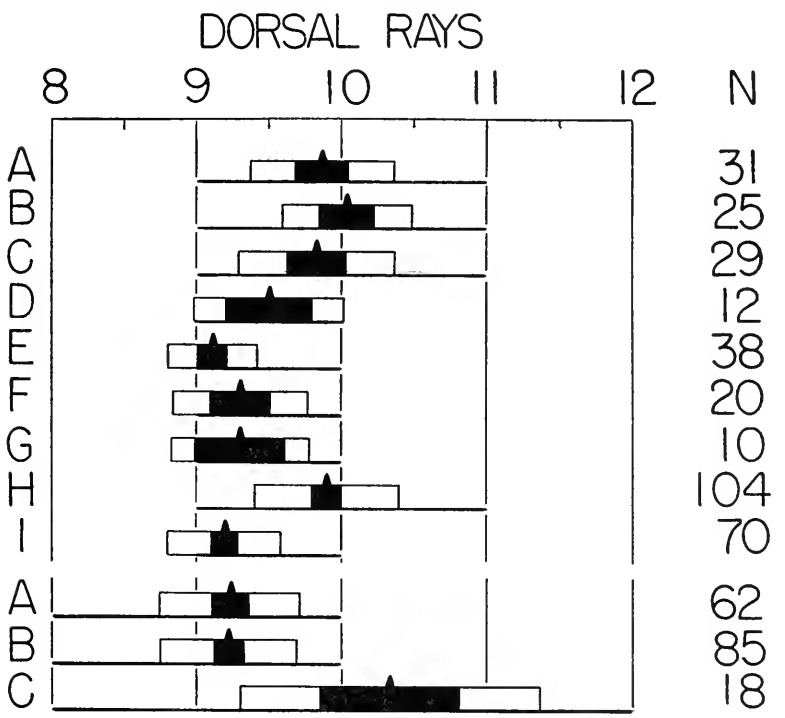

Figure 1. Dorsal ray counts. *Fundulus olivaceus:* **A.** Southern Illinois; **B.** Arkansas River, Ark.; **C.** Eastern Louisiana; **D.** Biloxi River, Miss.; **E.** Alabama River; **F.** Pensacola Bay drainage; **G.** Choctawhatchee River; **H.** Total Mississippi Valley and Louisiana; **I.** Total Alabama River to Chattahoochee River. *Fundulus notatus*— **A.** Northern Illinois; **B.** Total Mississippi Valley and Tombigbee River; **C.** Galveston Bay drainage, Texas.

line drawn between 11 and 12 anal rays separates 89% of 104 Mississippi Valley specimens from 53% of 70 Alabama-Florida specimens; average separation 71%; coefficient of divergence 0.54.

The number of scales in the lateral line (Table 3, fig. 3) is usually 34 or fewer, but in the three easternmost populations treated, the frequency distribution shows an unusual number with 35 scales. Samples from the Alabama River System are similar to western populations; whereas in numbers of dorsal and anal rays the Alabama population is similar to those from the eastern Gulf. A line drawn between 34 and 35 scales separates 59% of 32 specimens from the drainage systems of Pensacola Bay, Choctawhatchee River and Chattahoochee River from 89% of the rest of the specimens examined (140); average separation 74%; coefficient of divergence 0.52.

The number of scales around the caudal peduncle (Table 4, fig. 4)

TABLE 3.

NUMBER OF LATERAL-LINE SCALES IN *Fundulus olivaceus* AND *Fundulus notatus*

Populations	*Fundulus olivaceus* Number of Lateral-Line Scales								
	32	33	34	35	36	N	M	s	$2s_M$
Mo. R., Mo.	1	1	5	–	–	7	33.6	–	–
Southern Ill.	–	7	15	8	–	30	34.0	.72	.26
Clinch R., Tenn.	–	–	1	–	–	1	34.0	–	–
Western Tenn.	–	–	6	1	–	7	34.1	–	–
White R., Mo.	–	2	2	–	–	4	33.5	–	–
Ark. R., Ark.	–	1	18	3	1	23	34.2	.58	.24
Eastern La.	1	10	9	1	–	21	33.5	.68	.30
Biloxi R., Miss.	–	5	7	–	–	12	33.6	.52	.30
Ala. R.	–	12	21	2	–	35	33.7	.61	.19
Total	2	38	84	15	1	140	33.8	.66	.11
Pensacola Bay Dr.	–	3	3	13	1	20	34.6	.82	.37
Choctawhatchee R.	–	–	7	3	–	10	34.3	.48	.31
Chattahoochee R.	–	–	–	2	–	2	35.0	–	–
Total Pen.-Chatta.	–	3	10	18	1	32	34.5	.72	.25

Populations	*Fundulus notatus* Number of Lateral-Line Scales							
	32	33	34	35	N	M	s	$2s_M$
Northern Ill.	11	12	3	–	26	32.7	.68	.27
Marion Co., Ill.	3	1	–	–	4	32.3	–	–
Meramec R., Mo.	–	2	–	–	2	33.0	–	–
Western Tenn.	1	5	3	–	9	33.2	–	–
Tombigbee R., Ala.	–	4	–	–	4	33.0	–	–
Total	15	24	6	–	45	32.8	.66	.20
Galveston Bay Dr.	–	7	10	1	18	33.7	.59	.28

is 16 in most Gulf Coast specimens and varies from 16 to 20 in specimens from the central Mississippi Valley; there seems to be a correlation with latitude for this character. A line drawn between 16 and 17 separates 76% of 72 central Mississippi Valley specimens from 72% of 99 Gulf Coast specimens; average separation 74%; coefficient of divergence 0.67. The coefficient of divergence is not applicable in this instance since the standard deviation for the Mississippi Valley sample, 1.30, is more than 1½ times the standard deviation of the Gulf Coast sample, 0.76.

There is a difference in average body form between specimens of *olivaceus* from the Mississippi Valley and specimens from the Gulf Coast. The latter have a slimmer caudal peduncle (Figure 5), and their bodies are generally less deep and less wide.

The following generalizations seem appropriate. First, it is seen that the various characters which vary geographically are not well coordinated with each other. For example, the breaks between high and low numbers of lateral-line scales, fin rays, and caudal peduncle scales are located in different geographical areas. The differences in

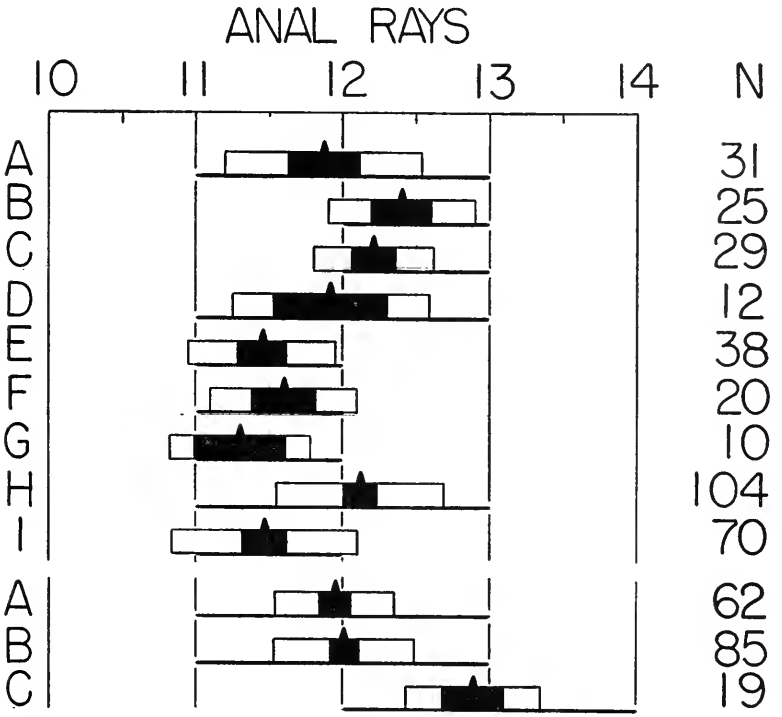

Figure 2. Anal ray counts. *Fundulus olivaceus*—**A.-I.** same as fig. 1. *Fundulus notatus*—**A.-C.** same as fig. 1.

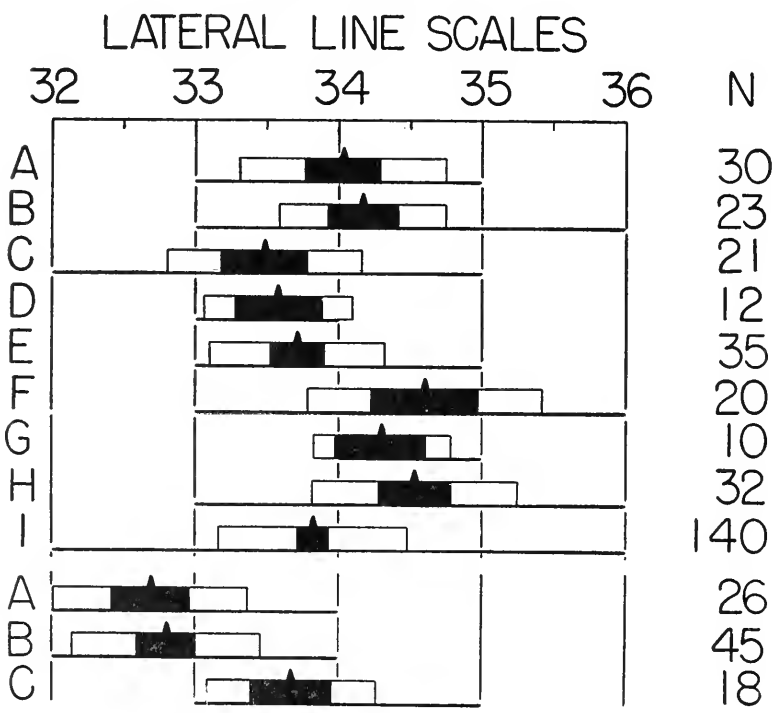

Figure 3. Lateral line scale counts. *Fundulus olivaceus*—**A.** Southern Illinois; **B.** Arkansas River, Ark.; **C.** Eastern Louisiana; **D.** Biloxi River, Miss.; **E.** Alabama River; **F.** Pensacola Bay drainage; **G.** Choctawhatchee River; **H.** Total Pensacola Bay to Chattahoochee River; **I.** Total Mississippi Valley and East along Gulf Coast through the Alabama River. *Fundulus notatus*—**A.** Northern Illinois; **B.** Total Mississippi Valley and Tombigbee River; **C.** Galveston Bay drainage, Texas.

proportions and number of scales around the caudal peduncle are apparently correlated with latitude. The number of anal and dorsal rays varies in an east-west direction. The highest lateral line frequency is restricted to a relatively small area in Alabama and Florida. These characters might be employed to divide the species into several races (not subspecies), but the author chooses to present only a general picture of variation for each important character.

Range of *Fundulus olivaceus*

The range extends from the Okefinokee Swamp, Georgia (?) (*"F. notatus"* of Fowler, 1945: 244), the Chattahoochee (CU 16081 and 15997) and Choctawhatchee River systems of Alabama and Florida, and the Clinch River System of Tennessee (CU 19148), to Texas (Jurgens and Hubbs, 1953; Knapp, 1953: 89) and the Ar-

TABLE 4.

NUMBER OF SCALES AROUND CAUDAL PEDUNCLE IN *Fundulus olivaceus* AND *Fundulus notatus*

Populations	*Fundulus olivaceus* Number of Caudal Peduncle Scales										
	14	15	16	17	18	19	20	N	M	s	$2s_M$
Mo. R., Mo.	–	–	2	2	1	2	–	7	17.4	–	–
Southern Ill.	–	–	4	4	9	8	4	29	18.1	1.25	.46
Clinch R., Tenn.	–	–	1	–	–	–	–	1	16.0	–	–
Western Tenn.	–	–	5	1	0	1	–	7	16.6	–	–
White R., Mo.	–	–	2	0	1	1	–	4	17.3	–	–
Ark. R., Ark.	–	–	3	9	4	6	2	24	17.8	1.22	.50
Total Miss. Valley	–	–	17	16	15	18	6	72	17.7	1.30	.31
Eastern La.	–	–	11	5	5	–	–	21	16.7	.85	.37
Biloxi R., Miss.	1	2	8	1	–	–	–	12	15.8	.75	.44
Ala. R.	–	–	24	7	4	–	–	35	16.4	.70	.24
Pensacola Bay Dr.	–	1	15	2	1	–	–	19	16.2	.60	.28
Choctawhatchee R.	–	–	8	1	1	–	–	10	16.3	.63	.43
Chattahoochee R.	–	–	1	1	–	–	–	2	16.5	–	–
Total Gulf Coast	1	3	67	17	11	–	–	99	16.3	.76	.15

Populations	*Fundulus notatus* Number of Caudal Peduncle Scales								
	16	17	18	19	20	N	M	s	$2s_M$
Northern Ill.	4	14	7	0	1	26	17.2	.86	.34
Marion Co., Ill.	1	1	1	1	–	4	17.5	–	–
Meramec R., Mo.	–	–	2	–	–	2	18.0	–	–
Western Tenn.	1	2	2	2	2	9	18.2	–	–
Total Northern	6	17	12	3	3	41	17.5	1.08	.34
Tombigbee R., Ala.	3	1	–	–	–	4	16.3	–	–
Galveston Bay Dr.	16	2	1	–	–	19	16.2	.54	.25
Total Southern	19	3	1	–	–	23	16.2	.52	.22

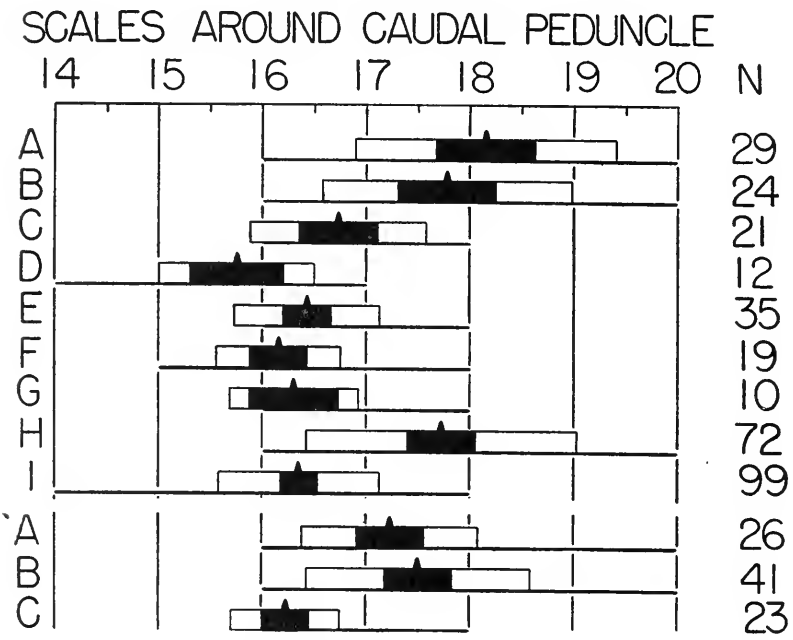

Figure 4. Scales around caudal peduncle. *Fundulus olivaceus*—**A.** Southern Illinois; **B.** Arkansas River, Ark.; **C.** Eastern Louisiana; **D.** Biloxi River, Miss.; **E.** Alabama River; **F.** Pensacola Bay drainage; **G.** Choctawhatchee River; **H.** Total Mississippi Valley; **I.** Total Gulf Coast. *Fundulus notatus*—**A.** Northern Illinois; **B.** Total northern specimens; **C.** Total Galveston Bay and Tombigbee River drainages.

kansas and Red River Systems of eastern Oklahoma (George A. Moore, *personal communication*), and north to Morgan County, Missouri (CU 11227), Union County, Illinois (CU 3464 and 3476), and western Kentucky and Tennessee (other CU collections).

Material Examined

Missouri R., Mo.—Morgan Co.: Little Gravois Cr., 2½ mi. N.E. of Gravois Mill, CU 11227, 7 specimens (standard length 38-62 mm). *Southern Illinois*.—Union Co.: E. of Cobden, CU 3464, 19 (22-61); E. of Anna, CU 3476, 12 (37-45). *Clinch R., Tenn.*—Anderson Co.: Poplar Cr., 5.8 mi. N.E. of Oliver Sprs., CU 19148, 1 (41). *Western Tennessee*.—Houston Co.: White Oak Cr., 8 mi. from McKinnon, Old Bridge at Crosswell's Farm, CU 23114, 7 (38-55). *White R., Mo.*—Butler Co.: Little Black R., 2.4 mi. E. of Fairdealing, Rt. 14, CU 24278, 4 (25-51). *Arkansas R., Ark.*—Pope Co.: Illinois Bayou, 4.2 mi. W. of Russelville, Rt. 22, CU 24368, 12 (25-37). Franklin Co.: White Oak Cr., 7.4 mi. E. of Ozark, Rt. 64, CU uncataloged,

13 (25-60). *Eastern Louisiana.*—West Feliciana Par.: Alexander Cr., trib. Thompson Cr., 1.1 mi. E. of jct. Rt. 65 and 61 with Rt. 35, CU 16302, 12 (21-53). Livingstone Par.: trib. Colyell Cr., 5.7 mi. W. of Livingstone, Rt. 190, Amite R. drainage, CU 15529, 5 (26-72). Tangipahoa Par.: trib. Selser Cr., 3.3 mi. E. of Hammond, Rt. 190, Pontchartrain drainage, CU 13945, 6 (26-50); Natalbany R., 0.8 mi. W. of Baptist, Rt. 190, Lk. Maurepas drainage, CU 21552, 6 (36-56). *Biloxi R., Miss.*—Stone Co.: headwaters Biloxi R., 12.2 mi. S.W. of Wiggins, CU 16636, 12 (26-58). *Alabama R., Ala.*—Macon Co.: trib. Sawacklahatchee Cr., 1.7 mi. W. of Society Hill, Rt. 80, CU 16028, 18 (26-58); trib. Cobebee R., 3.9 mi. S. of Tuskegee, Rt. 29, CU 14049, 16 (25-55); Sawacklahatchee Cr., trib. Uphapa Cr., 5.9 mi. W. of Society Hill, CU 16003, 4 (38-58). *Pensacola Bay Drainage.*—Okaloosa Co., Fla.: Blackwater R. 4.3 mi. N.W. of Baker, CU 12665, 1 (48); trib. Blackwater R., 100 yds. E. of Santa Rosa Co. line, Rt. 4, CU 16705, 7 (31-47); Yellow R., trib. Shoal R., 3.2 mi. E. of Crestville, CU 12156, 2 (47-52). Santa Rosa Co., Fla.: Sweetwater Cr., 12.4 mi. N.W. of Baker, Rt. 4, Blackwater R. drainage, CU 12141, 3 (42-47). Walton Co., Fla.: Gum Cr., trib. Shoal R., 5.9 mi. N.W. of De Funiak, CU 12125, 3 (22-48). Escambia Co., Ala.: Franklin Mill Cr., 3.9 mi. S.W. of Brewton, Rt. 29, Conecuh System, CU 14011, 2 (33-46). Conecuh Co., Ala.: Jay Br. of Mill Cr., 7.4 mi. E. of Evergreen, CU 16143, 1 (73); Boggy Br., trib. Sepulga R., 4.8 mi. S.W. of McKenzie, Rt. 84, CU 16204, 1. *Choctawhatchee R., Ala.*—Henry Co.: 5 mi. W. of Graball, Rt. 10, CU 17143, 10 (30-50). *Chattahoochee R., Ala.*—Barbour Co.: Barbour Cr., 2.3 mi. S. of Eufaula, CU 16081, 1 (50). Lee Co.: Uchee Cr., 0.7 mi. E. of M., CU 15997, 1 (56).

Variation in *Fundulus notatus*

A collection of 19 specimens of *F. notatus* from the Galveston Bay drainage of eastern Texas differs considerably from typical Illinois and Missouri samples in color, proportions, and numbers of scales and fin rays. In general it may be said that these Texas specimens differ from Illinois populations of *notatus* in many of the same ways that *olivaceus* differs from *notatus*. In the Texas specimens the lateral band is blacker, more intense, and has a more even edge; the cross bars are notably weak in males; and the predorsal stripe is less conspicuous. The spotting on the vertical fins is finer and less regular.

In proportions the body is much less robust, less wide, less deep, and generally more attenuate. The head is definitely narrower. Figure 5 shows the difference in relative depth of the caudal peduncle between male specimens of *notatus* from Texas and from Illinois and Missouri. In Texas specimens the muzzle appears more pointed from the side, and the premaxillary appears smaller when viewed from above.

Texas specimens have more anal rays (Table 2, fig. 2). A line drawn between 12 and 13 separates 84% of the 19 Texas specimens

from 88% of 85 more northern and eastern specimens; average separation 86%; the coefficient of divergence is 0.94, but the standard deviation of the Texas sample is more than twice that of the northern and eastern sample. Texas specimens also average higher in number of dorsal rays; a line drawn between 9 and 10 separates 89% of 18 specimens from 75% of 85 northern and eastern specimens; average separation 82%; coefficient of divergence 0.74, but unreliable because of the difference in standard deviations. In Texas specimens the number of scales in the lateral line (Table 3, fig. 3) averages higher; 61% of 18 specimens being separable from 87% of 45 other specimens by a line between 33 and 34; average separation 74%; coefficient of divergence 0.69. In northern collections of *notatus* the number of scales around the caudal peduncle (Table 4, fig. 4) is usually higher than 16; however, 3 of the 4 specimens from the Tombigbee system of Alabama and 16 of the 19 Texas specimens have 16 scales. A line drawn between 16 and 17 separates 83% of

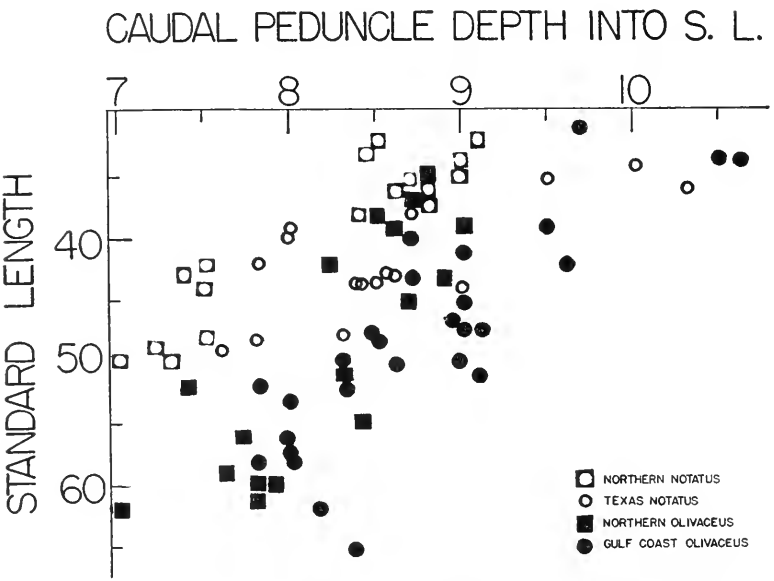

Figure 5. Caudal peduncle depth in relation to standard length in males of northern and southern populations of *Fundulus notatus* and *Fundulus olivaceus*.

the 23 southern specimens from 85% of 41 more northern specimens; average separation 84%; coefficient of divergence 0.81.

It is apparent that the pattern of geographical variation in *F. notatus* is strikingly similar to that found in *olivaceus*. Both are slimmer, less robust, and have somewhat fewer scales around the

TABLE 5.

A COMPARISON OF *Fundulus olivaceus* WITH *Fundulus notatus*, MODIFIED AND ENLARGED FROM MOORE AND PADEN (1950: 88)

Character	*olivaceus*	*notatus*
Spots on sides of back (more numerous in males)	Conspicuous, discrete, blacker on a lighter background	Inconspicuous, diffuse, lighter and browner on a darker background
Spots on vertical fins	Smaller, more irregular in shape and distribution, more numerous	Larger, rounder, often in rows, fewer
Cross bars in males	Less prominent, fewer	More prominent, more numerous
Lateral band in females	More intensely black, more even-edged	Less intense, less even-edged (serrated)
Dorsal and anal fins in adult males	Shorter, more rounded; usually not reaching past origin of caudal; shorter base	Larger, more pointed, reaching to or past origin of caudal; longer base
Dorsal and anal fins in adult females	Longer when depressed, longer base	Shorter when depressed, shorter base
Predorsal stripe	Weak and diffuse in young; absent in adult	Rather strong, though often broken in young; remnants usually retained in adult
Black pigment about base of anal fin of young	Well developed; area broad, more solidly black	Less developed; area narrower, less solidly black
Lateral-line scales in central and northern Mississippi Valley	Usually 34 or more	Usually 33 or fewer
Dorsal rays in Mississippi Valley	Mode 10	Mode 9
Caudal peduncle depth in males	Slimmer	Deeper
General body form	Averages less deep; head and body less wide	Averages deeper; head and body wider
Muzzle, lateral view	More pointed	More rounded
Premaxillary in dorsal view	Smaller	Larger

caudal peduncle in the south; and both species have a lower number of dorsal and anal rays in eastern populations.

Range of *Fundulus notatus*

The range extends from Mitchell and Grundy counties of northeastern Iowa (Harlan and Speaker, 1951: 137), southeastern Wisconsin (both sides of the divide), southern Michigan, and the prairie regions of western and central Ohio (Hubbs and Lagler, 1947: 78) south to Kentucky, the Duck River of Tennessee (Miller, 1955: 10), the Gulf drainages from the Tombigbee River System of Alabama (CU 15511) to the Guadalupe River drainage of Texas (Hubbs, Kuehne, and Ball, 1953: 231), and west to Kay, Creek, and Johnston counties of eastern Oklahoma (Moore, *personal communication*), and Kansas (Miller, *ibid.*).

Material Examined

Northern Illinois.—Cook Co.: Des Plaines R., at bridge, Deerfield Rd., CU 17975, 8 specimens (standard length 32-50 mm). Lake Co.: Des Plaines R., bridge, Rt. 59A, CU 18006, 11 (35-51); Des Plaines R., bridge, Rt. 22, CU 17941, 3 (42-46). Kanakee Co.: trib. Iroquois R., 4 mi. S. of Kanakee, CU uncataloged, 36 (small ad.). Livingston Co.: Vermillion R., CU 3399, 4 (37-46). *Marion Co., Ill.*—N. of Centralia, CU 3432, 8 (35-51). *Meramec R., Mo.*—Dent Co.: 2 mi. N.W. of Short Bend, CU 10781, 2 (32-42). *Western Tennessee.*—Cheatam Co.: White's Cr., 1 mi. N. of Bordeaux, Rt. 41A, CU 22146, 9. *Tombigbee R., Ala.*—Green Co.: trib. Tombigbee R., 0.8 mi. N.E. of Boligee, Rt. 11, CU 15511, 4 (30-37). *Galveston Bay Drainage, Texas.*—Montgomery Co.: 2 mi. W. of Conroe, Rt. 105, CU 21930, 18 (23-49). Walker Co.: Country Campus, Sam Houston S. I. C., 11 mi. E.N.E. of Huntsville, CU 15286, 1 (35).

Discussion

The characters which have been found most useful in separating these two closely related species are summarized in Table 5, which is taken for the most part from the one prepared by Carl L. Hubbs in Moore and Paden (1950: 88). Although the main differentiating characters are those of coloration, there also are differences in scalation, fin rays, proportions, and degree of sexual dimorphism.

Fundulus olivaceus is the slimmer, more attenuate species in a given region although this character varies from north to south. Figure 5 illustrates that, for a given size, when northern or southern populations are compared, *olivaceus* is found to have a slimmer caudal peduncle on the average than *notatus*. It also demonstrates that southern populations of each species have slimmer caudal peduncles than their conspecific northern populations.

It may be seen from Figure 6 that in northern populations *notatus* exhibits a definite difference between the sexes in depth of caudal peduncle, the females being slimmer at the same standard lengths. However, in northern populations of *olivaceus* there is no obvious

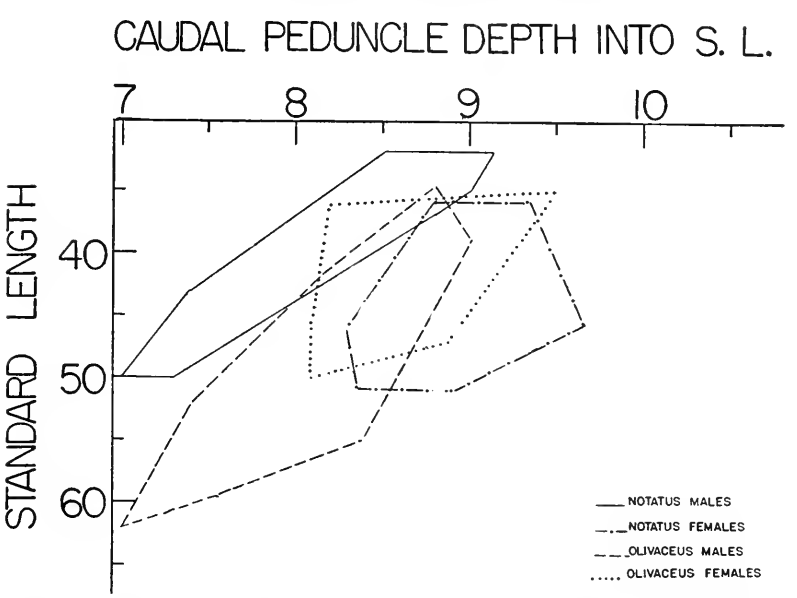

Figure 6. Sexual dimorphism of caudal peduncle depth in relation to standard length in Illinois and Missouri populations of *Fundulus notatus* and *Fundulus olivaceus*. Number of specimens: *F. notatus* (♂ = 17, ♀ = 10), *F. olivaceus* (♂ = 17, ♀ = 21). The polygons encompass the total range of variation encountered in each case.

sexual dimorphism in this character. In respect to length of dorsal and anal fins, measured either at their bases or from origin to tip of longest depressed rays, the same relationship exists. The males of *notatus* have longer fins and the females shorter ones than equal-sized specimens of both sexes of *olivaceus*.

Summary

The evidence that *olivaceus* and *notatus* are separate species may be summarized as follows: (1) Specimens of the two forms differ not only in several aspects of coloration, but also in proportions, degree of sexual dimorphism, and to a certain extent in scalation and number of fin rays. (2) Although *notatus* extends farther north and *olivaceus* reaches its greatest abundance in the south, their ranges overlap broadly. (3) The only cases of cohabitation which have been investigated have yielded no positive indication of interbreeding (Moore and Paden, 1950: 88).

Both species are slenderer and have fewer scales around the caudal peduncle in the south, and both have fewer dorsal and anal rays in the east.

References Cited

Bailey, Reeve M., Howard E. Winn and C. Lavett Smith 1954. Fishes from the Escambia River, Alabama and Florida, with

ecologic and taxonomic notes. *Proc. Acad. Nat. Sci., Phila.*, 101: 109-164.

FORBES, STEPHEN ALFRED and ROBERT EARL RICHARDSON 1920. The fishes of Illinois. *Nat. Hist. Surv. Ill.*, 2nd ed., 3: i-cxxi, 1-357, many figs.

FOWLER, HENRY W. 1945. A study of the fishes of the southern Piedmont and Coastal Plain. *Monogr. Acad. Nat. Sci. Phila.*, 7: i-vi, 1-408, figs. 1-313.

GARMAN, S. 1895. The cyprinodonts. *Mem. Mus. Comp. Zool.*, 19: 1-179, pls. 1-12.

HARLAN, JAMES R. and EVERETT B. SPEAKER 1951. *Iowa Fish and Fishing.* Iowa State Cons. Comm., pp. 1-238, pls. 1-22.

HUBBS, CARL L. and CLARK HUBBS 1953. An improved graphical analysis and comparison of series of samples. *Systematic Zool.*, 2: 49-56, 92, figs. 1-4.

HUBBS, CARL L. and KARL F. LAGLER 1947 (and second printing 1949). Fishes of the Great Lakes region. *Bull. Cranbrook Inst. Sci.*, 26: i-xi, 1-186, pls. 1-26, figs. 1-251.

HUBBS, CARL L. and A. I. ORTENBURGER 1929. Fishes collected in Oklahoma and Arkansas in 1927. *Publ. Univ. Okla. Biol. Surv.*, 1: 45-112, pls. 1-13.

HUBBS, CLARK, ROBERT A. KUEHNE and JACK C. BALL 1953. Fishes of the upper Guadalupe River, Texas. *Texas Jour. Sci.*, 5: 216-244.

JORDAN, DAVID STARR and BARTON WARREN EVERMANN 1896. Fishes of North and Middle America. . . . *Bull. U. S. Nat. Mus.*, 47, Pt. 1: i-lx, 1-1240.

JURGENS, KENNETH C. and CLARK HUBBS 1953. A checklist of Texas fresh-water fishes. *Texas Game and Fish*, 11: 12-15.

KUHNE, EUGENE R. 1939. *A Guide to the Fishes of Tennessee and the Mid-South.* Tenn. Dept. Cons., Nashville, Tenn., pp. 1-124, figs. 1-81.

MAYR, ERNST, GORTON E. LINSLEY and ROBERT L. USINGER 1953. *Methods and Principles of Systematic Zoology.* McGraw-Hill Book Co., New York, pp. i-ix, 1-328, figs. 1-45.

MILLER, ROBERT RUSH 1955. An annotated list of the American cyprinodontid fishes of the genus *Fundulus*, with the description of *Fundulus persimilis* from Yucatan. *Occ. Pap. Mus. Zool. Univ. Mich.*, No. 568: 1-25, figs. 1-2.

MOORE, GEORGE A. and JOHN M. PADEN 1950. The fishes of the Illinois River in Oklahoma and Arkansas. *Amer. Midl. Nat.*, 44: 76-95.

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THE PHYSIOLOGY OF THE MELANOPHORES OF THE ISOPOD *IDOTHEA EXOTICA*

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ERRATUM

Tulane Studies in Zoology, volume 3, number 8

Through a regrettable error the isopod used by Dr. Milton Fingerman in his study of melanophore physiology was mis-labeled *Idothea exotica.* The correct name for this isopod is *Ligia exotica.*

THE PHYSIOLOGY OF THE MELANOPHORES OF THE ISOPOD *IDOTHEA EXOTICA*[1]

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Alteration of body color in isopods was first described by Matzdorff (1883). He noted that specimens of *Idothea tricuspidata* would blanch upon a white background because of pigment concentration and darken on a black background because of pigment dispersion in the melanophores. Melanin of isopods whose eyes had been either destroyed or covered with an opaque material dispersed to the same extent as the melanin of normal isopods on a black background as demonstrated in *Ligia oceanica* by Tait (1910), in *Idothea tricuspidata* by Pieron (1914), in *Ligia baudiniana* by Kleinholz (1937), and in *Ligia exotica* by Enami (1941).

Daily rhythms of color change have been described in a few species of isopods, *e.g.* in *Idothea tricuspidata* by Menke (1911) and Pieron (1914) and in *Ligia baudiniana* by Kleinholz (1937). Specimens of *Idothea tricuspidata* and *Ligia baudiniana* maintained in constant darkness darkened by day and lightened by night because of rhythmical migration of melanin within the chromatophores. The pigmentary rhythm was not present in *Ligia baudiniana* kept on a black background under constant illumination; the pigment remained maximally dispersed throughout the 24-hour day (Kleinholz, 1937).

Color changes in isopods, just as in other crustaceans, are controlled by hormones rather than nerve impulses (Brown, 1952). Isopods form a diverse group with respect to the endocrine control of their chromatophore systems. Head extracts of some species of isopods caused pigment concentration alone when injected into isopods (Kleinholz, 1937; Okay, 1945a, b; Suneson, 1947; Carstam and Suneson, 1949); head extracts of another species dispersed pigment only (Enami, 1941); and extracts of tissues of still another species caused both pigment concentration and pigment dispersion (McWhinnie and Sweeney, 1955). In species which produce one hormone only, *e.g.* a pigment-dispersing principle, melanin concentration is assumed to be due to removal of darkening hormone from the blood.

Kleinholz (1937) demonstrated that head extracts of *Ligia baudiniana* caused pigment concentration when injected into specimens with dispersed melanin. Head extracts had no dispersing effect upon concentrated pigment.

Smith (1938) postulated a dual endocrine control of the chromatophores of *Ligia oceanica*. On the basis of experiments in which different portions of the compound eye were either covered with an opaque material or differentially stimulated by light and background,

[1] This investigation was supported by grant No. B-838 from the National Institutes of Health.

he concluded that stimulation of the dorsal ommatidia results in release of darkening hormone and stimulation of the lateroventral ommatidia results in release of lightening hormone.

Enami (1941) found that blood transfused from a dark to a light specimen of *Ligia exotica* caused melanin dispersion. Extracts of heads of *Ligia exotica* also caused pigment dispersion. In a few experiments Enami observed that a transitory pigment concentration was caused by the head extracts and transfused blood before the melanin dispersed. Nagano (1949) reported quite different results from those reported by Enami (1941) for head extracts of *Ligia exotica.* Nagano reported concentration of melanin following injection of *Ligia exotica* head extracts into *Ligia exotica.*

Another investigator, Okay, noted that extracts of heads of *Sphaeroma serratum* (1945a) and *Idothea baltica, Armadillidium granulatum,* and *Ligia italica* (1945b) produced only melanin concentration when injected into specimens of the same species. Suneson (1947) and Carstam and Suneson (1949) demonstrated that heads of *Idothea neglecta* also cause melanin concentration when injected into isopods whose pigment was maximally dispersed. In a few experiments Carstam and Suneson (1949) observed some pigment dispersion 60 to 120 minutes after injection of the head extracts into isopods whose pigment was concentrated. These investigators also observed that extracts of heads of *Idothea neglecta* both dispersed and concentrated the red pigment of the prawn *Leander adspersus.*

Structures have been described in the isopods *Oniscus asellus* by Walker (1935) and in *Trachelipus rathkei* by McWhinnie and Sweeney (1955) which are similar in appearance to the sinus glands of the more highly evolved crustaceans. Histological changes during the intermolt cycle which are suggestive of a functional intervention by the sinus glands in the molt cycle have been described in *Oniscus asellus* by Gabe (1952a) and in *Sphaeroma serratum* by Gabe (1952b).

McWhinnie and Sweeney (1955) have demonstrated conclusively that two chromatophorotropins are produced by the terrestrial isopod *Trachelipus rathkei.* These investigators demonstrated that extracts of sinus glands, optic tracts, and cerebral ganglia from *Trachelipus rathkei* dispersed the red pigment of a crawfish *Cambarus* sp. Circumesophageal connectives and thoracic nerve cord extracts concentrated the same pigment. The responses of *Trachelipus* itself to the extracts could not be interpreted readily although there was indication from the data that the chromatophores of *Trachelipus* responded in a manner opposite to the chromatophores of *Cambarus.*

Preliminary experiments have indicated that the endocrine control of the chromatophores of the coastal isopod *Idothea exotica* is different from that reported in the literature for other species of *Idothea.* The present study was undertaken, therefore, to investigate in detail the physiology of the chromatophore system of *Idothea exotica.*

Materials and Methods

Specimens of *Idothea exotica* were collected during July and August, 1955, on pilings along the shore of Lake Pontchartrain at Point Aux Herbes, 15 miles northeast of New Orleans, Louisiana. The stock supply of isopods was kept at 22-24°C in loosely covered glass jars. Water was placed in the containers in order to maintain a high humidity.

The method devised by Hogben and Slome (1931) was employed in order to stage the chromatophores. According to their scheme stage 1 represents maximum pigment concentration, stage 5 maximum pigment dispersion, and stages 2, 3, and 4 the intermediate conditions. Chromatophores on the dorsal surface of the isopods were staged with the aid of a stereoscopic dissecting microscope and reflected light.

Experiments and Results

Background responses of Idothea exotica.—Specimens were collected in the morning and returned to the laboratory by noon. At 1:30 P.M. two lots of 10 individuals each were selected from the stocks. One group was placed in a white enameled pan, the other in a black enameled pan. Both pans were then placed under an illumination of 40 ft.-c. light intensity. Sixty minutes later, the average chromatophore stage of the isopods in each pan was determined and the backgrounds were interchanged with the result that the isopods which originally had been on a white background were on a black background and vice versa. The average chromatophore stage of the isopods in each pan was then determined 15 and 30 minutes after the backgrounds had been switched.

The results of these observations are presented in Figure 1D. As is evident, the black pigment of specimens on a black background dispersed whereas the black pigment of specimens on a white background

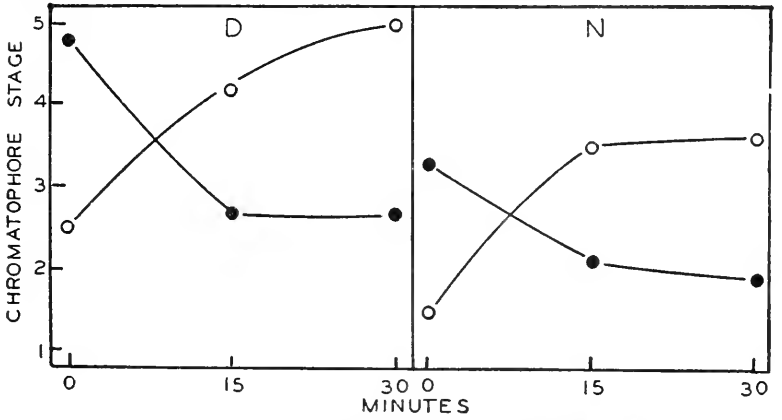

Figure 1. Responses of melanophores of *Idothea exotica* to background changes during the day (D) and night (N). Circles, from white to black. Dots, from black to white.

concentrated. Adaptation of the melanophores of specimens placed on black and white backgrounds was complete in 15 to 30 minutes. The melanin of specimens on a black background became completely dispersed but was not completely concentrated on a white background.

The existence of a daily rhythm of color change was suggested by the incomplete concentration of the melanin of specimens on the white background. Complete concentration of melanin of the blue crab, *Callinectes sapidus,* on a white background occurs at night only. During the day a daily rhythm of pigment migration keeps the pigments dispersed (Fingerman, 1956a). On the other hand, the dwarf crawfish, *Cambarellus shufeldtii,* does not exhibit a daily rhythm of pigment migration; the chromatophore pigments concentrate maximally during the day when specimens are placed on the appropriate backgrounds (Fingerman, 1956b). The experiment described above was performed, therefore, at night in order to determine if background adaptation is influenced by a daily rhythm of pigment migration. Twenty isopods were taken from the stock containers, divided into two equally sized groups, and placed on black and white backgrounds at 3:00 P.M. At 9:00 P.M. the average chromatophore index of the isopods in each pan was determined and the backgrounds were interchanged. The results have been presented in Figure 1N.

The melanophore behavior at night was indicative of a 24-hour rhythm of color change. The melanin of specimens on both black and white backgrounds was less dispersed at night than during the day. However, the rates of pigment dispersion and concentration were the same during the day and night.

Daily rhythm of color change.—The stock supply of isopods was placed in darkness at 5:00 P.M. The following morning at 7:00 A.M. specimens were selected from the stocks and divided into two lots of 12 individuals each. One group was placed in a white enameled pan, the other in a black enameled pan. Both pans were then placed under an illumination of 40 ft.-c. light intensity. The stock supply was not removed from darkness. Beginning at 8:00 A.M. and every two hours for the following 32 hours the average chromatophore index of 10 of the 12 individuals in each pan and of 10 in the stock supply was determined. If one of the 12 specimens in either the black or white pan was dead at the time the average chromatophore index was determined the isopod was replaced with an individual from the stock supply. The specimen adapted to the background within the two hours prior to the next determination of the average chromatophore index. The procedure introduced no error and was valid in view of the rapidity with which the chromatophores adapt to black and white backgrounds (fig. 1).

The results of observation of the melanophores are presented in Figure 2. A daily rhythm of melanin migration was evident in the three groups of *Idothea. Idothea* was darker during the day than at night. From the first observation at 8:00 A.M. until 6.00 P.M. of the same day the melanophores of the isopods in darkness and under

constant illumination on the black background were equally dispersed. However, at night the melanin of specimens in constant darkness became more concentrated than the melanin of individuals on a black background under a constant illumination of 40 ft.-c. light intensity and remained more concentrated as long as the observations continued. Melanin of individuals on a white background was at no time as dispersed as the pigment of individuals on a black background and in darkness.

Each of the three groups of isopods was lightest in coloration about 11:00 P.M. and became darkest about 6:00 A.M. Obviously, the form of the daily rhythm was not symmetrical about noon and midnight as are the vast majority of rhythms which are described in the literature. For example, the daily rhythm of migration of the distal

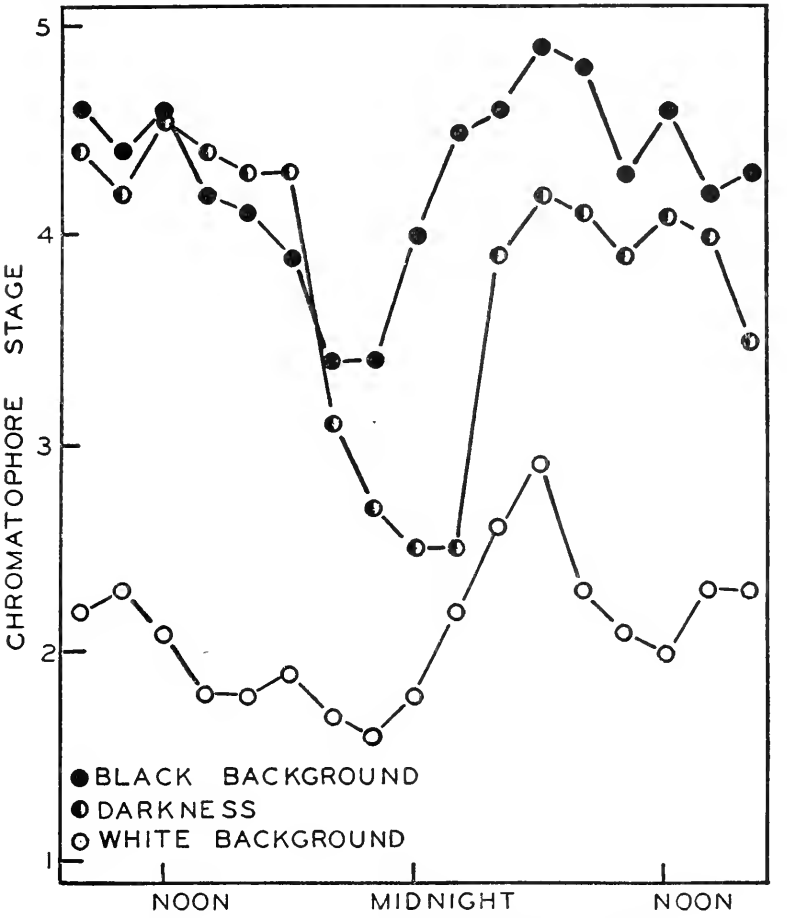

Figure 2. Daily rhythm of color change of *Idothea*.

retinal pigment in the dwarf crawfish, *Cambarellus shufeldtii,* was symmetrical about noon and midnight (Fingerman and Lowe, 1956).

Endocrine control of the melanophores.—The following experiments were designed to determine the sources and actions of the hormones which control chromatophoric pigment migration in *Idothea exotica.* The sinus glands and central nervous organs were the logical sites of hormone production in view of the results of McWhinnie and Sweeney (1955). The location and gross structure of the sinus glands and central nervous organs of *Idothea exotica* were the same as described for *Oniscus asellus* by Walker (1935) and in *Trachelipus rathkei* by McWhinnie and Sweeney (1955).

Extracts of the sinus glands, thoracic nerve cord, and optic ganglia-cerebral ganglia-circumesophageal connectives complex were prepared. While the structures were under observation with a steroscopic dissenting microscope, they were removed from isopods 17 to 25 mm long and placed in van Harreveld's solution. When the desired numbers of each organ had been removed, they were transferred with a

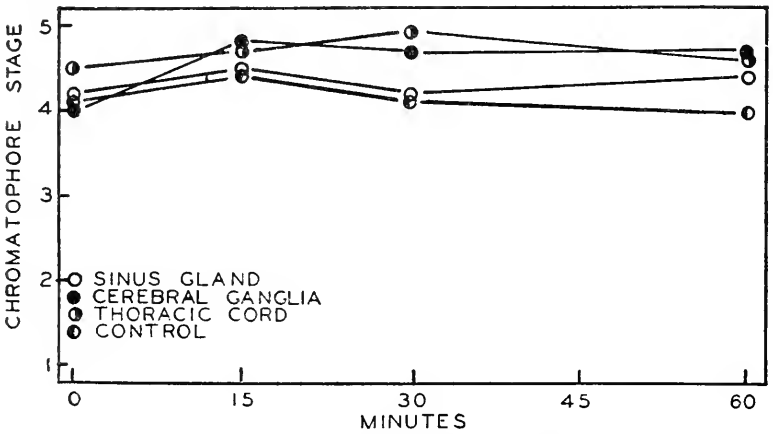

Figure 3. Responses of the melanophores of *Idothea exotica* maintained on a black background to extracts of sinus gland, central nervous organs, and saline as a control. Each point represents the average of 10 individuals.

minimum of saline to glass mortars in which they were triturated. The organs were then resuspended in a sufficient volume of van Harreveld's solution so that the final concentration of extract was one-third of each organ in 0.02 ml of extract.

Previous investigators have found that head extracts of *Idothea baltica* caused pigment concentration (Okay, 1945b). Suneson (1947) and Carstam and Suneson (1949) found that head extracts of *Idothea neglecta* also cause pigment concentration. Pigment dispersion following concentration was noted in some of the experiments with *Idothea neglecta.* The first endocrinological experiments performed

with *Idothea exotica* were designed, therefore, to investigate pigment concentration.

At noon four lots of five isopods each were selected from the stock supply and placed on a black background under an illumination of 40 ft.-c. light intensity. Sixty minutes later the average chromatophore index of the isopods in each pan was determined and the melanin was found to be almost completely dispersed. The isopods in the four pans were injected respectively with extracts of sinus gland, cerebral ganglia complex, thoracic nerve cord, and van Harreveld's solution as a control.

The average chromatophore stage of the isopods in each pan was then determined 15, 30, and 60 minutes after the extracts had been administered. The experiment was repeated once. No pigment concentration was observed following injection of the extracts. Slight pigment dispersion was evident, however, although the magnitude of the dispersion was small because the pigment was almost completely dispersed prior to injection (fig. 3).

In view of the results obtained with isopods whose pigment was dispersed, extracts were prepared as described above and injected into isopods whose pigment was almost fully concentrated. The pigment was obtained in a concentrated condition by placing the isopods on a white background and performing the experiment late in the afternoon, at which time the pigment tends to concentrate because of the daily rhythm. Five individuals were injected with each extract and five with van Harreveld's solution as a control. The experiment was repeated once. As is evident (fig. 4), each extract contained a hormone which caused melanin dispersion. No evidence of pigment concentration was evident 60 minutes after the injection of the extracts.

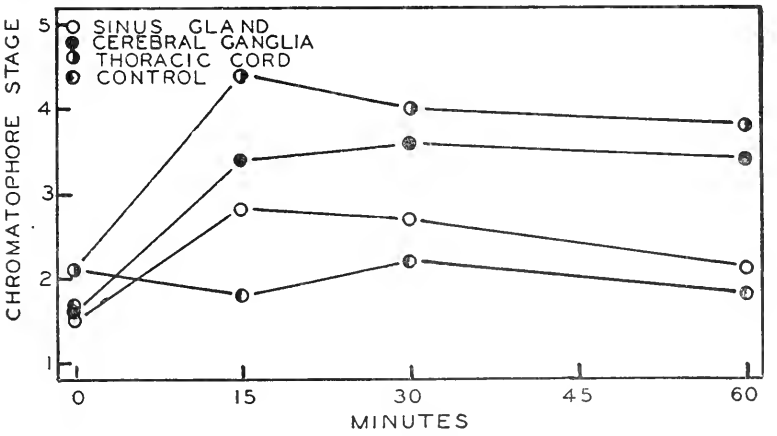

Figure 4. Responses of the melanophores of *Idothea exotica* maintained on a white background to extracts of sinus gland, central nervous organs, and saline as a control. Each point represents the average of 10 individuals.

Activity (potency) values of the tissue extracts and saline which had been injected into isopods with concentrated melanin were calculated in order to facilitate comparison of the extracts. The values were calculated by summing the average chromatophore indices determined 15, 30, and 60 minutes after the isopods had been injected. The product of three times the initial average chromatophore stage was then substracted from the respective sum for each group of isopods, because, if there had been no pigment activation, the sum of the average chromatophore stages which were determined 15, 30, and 60 minutes after the administration of the extracts would have been three times the initial average chromatophore stage. In order to obtain the true activity value for each extract the activity of the control group was subtracted from the values calculated for the three groups of isopods which had been injected with organ extracts. The order of melanin dispersing activity was: thoracic nerve cord (4.9 activity units) > cerebral ganglia complex (4.6 activity units) > sinus gland (2.1 activity units).

Discussion

The experiments showed only that direct injection of extracts failed to demonstrate the presence of a pigment-concentrating hormone and not that a pigment-concentrating hormone is lacking in *Idothea exotica.* A similar situation in the fiddler carb *Uca pugilator* was noted by Sandeen (1950) who was able to demonstrate only a melanin-dispersing hormone. No direct endocrinological approach had shown the existence of a melanin-concentrating hormone although the existence of such a hormone had been postulated. Fingerman (1956c) demonstrated the existence of a melanin-concentrating hormone in *Uca pugilator* by bringing about rapid melanin concentration in isolated legs which had been perfused with blood taken from specimens of *Uca* whose pigment was maximally concentrated and presumably maintained in the concentrated condition by a melanin-concentrating hormone.

Chromatophore systems of isopods have proven to be as diverse physiologically as those of decapod crustaceans, concerning which an abundant literature has been accumulated. Some isopods produce a pigment-concentrating hormone only (Kleinholz, 1937; Okay, 1945a, b); another may be physiologically similar to *Idothea exotica* and produce a pigment-dispersing hormone with no clear evidence of a concentrating effect (Enami, 1941); and for still another there is conclusive evidence for pigment-concentrating and dispersing hormones (McWhinnie and Sweeney, 1955).

The daily rhythm of pigment migration in *Idothea exotica* persisted in darkness and under constant illumination on both black and white backgrounds. However, the pigmentary rhythm of *Ligia baudiniana* was apparent in individuals in constant darkness only (Kleinholz, 1937). Evidently the nature of the rhythmical mechanism differs in each of these two species.

Head extracts of each species of *Idothea* investigated have caused body lightening when injected into specimens of *Idothea.* However, *Idothea exotica* differs from all other species of *Idothea* which have been investigated. Contrary to other species of *Idothea,* extracts of endocrine sources of *Idothea exotica* caused body-darkening but not body-lightening. Evidently, among the species of a single genus of isopods the chromatophore systems may be extremely diverse.

Summary and Conclusions

1. The melanophores of *Idothea exotica,* a coastal isopod, readily adapt to black and to white backgrounds. Individuals are lighter in color on a white background than on a black background.

2. A daily rhythm of melanin migration was observed in isopods maintained under constant illumination upon both black and white backgrounds and in constant darkness. *Idothea* is dark by day and light by night.

3. Extracts of sinus glands and central nervous organs injected into *Idothea exotica* caused pigment dispersion only. In all other species of *Idothea* which have been investigated conclusive evidence has been presented for a pigment-concentrating hormone but not for a dispersing principle.

4. The physiological diversity of isopod chromatophore systems is discussed.

References Cited

Brown, Frank A., Jr. 1952. Hormones in crustaceans, in *The Action of Hormones in Plants and Invertebrates.* Academic Press, Inc., New York, N. Y.

Carstam, Sven Ph. and Svante Suneson 1949. Pigment activation in *Idothea neglecta* and *Leander adspersus. Kungl. Fysiograf. Sallskapets Lund Forhandl.,* 19: 1-5.

Enami, Masashi 1941. Melanophore responses in an isopod crustacean, *Ligia exotica.* II. Hormonal control of melanophores. *Japan. Jour. Zool.,* 9: 515-531.

Fingerman, Milton 1956a. The physiology of the black and red chromatophores of the blue crab, *Callinectes sapidus.* (in press.)

---------- 1956b. Endocrine control of the red and white chromatophores of the dwarf crawfish, *Cambarellus shufeldtii.* (in press.)

---------- 1956c. A black pigment concentrating factor in the fiddler crab, *Uca. Science* (in press).

Fingerman, Milton and Mildred E. Lowe 1956. A daily rhythm in the regulation of the distal retinal pigment of the dwarf crawfish, *Cambarellus shufeldtii.* (in press.)

Gabe, M. M. 1952a. Histophysiologie-sur l'existence d'un cycle secretoire dans la glande du sinus (organe pseudofrontal) chez *Oniscus asellus* L., *C. R. Acad. Sci.,* 235: 900-902.

---------- 1952b. Histophysiologie-particularités histologiques de la glande du sinues et l'organe X (organe de Bellonci) chez *Sphaeroma serratum* Fabr., *Ibid.,* 235: 973-975.

HOGBEN, LANCELOT T. and D. SLOME 1931. The pigmentary effector system. VI. The dual character of endocrine coordination in amphibian colour change. *Proc. Roy. Soc., Lond., B,* 108: 10-53.

KLEINHOLZ, LEWIS H. 1937. Studies in the pigmentary system of Crustacea. I. Color changes and diurnal rhythm in *Ligia baudiniana. Biol. Bull.,* 72: 24-36.

MATZDORFF, C. 1883. Uber die Farbung von *Idothea tricuspidata.* Desm. *Jena. Zeitschr. Naturwissen,* 16: 1.

MCWHINNIE, MARY ALICE and H. M. SWEENEY 1955. The demonstration of two chromatophorotropically active substances in the land isopod, *Trachelipus rathkei. Biol. Bull.,* 108: 160-174.

MENKE, HEINRICH 1911. Periodische Bewegung und ihr Zusammenhang mit Licht und Stoffwechsel. *Pflug. Archiv. fur Physiol.,* 140: 37-91.

NAGANO, T. 1949. Physiological studies on the pigmentary system of Crustacea. III. The color changes of an isopod *Ligia exotica* Roux. *Sci. Repts. Tohoku Univ.,* 4th Ser. (Biology), 18: 167-175.

OKAY, SALAHADDIN 1945a. Sur l'excitabilité directe des chromatophores, les changements periodiques de coloration et le centre chromatophortropique chez *Sphaeroma serratum* Fabr., *Rev. Fac. Sci. Univ. Istanbul, Ser. B,* 9: 1-21.

..... 1945b. L'hormone de contraction des cellules pigmentaires chez les isopodes. *Ibid.,* 10: 116-132.

PIERON, H. 1914. Recherches sur le comportement chromatique des Invertébrés et en particulier des Isopodes. *Bull. sci. de la France et Belg.,* 48: 30.

SANDEEN, MURIEL I. 1950. Chromatophorotropins in the central nervous system of *Uca pugilator,* with special reference to their origins and actions. *Physiol. Zool.,* 23: 337-352.

SMITH, H. G. 1938. The receptive mechanism of background responses in the chromatic behavior of Crustacea. *Proc. Roy. Soc., Lond.,* B, 125: 250-263.

SUNESON, SVANTE 1947. Colour changes and chromatophore activators in *Idothea. Kungl. Fysiograf. Sallskapets Lund Forhandl.,* 17: 120-130.

TAIT, J. 1910. Colour changes in the isopod, Ligia oceanica. *Jour. Physiol.,* 40: xl-xli.

WALKER, R. 1935. The central nervous system of *Oniscus. Jour. Comp. Neurol.,* 62: 75-129.

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OSMOTIC BEHAVIOR AND BLEEDING OF THE OYSTER *CRASSOSTREA VIRGINICA*

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OSMOTIC BEHAVIOR AND BLEEDING OF THE OYSTER *CRASSOSTREA VIRGINICA* [1]

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The physiological processes required by aquatic molluscs to maintain a constant internal environment are more complex in fresh water than marine species. The body fluids of fresh water molluscs are kept hypertonic to their environment by an active regulatory process, primarily salt absorption against the concentration gradient. For example, the osmotic pressure of the blood of *Anodonta cygnea,* a freshwater bivalve, is lower than the osmotic pressure of the blood of all marine molluscs studied and greater than the osmotic pressure of its fresh water environment (Schlieper, 1935). Within limits, the blood concentration of *A. cygnea* remains more concentrated than its environment as the salinity of its environment is increased (Florkin, 1938).

On the other hand, marine molluscs are typically isotonic with their environment and poikilosmotic, as is characteristic of most marine invertebrates (Prosser et al., 1950). However, some marine molluscs are able to regulate their volume. Volume regulation is accomplished by the gain or loss of salts following an initial osmotic loss or gain of water. Molluscs unable to volume regulate will swell in hypotonic media and shrink in hypertonic media.

The blood and pericardial fluid of the Japanese oyster, *Ostrea circumpicta,* are hypertonic to the environment and the salinity of these fluids closely follows changes in the salt concentration of the environment. The blood is more concentrated than the pericardial fluid (Yamazaki, 1929).

The authors have learned through Dr. Thurlow C. Nelson that Dr. Imai of Japan is practically certain that the oyster referred to as *Ostrea circumpicta* by Yamazaki (1929) was actually *Crassostrea nippona.* The reason for believing the original name was incorrect is that *Ostrea circumpicta* is larviparous and belongs to the salt water flat type of oyster whereas *Crassostrea nippona* is oviparous.

Nelson (1938) postulated that the genus *Crassostrea* which is armed with a superior cleansing mechanism, the promyal chamber, has in its evolution invaded the upstream zones of its environment in contrast to *Ostrea* which has remained in the sea or at least in waters of higher salinity. *Crassostrea* should, therefore, be a better osmoregulator than *Ostrea.* Cole (unpublished data) has shown that the clam *Mercenaria*

[1] This study was conducted under a contract between Tulane University and the United States Fish and Wildlife Service. It was financed with funds made available under provisions of P. L. 466, 83rd Congress, approved July 1, 1954, commonly called the Saltonstall-Kennedy Act.

has no power of osmoregulation and is limited to waters of salinity which do not fall below approximately 15 ppt for any considerable length of time.

Hopkins (1936) showed that the initial effect of a rise or fall in salinity is to cause partial or complete adductor muscle contraction and slowing or cessation of water flow in *Ostrea gigas.* Adaptation of the adductor muscle and gill activities, as indicated by the openness of the valves and rate of pumping, was more rapid in response to increase in salinity than to decrease in salinity. Loosanoff (1952) demonstrated that as long as the valves of *Crassostrea virginica* remained open the changes in salinity of their shell and body fluids followed changes in salinity of the surrounding water.

Stauber (1950) has shown that three distinct physiological varieties of *Crassostrea virginica* occur along the Atlantic Coast with critical spawning temperatures of 16.4°C in Long Island Sound, 20°C in the Bideford River, and 25°C in Delaware Bay.

The fact that Gulf Coast oysters "bleed" to a greater extent than

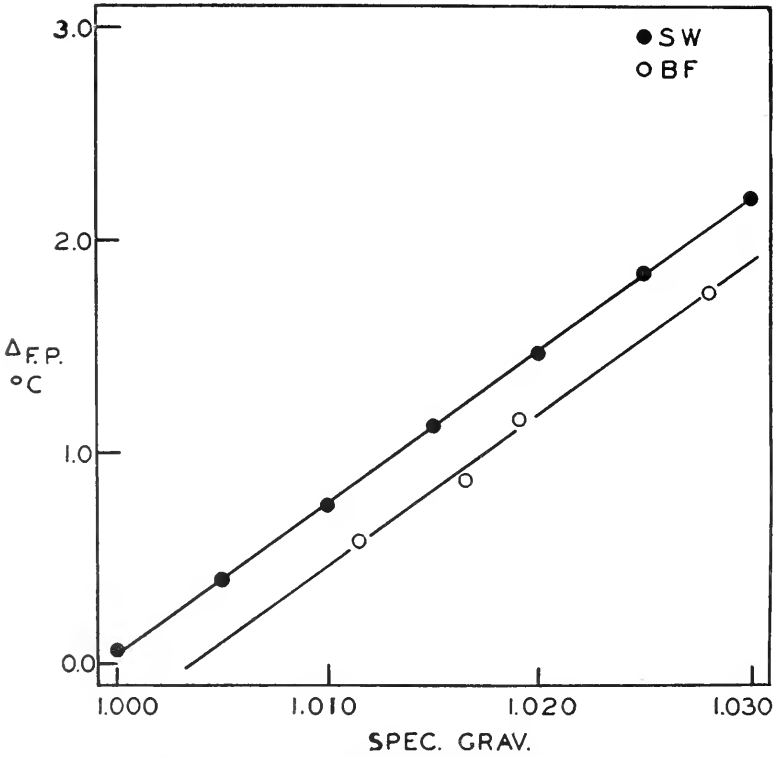

Figure 1. Freezing-point depression of sea water (SW) and oyster body fluid (BF) of various specific gravities.

Northern oysters is general information. Gulf Coast oysters may be, therefore, a fourth physiological variety.

The present investigation was undertaken with a twofold purpose. The first aim was to obtain quantitative information concerning the weight changes and fluid losses that occur during the summer months in Southern oysters after the body has been removed from the shell. The second aim was to investigate in a detailed fashion the osmoregulatory ability of the American oyster, *Crassostrea virginica.* Preliminary studies (*e.g.,* Loosanoff, 1952) of the osmotic behavior of *Crassostrea virginica* have been performed but as yet no detailed information is available.

Materials and Methods

Specimens of *Crassostrea virginica* used in these experiments were grown in the waters of Louisiana; the majority were from Barataria Bay.

The oysters were maintained in large plexiglass aquaria containing water filtered through cotton, glass wool, and charcoal before being recirculated. The salinity of the sea water in the aquaria was maintained at 17 ppt. Water with this salinity has a freezing-point depression of 0.88°C. Distilled water was added to the aquaria to compensate for evaporation. The oysters were allowed to acclimate to the water in the aquaria for at least 24 hours before they were used in an experiment.

The laboratory was airconditioned to assure that the temperature would not become lethal to the oysters. The water temperature was 18°C when the experiments were initiated and gradually increased to 24°C by the termination of the experiments reported below.

Specific gravities were determined by use of mixtures of chloroform and benzene. A mixture of these liquids was prepared such that a droplet of the fluid whose specific gravity was to be determined would neither rise nor sink in the mixture but would remain at whatever level it was placed. The specific gravity of this mixture was then determined by means of a hydrometer and was considered to be the specific gravity of the droplet.

The specific gravities of the body fluids were determined at 24°C and converted to the freezing-point depression at 15°C. Figure 1 was used in converting from the specific gravity to the freezing-point depression after the appropriate correction for room temperature was applied to the specific gravity value. The data of Figure 1 for sea water were taken from Zerbe and Taylor (1953). The data for body fluids were obtained experimentally. The highest specific gravity was obtained by adding salt to body fluid. The three lower specific gravity values were obtained by placing oysters overnight in aquaria which contained sea water of different salinities. The following morning the body fluids of the oysters were collected and the specific gravities were determined. The freezing-point depressions of the body fluids with different specific gravities were then determined

with the aid of a cryoscope thermometer. The line relating specific gravity of body fluid to freezing-point depression is parallel to and 0.30°C below that of sea water. This difference between sea water and body fluid was anticipated since freezing-point depression is a colligative property. The large protein molecules in body fluids have the same effect upon freezing-point as a chloride ion, for example, but have a greater effect upon specific gravity because of their large size.

The method of determination of freezing-point depression from specific gravity determinations allowed rapid determination of freezing-points with the result that more determinations could be run on a single day than would have been possible otherwise. In addition, the freezing-points could be determined with volumes too small for direct determination by standard cryoscopy.

Experiments and Results

Fluid and weight losses due to injury to the mantle and pericardium during shucking.—Eighteen oysters from each of eight lots, obtained on different dates, were shucked. In order to cause maximal fluid loss the mantle and pericardium were pierced while the oyster body was being removed from the shell.

The bodies of the oysters were placed in individual, covered containers after shucking and the initial body weight, including the fluids, was immediately determined. Fifteen, 30, 45, 60, 90 and 120 minutes following the initial determination of the weight, the weight of the body alone was determined. Before each of these weighings, the body was blotted to remove the external moisture.

The results have been expressed as the percentage of the original weight of the intact oyster body including the fluids. The data for each group of 18 oysters are presented in Table 1 which includes the date each experiment was performed. The averages of the eight

TABLE 1.

Weight Changes of Oysters Shucked with Injury to the Mantle and Pericardium. Weights are Expressed as the Percentage of the Original Body Weight.

Date	Minutes after Shucking						
	0	15	30	45	60	90	120
May 27	100.0	57.5	53.5	51.5	50.0	50.0	49.5
June 2	100.0	67.8	64.3	63.0	61.7	60.7	59.7
June 9	100.0	57.0	51.0	50.0	49.0	47.0	45.0
June 19	100.0	70.0	65.0	63.0	62.0	61.0	60.0
June 22	100.0	61.5	60.0	59.0	58.0	57.5	57.0
June 28	100.0	48.0	44.0	43.0	41.0	41.0	40.0
July 12	100.0	67.0	63.0	61.0	60.0	59.0	57.0
July 17	100.0	55.0	50.0	48.0	47.0	45.0	44.0
Average	100.0	60.5	56.4	54.8	53.7	52.7	51.5

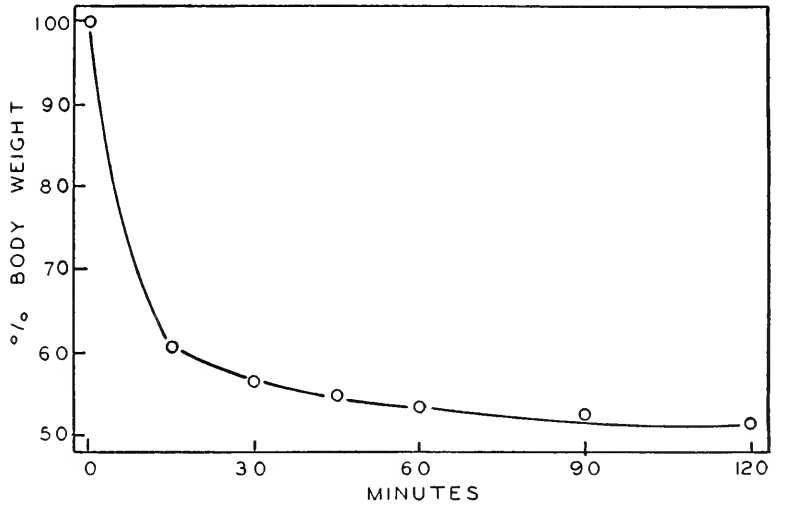

Figure 2. Weight changes of the body of oysters after shucking. The mantle and pericardium were intentionally ruptured during the shucking process.

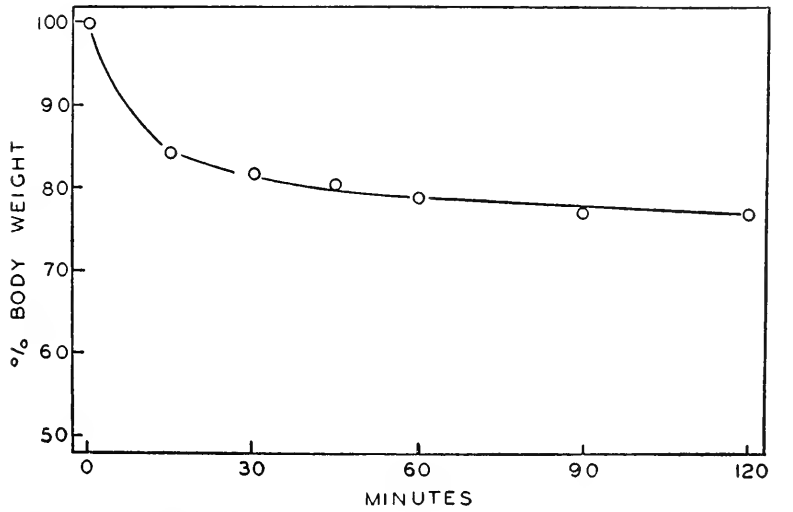

Figure 3. Weight changes of the body of oysters shucked without injury to the mantle or underlying parts.

experiments were used in the preparation of Figure 2. The greatest weight loss occurred during the first 15 minutes following the shucking. The rate of fluid loss then decreased sharply. Fifty percent of the original body weight was lost after two hours.

Fluid and weight losses following removal from the shell with no injury to the mantle.—Eleven oysters were shucked with a minimum of injury to the mantle and pericardium. The oyster shells were spread slightly. The adductor musle attachment was then carefully scraped away from each shell without putting the edge of the knife against the mantle. These oysters were placed in individual, covered containers and weighed in the manner described above at 0, 15, 30, 45, 60, 90, and 120 minutes from the time the oysters were removed from the shells.

The results of this experiment have been presented in Figure 3. As is evident from a comparison of Figures 2 and 3, approximately 25 per cent more of the body weight was lost when the mantle and pericardium were pierced. The weight loss of the oysters with the intact mantles was probably due to fluid exuded from the sinuses in the mantle and from the cut adductor muscle. The over-all shape of the curves of Figures 2 and 3 was the same. After the large initial weight loss the slopes of the curves in Figures 2 and 3 were also the same. Similarity of both shape and slope after the initial loss of fluid indicated that the mechanism of fluid loss from 15 to 120 minutes was the same in all the oysters, whether the mantle was punctured or not.

Weight losses induced by draining the free fluid between the shells.—Wedges were placed between the shells of each of 10 oysters. While the shells were agape in the aquaria the oysters were allowed to close on wedges which prevented complete closure of the shells. These oysters were then removed from the aquaria. The water between the shells was shaken out and the shells were blotted. The oysters were kept on the table top for 120 minutes as were the controls and were weighed at the same time intervals as the controls. Prior to each weighing the fluid which had accumulated between the shells was discarded. After the weighing at 120 minutes the oysters were sacrificed. Their original body weight was then determined by subtracting the weight of the shells from the original total weight. The weight changes of these wedged oysters were expressed as the percentage of the original body weight and are presented in Figure 4B.

A second group of 10 oysters was taken from the aquaria, blotted, and also kept on the table for the extent of the experiment. These oysters were weighed at the same time intervals as the controls and as the oysters with wedges. Prior to each weighing the shells were forced apart slightly and the free liquid shaken out. At the end of the experiment these oysters were also sacrificed and weighed. These weights were treated in the same fashion as the weights of the oysters that had been wedged open (Figure 4C).

As is evident from Figure 4, after 120 minutes the experimental

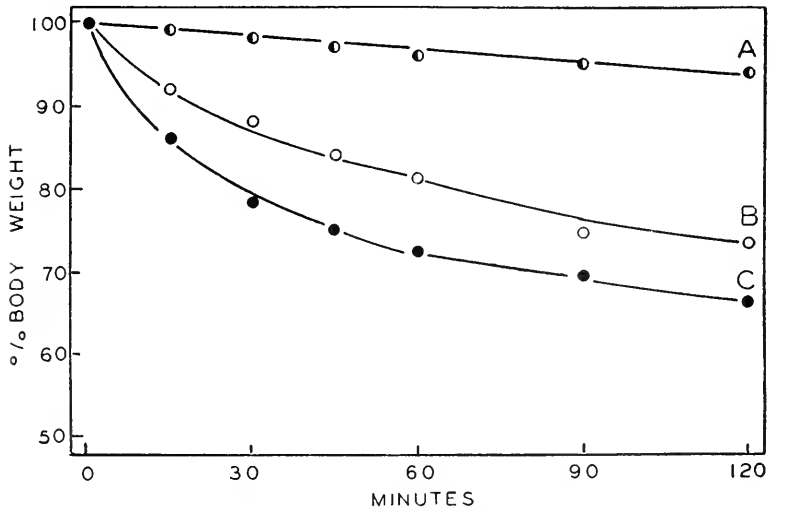

Figure 4. Weight changes of oysters kept in air for 120 minutes. **A**, weight loss of oysters due only to evaporation of water from the shell. **B**, weight loss of oysters kept agape in air by means of a wedge; fluid which accumulated between the shells was discarded prior to each weighing. **C**, weight loss of oysters whose shells were forced apart in order to discard the accumulated free fluid prior to each weighing. Actual weights are expressed as the percentages of the original body weight.

oysters had lost approximately 30 percent of their original body weight. The difference in weight loss between the oysters of Figure 4B and 4C was not significant.

Ten oysters were taken from the stocks in the aquaria to serve as controls. The outer surfaces of their shells were blotted to remove the excess water. These oysters were then kept on the table top for two hours and were weighed at 0, 15, 30, 45, 60, 90, and 120 minutes after blotting. After the final weighing the oysters were sacrificed and the body weights including the fluids were determined. The weight losses due to evaporation from the outer surface of the shells were then expressed as a percentage of the original body weight. Although the loss of weight was due to loss of fluid from the shells and not the body, this method of expressing the data was employed because a small portion of the weight loss experienced by the experimental oysters was due to evaporation from the surface of the shell. However the major portion of the weight loss of the experimental oysters was due to fluid loss by the body of the oyster. The control oysters which had been kept on the table top for two hours, lost the equivalent of six percent of their original body weight by evaporation of water from the outer surface of their shells (Figure 4A).

The oyster must be free to open and close its shell in a normal fashion in order to regulate its weight and consequently its volume.

Disruption of the rhythmic opening and closing of the shells interferred with the ability of the oysters to volume regulate. Removal of the free liquid between the shells stimulated further secretion to replace this fluid at the expense of the internal body fluids.

Weight losses of oysters drained of the free fluid between the shells and subsequently returned to the aquaria.—Ten oysters were wedged open in the manner described above and removed from the aquaria. The free fluid between the shells was then drained and the shells were blotted. The oysters were kept on the table top and weighed at 0, 15, 30, 45, 60, and 75 minutes after the free fluid had been drained from between the shells. The oysters with the wedges still between their shells were returned to the aquaria following the weighing at 75 minutes. The oysters were weighed at 15 minute intervals for 75 minutes after their return to the aquaria. Prior to each weighing of the oysters, which had been returned to the aquaria, their shells were blotted and the free fluid between the shells was drained.

The free fluid of a second group of 10 oysters was drained by forcing the shells apart prior to each weighing. This group was also kept on the table top and weighed at the same intervals as were the wedged oysters. The non-wedged oysters were also returned to the aquaria after 75 minutes on the table top and were weighed for an additional 75 minutes.

Both groups of oysters were sacrificed after the completion of the weighings. The original body weight was calculated by subtracting

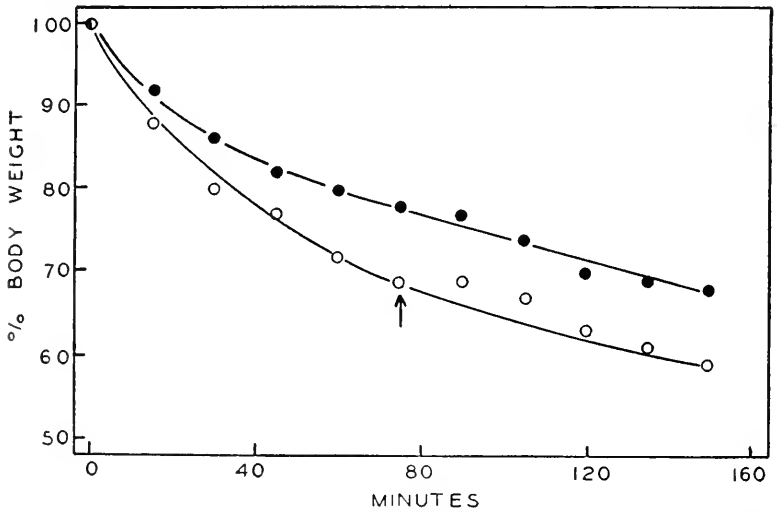

Figure 5. Weight loss of oysters whose shells had been wedged open (circles) or forced apart (dots) prior to each weighing. Both lots of oysters were kept out of water for the first 75 minutes of the experiment. Arrow shows when the oysters were returned to the aquaria. Free fluid between the shells was discarded prior to each weighing.

the weight of the shells from the original weight of the intact oyster. The weight changes, based on the original body weight, have been plotted in Figure 5. The circles represent the oysters which had been wedged open; the dots represent the oysters which had been forced open. The difference in weight loss between the two groups of oysters was not significant. Both groups of oysters continued to lose weight because of the removal of the free fluid after their return to sea water. A portion of the weight loss of oysters which had been forced open periodically may have been due to tearing of muscle fibers with concomitant injury to the blood spaces within the adductor muscle.

A control group of oysters had been weighed and immediately returned to the aquaria for the duration of this experiment, *i.e.*, 150 minutes. The control oysters experienced no weight change.

This experiment also demonstrated that the oyster was unable to regulate its weight unless free to open and close its shell in the normally rhythmic fashion. Forcing the shells open at regular intervals or keeping the shells agape by means of a wedge prevented the oyster from regulating its weight and consequently its volume both in air and in sea water. Non-wedged oysters would open their shells and pump water in the aquaria.

Weight changes of oyster wedged open in several concentrations of sea water.—Thirty oysters were wedged open, drained, blotted, and weighed in the manner described above. Ten of these oysters were

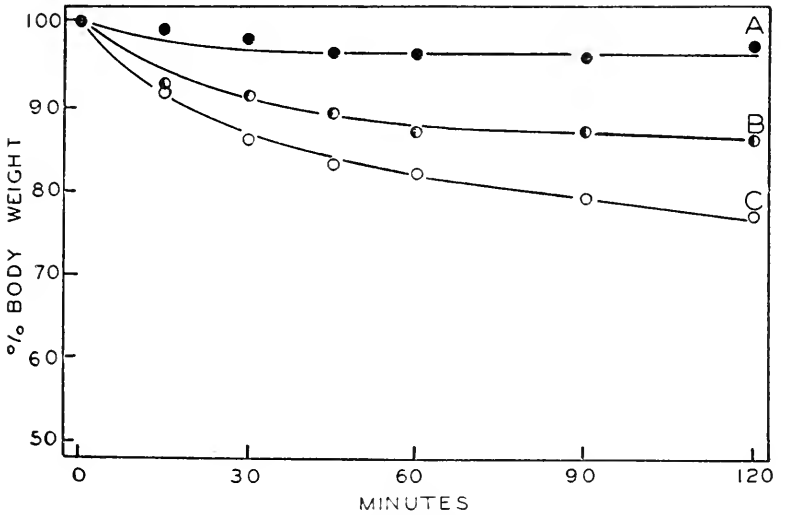

Figure 6. Weight changes of oysters with a wedge between their their shells. **A**, oysters in sea water with a freezing-point depression (Δ_0) of 0.61° C.; **B**, oysters in sea water with a freezing-point depression of 1.03° C.; **C**, oysters in sea water with a freezing-point depression of 1.54° C.

placed in an aquarium which contained sea water with a freezing-point depression (Δ_0) of 0.61°C, 10 in water with a freezing-point depression of 1.03°C, and 10 in water with a freezing-point depression of 1.54°C.

These oysters were also weighed at 15, 30, 45, 60, 90, and 120 minutes after having been placed in their respective aquaria. The weights have been converted to the percentage of the original body weight. The latter was determined by subtracting the weight of the shells from the original weight of the intact animal.

The results have been plotted in Figure 6. Curve A represents the weight changes of the oysters wedged open in the most dilute sea water, Δ_0 0.61; B, the weight changes in the intermediate salinity Δ_0 1.03; and C, the weight changes in the most concentrated environment Δ_0 1.54. The weight losses were directly proportional to the salinity of the environment. A simple osmotic phenomenon is the probable explanation of these results. This experiment led to the same conclusion arrived at in the previously described experiments; to regulate its weight and volume the oyster must be free to open and close its shells in a normal fashion.

Changes in the concentration of the combined mantle and pericardial fluids with changes in the salinity of the environment.—Four lots of 40 normal oysters each were taken from the stocks. A lot was placed in one of four concentrations of sea water. The freezing-point depressions of the sea water in each aquarium were (Δ_0) 0.54, 1.26, 1.62, and 1.98°C. At 0, 2, 4, 6, 8, 10, and 12 hours after having been put into the respective aquaria, three oysters from each salinity were weighed and sacrificed. At the same time, three oysters from the stock supply were also weighed and sacrificed. The freezing-point depression of the water in the stock aquaria was 0.88°C.

The mantle and pericardium were punctured when the oysters were sacrificed and the escaping fluid was collected. This fluid was a mixture, therefore, of the pericardial and mantle fluids. The specific gravity of this mixture was then determined. The changes in salinity of the body fluid (Δ_i) have been presented in Figure 7 for each of the salinities from which the oysters had been taken (Δ_0). In the dilute medium the combined body fluids became diluted and in a concentrated medium these body fluids became concentrated. These data indicate that the oysters did not osmoregulate but rather osmoadjusted.

In Table 2 are listed the percentage weight changes of the oysters in this experiment. These percentages have been based on the oyster body plus the shell. These percentages would have been magnified approximately five times if calculated on the weights of the body without the shell. The weight changes of the oysters in all but the most concentrated sea water were, without doubt, insignificant. In the most concentrated sea water, if any weight change occurred one would expect the weight to decrease rather than increase. This weight increase must have been due to some phenomenon other than osmotic. Acting on the valid assumption that weight and volume

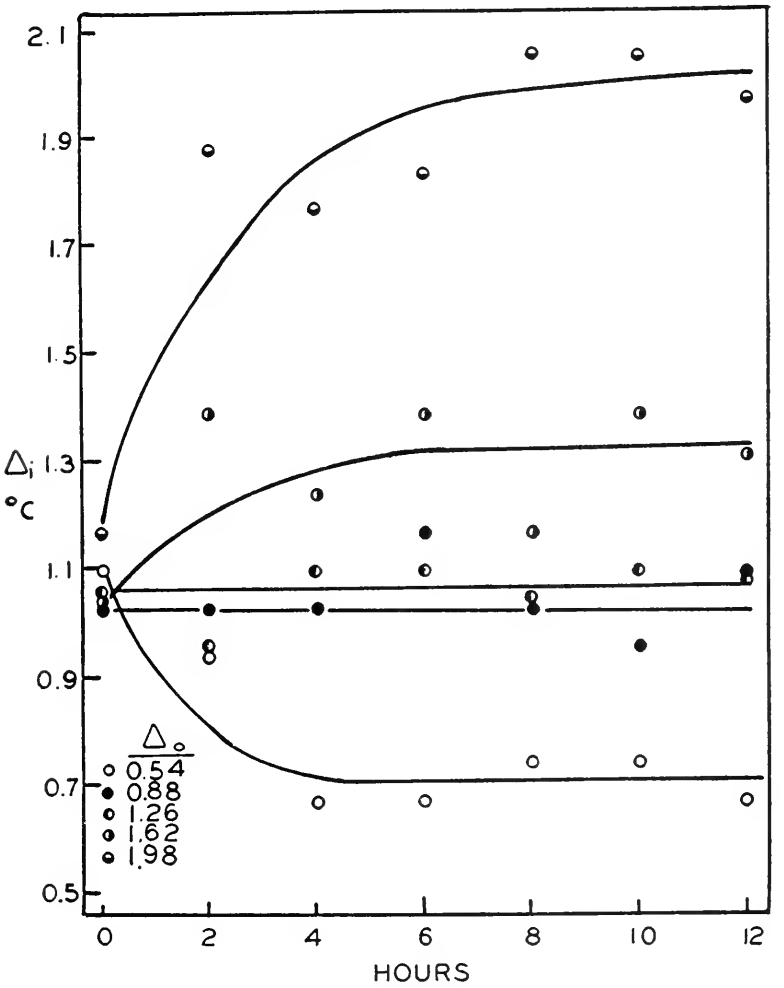

Figure 7. The changes with time of the freezing-point depression of the combined mantle and pericardial fluids (Δ_i) of oysters maintained in sea water of different salinities (Δ_o).

vary directly with one another, one may conclude that the oysters showed a volume regulation at least in sea water with freezing-point depressions ranging from (Δ_o) 0.54 to 1.62°C and perhaps as high as 1.98°C. Since the density of the combined body fluids changed and the body weight was constant, the changes in freezing-point depression must have been due to transfer of salts and not water.

The freezing-point depression values for the combined body fluids (Δ_i) from the 2, 4, 6, 8, 10, and 12 hour determinations for each

TABLE 2.

WEIGHT CHANGES OF OYSTERS MAINTAINED IN SEVERAL CONCENTRATIONS OF SEA WATER (Δ_0). WEIGHT CHANGE IS EXPRESSED AS THE PERCENTAGE OF THE ORIGINAL WEIGHT. WEIGHT OF THE SHELL IS INCLUDED IN THE CALCULATIONS.

	Hours						
Δ_0	0	2	4	6	8	10	12
0.54	100.0	100.0	99.5	99.6	99.6	99.8	99.9
0.88	100.0	99.6	99.8	100.7	100.2	99.7	99.7
1.26	100.0	99.4	99.7	99.5	100.0	100.2	100.2
1.62	100.0	100.3	99.9	100.1	100.1	100.1	100.1
1.98	100.0	101.5	100.8	100.6	101.4	101.5	100.5

environmental salinity (Δ_0) were averaged and have been plotted against the environmental salinity (Figure 8). At the intermediate environmental salinities in the range of 20 ppt the salinity of the body fluids was relatively constant. The salinity in which the oysters were grown along the Louisiana coast is usually between 14 and 25 ppt. Obviously, the environmental salinities best for the production of oysters are the salinities in which the oyster is best able to regulate its salt content.

Fractionation of the body fluids and osmoregulation.—Five lots of three oysters each taken from the stocks were placed in aquaria of

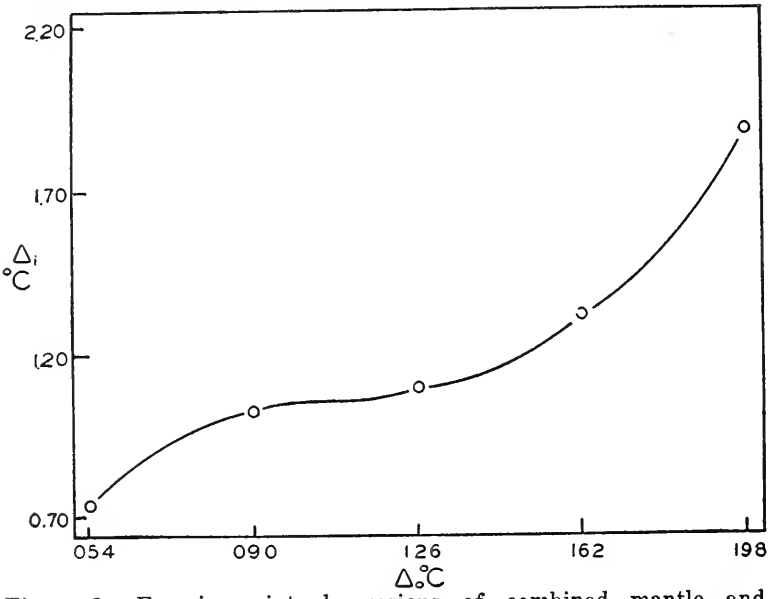

Figure 8. Freezing-point depressions of combined mantle and pericardial fluids (Δ_i) of oysters from several concentrations of sea water (Δ_0).

graded salinities. The freezing-point depressions of the water in the respective aquaria were: 0.54, 1.17, 1.24, 1.62, and 1.98°C. After six hours all oysters from each salinity plus three oysters from the stocks were sacrificed. The freezing-point depression of the water in the stock aquaria was 0.88°C. Instead of combining the body fluids as had been done in the experiment above, the body fluids were removed from the oysters in a manner that yielded four fractions. First, the shells were spread slightly and the free fluid between the shells was collected. Then, the adductor muscle was gently scraped from one of its attachments to the shell. This valve was removed. The mantle was then punctured and the mantle fluid was removed. The pericardium was pierced next and the pericardial fluid also collected. The fourth fraction was blood taken directly from the ventricle. The latter three fluids were collected in a syringe.

The specific gravity of each fraction was determined for all the oysters. The values for each lot of three oysters were averaged. These data have been plotted in Figure 9. The salinity of the blood, the fluid most removed from the environment, was the most constant and the fluid between the shells, the fraction closest to the environment, was the least constant in its salinity. Obviously, the oyster has at least a limited ability to osmoregulate. The salinity of the blood tended to remain constant at the expense of the other body fluids. The data of Figure 9 have been replotted in Figure 10. In this latter figure the freezing-point depressions of each of the body fluids (Δ_i) has been plotted versus the environmental salinities (Δ_0). Plotting the data in this fashion yielded additional information and facilitated the discussion of the results. The fluid in the mantle of the oysters kept in the most dilute sea water was hypertonic to the other body fluids considered in this series of experiments. The high salinity of the fluid in the mantle was probably due to an active physiological process. Between the environmental freezing-point depressions of 0.54 and 1.17°C the shell fluid was hypotonic to the other body fluids, but hypertonic to the environment. This hypertonicity was probably due to salt acquired from the mantle. In the dilute environment the pericardial fluid was hypotonic to the other internal body fluids. This hypotonicity was probably due to water removed from the blood by the nephridial organs and secreted into the pericardial cavity in an effort to maintain constant the salinity of the ventricular (arterial) fluid. The mantle was probably resistant to osmotic uptake of water from the environment because the mantle fluid was hypertonic to both the environment and the shell fluid when the oysters were in the extremely dilute medium (Δ_0 0.54°C).

The lack of a significant loss of weight after 12 hours in the gradient of salinities (Table 2), showed that the oysters were able to volume regulate. The changes in the salt concentration of the body fluids were due to loss or gain of salt rather than water.

The experiment was repeated twice in the same manner as described above with a change in exposure time only. Exposure times of four

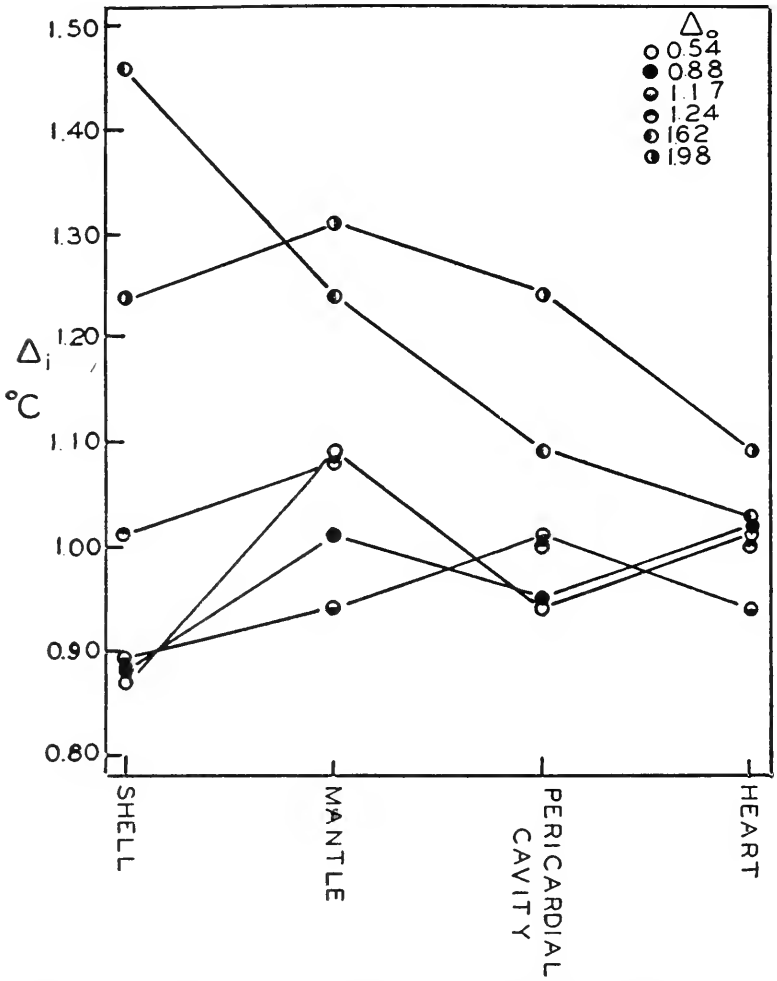

Figure 9. Freezing-point depressions of the body fluids (Δ_i) of the oysters maintained in several concentrations of sea water. Body fluids were not mixed to allow determination of the freezing-point depressions of the fluids (1) between the shells, (2) in the cavities of the mantle, (3) within the pericardium, and (4) within the heart.

and eight hours were used instead of the six hours of the first experiment. The results were essentially the same in the three experiments. The deeper in the oyster the fluid was obtained, the more constant was the freezing-point of the fluid. The difference between the lowest and highest freezing-point depressions with increased environmental salinity in the four hour experiment was: shell fluid, 0.58°C; mantle fluid, 0.37°C; pericardial fluid, 0.30°C; blood, 0.15°C. The

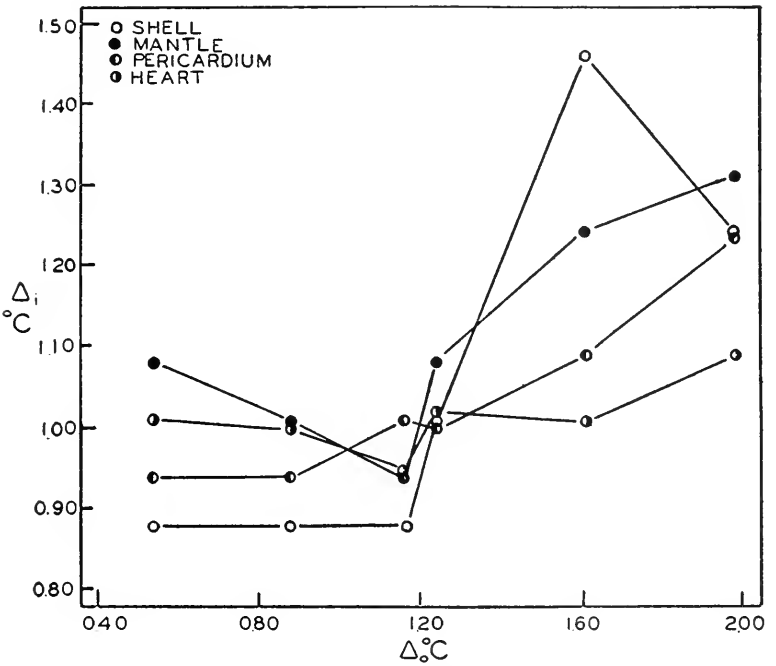

Figure 10. Relationship between the freezing-point depression of each fraction of the body fluids (Δ_i) and the salinity of the environment (Δ_0).

respective values for the eight hour experiment were: 0.44°C, 0.51°C, 0.30°C, and 0.22°C.

Growth of the oyster.—The oysters in the experiments described above were first and second year individuals. The combined weight of both shells has been plotted versus the number of individuals in each weight class (Figure 11). These values do not includes all the oysters used in these experiments because the weights of the shells of many of the oysters were not determined. The data form a bimodal curve. Each peak is probably due to the weights of the shells of individuals in the two age classes. The body weights and shell weights of the oysters have been presented in Table 3. As is expected, as the shell weight increased, the body weight also increased.

Discussion

The major portion of the exuded fluids was lost through ruptures in the mantle and pericardium. Fluids may, however, also be lost through the cut edges of the adductor muscle. The latter structure receives arteries directly from the heart. The heart in turn receives blood from the lacunar spaces of the mantle. These spaces are usually filled with fluid. Contraction of muscle fibers in the mantle may

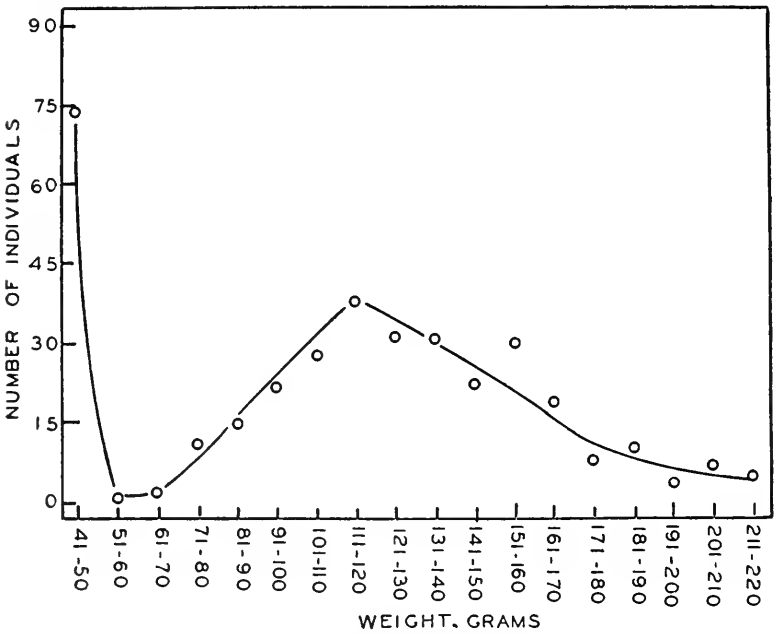

Figure 11. Combined weight of both valves of the oyster versus the number of individuals in each weight class.

contribute to an additional loss of fluid by actively forcing out the mantle fluid.

The limited osmoregulatory ability of the oyster *Crassostrea virginica* was probably due in part to the ability of the mantle (1) to resist the osmotic influx of water when the oysters were in an environment of low salinity and (2) to remain hypertonic to the other internal fluids in the upper and lower limits of the environmental salinity gradient used in these experiments. The nephridial organs probably also play a major role in osmoregulation (1) by removing salt from the fluid entering the arterial circulation when the animal is in a medium of high salinity and (2) by secreting a dilute urine when the animal is in an environment of low salinity.

The osmoregulatory abilities of the American oyster, *Crassostrea virginica,* and the Japanese oyster, *Crassostrea nippona* appear to be distinct. The salinity of the blood in the Japanese oyster, unlike that of the American oyster, closely follows changes in the salinity of the environment (Yamazaki, 1929). The American oyster tends to maintain the salinity of its blood constant at the expense of the other body fluids in spite of changes in the environmental salinity (Figures 9 and 10). The American oyster has evidently evolved a more efficient osmoregulatory ability than has been found in the Japanese oyster.

TABLE 3.

TOTAL WEIGHT OF BOTH SHELLS VERSUS WEIGHT OF THE BODY.

Shell Weight (grams)	Body Weight (grams)									
	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	Totals
41-50	21	30	7	11	1	4	0	0	0	74
51-60	0	1	0	0	0	0	0	0	0	1
61-70	0	1	0	1	0	0	0	0	0	2
71-80	2	9	0	0	0	0	0	0	0	11
81-90	3	5	5	1	1	0	0	0	0	15
91-100	1	7	9	4	0	0	0	0	0	21
101-110	1	8	14	4	1	0	0	0	0	28
111-120	2	9	15	9	3	0	0	0	0	38
121-130	2	7	11	6	2	2	1	0	0	31
131-140	0	5	10	12	3	1	0	0	0	31
141-150	1	1	5	6	5	2	2	0	0	22
151-160	0	4	7	9	8	1	0	1	0	30
161-170	0	1	4	4	5	4	1	0	0	19
171-180	0	0	1	0	2	4	1	0	0	8
181-190	0	0	1	3	1	3	1	1	0	10
191-200	0	0	0	0	1	1	1	1	0	4
201-210	0	1	0	0	2	1	2	0	1	7
211-220	0	0	0	1	2	1	0	0	1	5

Summary

1. Oysters which had been removed from their shells with no injury to the mantle and pericardium lost fluids equivalent to 26 per cent of their original body weight after 120 minutes. Most of this fluid loss occurred within 15 minutes after shucking. Puncturing the mantle and pericardium of shucked oysters resulted in a 50 per cent weight loss.

2. Oysters must be free to open and close their shells for weight and volume regulation. Oysters prevented from completely closing their shells lost weight both in and out of water due to secretion of body fluids.

3. Oysters have a limited ability to osmoregulate. The oysters tended to keep the salinity of their blood constant while the environmental salinity was altered.

4. The osmoregulatory abilities of an American and Japanese oyster are discussed.

References Cited

Florkin, Marcel 1938. Contributions à l'étude de l'osmoregulation chez les invertébrés d'eau douce (1). *Arch. Internat. de Physiol.* 47: 113-124.

Hopkins, A. E. 1936. Adaptation of the feeding mechanism of the oyster *(Ostrea gigas)* to changes in salinity. *Bull. U. S. Bur. Fish.* 48: 345-364.

Loosanoff, Victor L. 1952. Behavior of oysters in water of low salinities. *Nat. Shellfisheries Assoc., Convention Addresses,* 1952.

Nelson, Thurlow C. 1938. The feeding mechanism of the oyster. I. On the pallium and the branchial chambers of *Ostrea virginica, O. edulis,* and *O. angulata,* with comparisons with other species of the genus. *Jour. Morph.* 63: 1-61.

Prosser, C. Ladd, ed., 1950. *Comparative Animal Physiology.* W. B. Saunders Co., Philadelphia.

Schlieper, C. 1935. Neuere Ergebnisse und Probleme aus dem Gebiet der Osmoregulation wasserlebender Tiere. *Biol. Rev.* 10: 334-360.

Stauber, Leslie A. 1950. The problem of physiological species with special reference to oysters and oyster drills. *Ecology* 31: 109-118.

Yamazaki, M. 1929. On some physicochemical properties of the pericardial fluid and of the blood of the Japanese oyster, *Ostrea circumpicta,* Pils. with reference to the change of milieu exterieur. *Sci. Rept. Tohoku Imperial Univ.,* (4th ser.) *Biol.,* 4 (1, fasc. 2): 286-314.

Zerbe, W. B. and C. B. Taylor 1953. Sea water temperature and density reduction tables. *U. S. Coast and Geodetic Surv., Spec. Publ.* No. 298: 1-21.

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ANATOMY OF THE EYESTALK OF THE WHITE SHRIMP, *PENAEUS SETIFERUS* (LINN. 1758)

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ANATOMY OF THE EYESTALK OF THE WHITE SHRIMP, *PENAEUS SETIFERUS* (LINN. 1758)[1]

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In some of the lower Crustacea and in many of the higher Crustacea the compound eyes are set upon movable stalks or peduncles. Their presence at the ends of extensions has excited speculation for many years. Carcinologists have long discussed the reasons for the eyestalks, their similarity with the other appendages (Calman, 1909), and the nature of vision in a stalked-eyed animal, among other things. Yet little has been written about the mechanics of the eyestalk with respect to vision. No one has proposed any useful explanation for the fine adjustments presumably available to a compound eye which has as numerous oculomotor muscles as the crustacean stalked eye.

The presence of a set of muscles to move the corneal surface of the compound eye on the eyestalk, and of muscles to move the eyestalk about with respect to the body suggests the importance of the position of the corneal surface relative to the environment. By contrast, adjustments of corneal position in an arthropod without eyestalks suggests a function of head and "neck" muscles for activities other than feeding, if we assume any importance to the arthropod of corneal position adjustments.

Recently, the eyestalk nerves of a few crustaceans have been shown to contain neurosecretory elements which evidently proliferate hormone systems controlling such processes as molting (Passano, 1953), retinal pigment migration (Welsh, 1941), and chromatophore movements (Perkins, 1928). In view of the concentrated attention currently being paid to matters of neuro-hormonal control of physiological functions in the arthropods, an understanding of the relation of vision to neurosecretion appears to be near at hand.

The white shrimp, *Penaeus setiferus,* carries its eyestalks at an angle of about 75° to the median sagittal plane and at an angle of about ten to fifteen degrees to a frontal plane at the ocular plate (fig. 1). Only rarely are the eyes brought forward to lie in the optic depressions of the antennules, and then but for an instant for protection or possibly cleaning against the long plumules surrounding the depressions. Normally, therefore, in *P. setiferus* and many other species of shrimps, the eyes and stalks are widely spread and slightly upturned, a situation not understood by morphologists who, working with preserved materials, have described the eyestalks as projecting anteriorly (Cochran, 1935). Had previous workers taken into ac-

[1] This study was supported by funds made available in the Saltonstall-Kennedy Act, under a contract between Tulane University and the U. S. Fish and Wildlife Service.

count the lateral position of the eyestalk in the shrimps, and for that matter in the crawfishes, a certain amount of confusion in the naming of eyestalk musculature might have been avoided. For in fact, medial muscles are anterior and lateral muscles are posterior. By way of uniformity, however, certain of the incorrect names are here employed.

P. setiferus, an omnivorous scavenger like many shallow water and intertidal Crustacea, is a bottom feeder. According to an unpublished observation by Charles Dawson, of the University of Texas, schools of penaeid shrimps are frequently to be found on muddy bottoms. This worker describes placing several *P. aztecus* Ives 1891, in aquaria with an inch or two of mud on the bottom, into which the animals immediately burrow, except for the eyes. Such behavior suggests that the long eyestalks are among the organs enabling the penaeid shrimp to make use of mud for protection, especially after molting.

In the past, observers have described square corneal facets in the eyes of several species of decapod crustaceans (Huxley, 1906; Calman, 1909). A study of slides made of the corneal cuticle shows that the corneal facets in the compound eye of *Penaeus setiferus* are also square. Likewise the underlying ommatidial cells are square in *P. setiferus* and total four per ommatidium, as determined by the study of tangential sections of the eye from which the corneal cuticle had been removed. In longitudinal section the ommatidia of *P. setiferus* are seen to be similar to those of *Astacus,* with comparatively elongate crystalline cone and short rhabdom cells (Bernhards, 1916; Ramadan, 1952). A light pink substance which is thought to give the dark-adapted shrimp eye its bright pink color in strong lights is associated with the proximal or retinal pigment of the ommatidia.

The ommatidial surface arises from a sclerotized cup, here named the *optic calathus,* or basket, to avoid confusion with the optic cup of the vertebrate embryo (fig. 1). The optic calathus rests upon the elongate stalk segment in a structural relationship permitting universal movements, although the degree of movement varies in different planes.

Two points of articulation in the dorso-ventral plane allow the optic calathus considerable horizontal movement around the distal end of its supporting stalk. These dorso-ventral hinges are, however, sufficiently loose to permit vertical and rotational calathus movements, but to a lesser extent than horizontal movements. The long stalk is comprised externally of several longitudinal sclerotized bars which are separated by pliable cuticle. Two of the bars give support to the dorso-ventral points of articulation and others to less well-defined points of articulation between the stalk and calathus, and between the stalk and basal segment.

The stalk is movable upon the short, box-like, basal segment in the horizontal plane. Vertical movements between the basal segment and the stalk are restricted. With respect to the structure here labelled

the median tubercle (fig. 1), it may be noted that the shrimps of the subfamily Penaeinae are said to have no distinct median tubercle on the ocular peduncle (Anderson and Lindner, 1943; Voss, 1955). However, many of the shrimps of this group do possess large, blunt, median tubercles, similar to those in *Penaeus setiferus*.

Set between the basal segments is the *ocular plate* or lobe, a broad, roughly rectangular sclerotized structure which encloses laterally the medial parts of the basal segments (fig. 1). The ocular plate is the dorsal-most region of the protocephalon, a tagma about which more will be written later.

Movements between the basal segment and the ocular plate are similar in extent to those between the stalk and the basal segment. Horizontal movements are limited to an arc of about fifteen or twenty degrees.

Techniques

The anatomical study of the eyestalks of *Penaeus setiferus* was made for the most part on white shrimp purchased alive from bait shrimp fishermen. The animals were fixed in Zenker's fluid, dehydrated to 70% ethyl alcohol and there stored. In spite of the difficulties in its use in the field, Zenker's fluid was found to have several advantages over formalin. Zenker's fluid softens or removes the calcareous deposits and leaves the cuticle in a condition similar to thick cellophane. This mixture quickly penetrates to and fixes the internal organs, and in doing so prevents internal maceration caused by the post-mortem enzymatic activity of the hepato-pancreas. Formalin-fixed material is useless for the study of internal organs. The fixative greatly hardens the cuticle and the external muscles and fails to penetrate to the internal organs.

Dissections were performed under a stereomicroscope. Dissecting needles which were sharpened to fine points in mixtures of strong nitric acid and ethyl alcohol were employed. Locations of muscle attachments were verified on specimens of white shrimps cleared in strong alkali and stained in picro-fuchsin. The outlines of whole structures were used as templates within which muscles and other organs were sketched in layers on tracing paper as the dissections progressed. The tracings were transferred to drawing papers on a light box. The drawings were finished in ink and carbon pencil.

Morphological Note

For purposes of comparison the present work will have reference to the work of Berkeley (1928) on the "coon stripe" shrimp, *Pandalus danae* Stimpson 1857, to the works of Schmidt (1915) and Keim (1915) on *Astacus astacus* (Linn. 1758), to that of Welsh (1941) on *Cambarus bartoni* (Fabricius 1798) and to the work of Cochran (1935) on the blue crab, *Callinectes sapidus* Rathbun 1896. Of these animals, the white shrimp, *Penaeus setiferus,* appears to be the

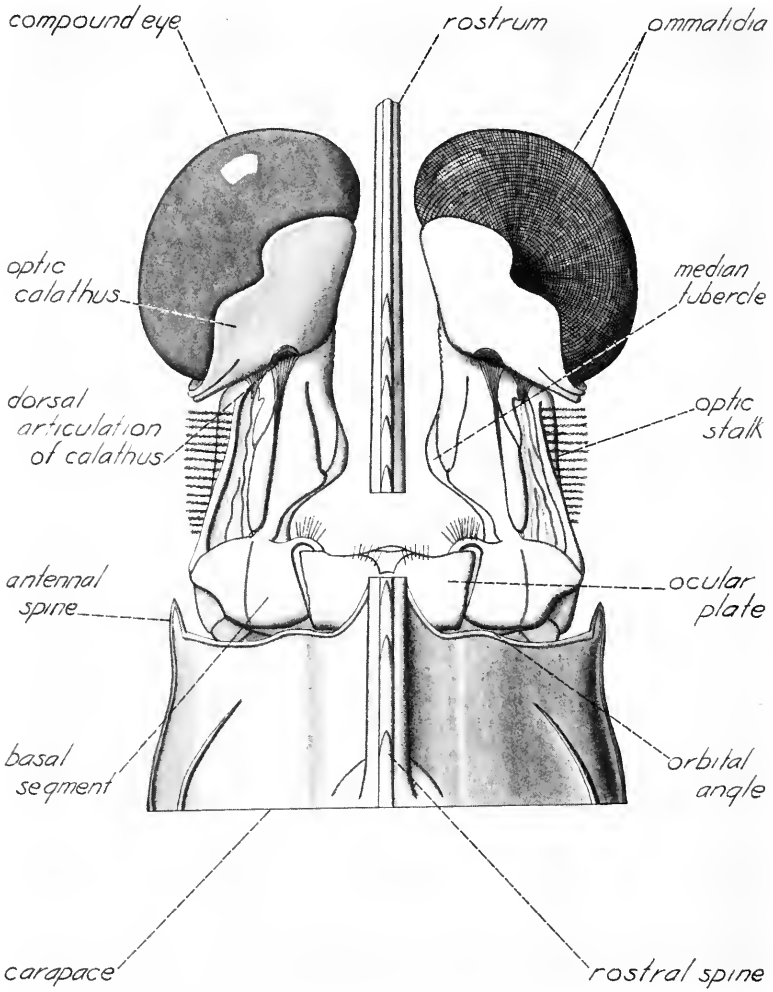

Figure 1. *Penaeus setiferus.* Dorsal view of eyestalks in anterior position. Rostrum cut away to show ocular plate.

most generalized form, the modern species most like the generalized ancestral type.

Protocephalon Muscles of Ocular Region

Taking origin from either the epistomal invagination or the dorsal surface of the carapace and inserting upon basal parts of the eyestalks are four pairs of muscles. The basal regions of the eyestalks will be assigned here to the dorsal part of that morphologically

separable pre-gnathal group of segments designated by Snodgrass (1951) as the protocephalon. This simple head includes, in the order of their occurrence in the adult, the eyes, antennules, antennae, and labrum. The protocephalon is clearly distinct from the succeeding gnathal, thoracic, and abdominal tagmata, and in *Penaeus setiferus,* and other species of the genus (Grobben, 1917), is independently movable.

Not shown in any of the accompanying plates is a pair of muscles which will be included in the present discussion, the tiny *anterior protocephalon levator* muscles, which are probably the muscles designated by Grobben (1917) as the protocephalon levators in a European penaeid. These muscles are difficult to make clear, either by dissection, or by illustration, since they take origin on the carapace, upon the nearly vertical sides of the rostral base. During removal of the carapace and the underlying layers of tough, fibrous epidermis and connective tissue, these muscles are torn away. The anterior protocephalon levators insert in the heavy connective tissue associated with the posterior edge of the protocephalon. Their actual levation of the protocephalon is negligible, since they are not only minute in cross section, but short in length. No counterpart of the anterior protocephalon levator muscles has been described for any of the species of decapod Crustacea referred to above, from which forms we must conclude that the muscles have been lost in the course of evolution.

Posterior Protocephalon Levator Muscles
(figs. 2, 3)

The function of moving the protocephalon dorsally is performed by a pair of large muscles, the *posterior protocephalon levator muscles,* which originate close together at the dorsal midline of the carapace somewhat posterior to the origin of the anterior protocephalon levator muscles and which run forward and downward to attach on a nearly verticle transverse plate, posterior to the post-ocular region of the eyestalk base (fig. 3). The muscle inserts ventrally to the insertion of the anterior levators. The contraction of the posterior protocephalon levators may also act to rotate posteriorly the eyestalk base and hence raise the extended eyestalks.

Possible homologues of the posterior protocephalon levator muscles are the median dorsal muscles designated as the musculus oculi basalis posterior. In *Astacus,* Schmidt (1915) found that these muscles arise on the median dorsal surface of the carapace and are attached by short tendons to the much longer tendons of other, more anteriorly-placed muscles, the musculus oculi basalis anterior. The anterior eye base muscles, to anglisize freely, are attached to the median dorsal region of the eyestalk base (Schmidt, 1915). More will be said of the latter muscles below.

The posterior eye base muscles, it should be emphasized, do not attach to the eyestalk base in *Astacus,* but if the assumption is made

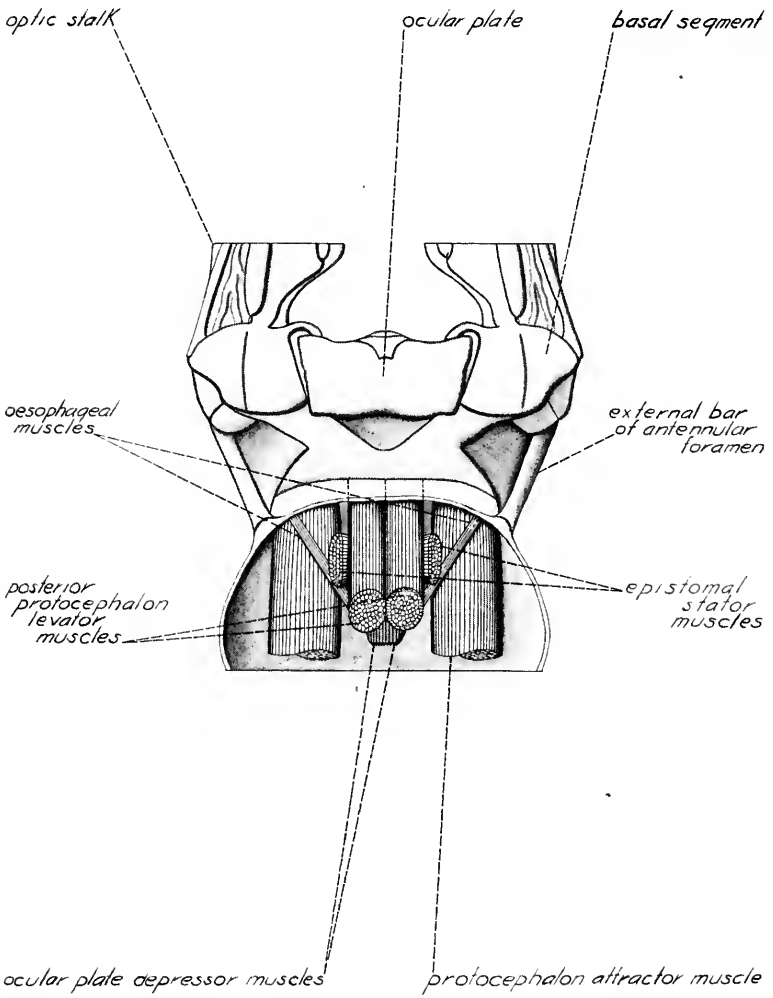

Figure 2. *Penaeus setiferus.* Dorsal view of protocephalon, carapace removed, showing muscles of postocular region.

that, due to the immovable protocephalon in *Astacus,* the attachment of the muscles to the eyestalk base has moved in that animal to the tendons of the anterior eye base muscle, then a homology with the posterior levators in the white shrimp may be proposed. However, the extensive rearrangement of muscle attachments upon which the assumption is based weakens the proposal.

Even more significant, muscles exist in *Penaeus setiferus,* as will

be shown below, which are more likely to be the homologues of the anterior and posterior eye base muscles in *Astacus, Pandalus,* and *Callinectes* than are the posterior protocephalon levator muscles. If the latter is true then the posterior protocephalon levators have been lost during the evolution of *Astacus, Pandalus,* and *Callinectes,* in which forms no trace of the muscles appears (Schmidt, 1915; Berkeley, 1928; Cochran, 1935).

Ocular Plate Depressor Muscles
(figs. 2, 3, 4)

The *ocular plate depressor muscles* originate on the posterior surface of the epistomal invagination. They run antero-dorsally, passing beneath the insertions of the posterior protocephalon levator muscles, and insert broadly on the posterior edge of the ocular plate (figs. 2, 3, 4). Upon contraction, the ocular plate depressors draw the ocular plate posteriorly and ventrad. Based on the attachment points of the muscles in *Penaeus setiferus,* they may have given rise by partial fusion to the anterior eye base muscles (musculus oculi basalis anterior) as they are found in the European crawfish, where the muscles are attached ventrally to the epistomal region by a long tendon and run dorsad to the edge of the eyestalk base. Cochran (1935) describes in *Callinectes* a pair of anterior eye base muscles which arise from a kind of epistomal invagination rather like that in the white shrimp, but instead of fusing as in the European crawfish, they diverge slightly laterad in the blue crab in probable accompaniment with the general broadening of the body to be seen in the Brachyura.

The ocular plate depressor muscles are apparently homologous with the musculus oculi basalis anterior in *Pandalus,* the name for which muscles Berkeley (1928) has taken from Schmidt (1915). In *Pandalus,* these muscles are similar to those in *Penaeus,* except for the fact that they are slightly separated, where in *Penaeus setiferus* they are very close together.

Protocephalon Attractor Muscles
(figs. 2, 3, 4, 5)

The *protocephalon attractor muscles* are two very large muscles which take broad "L-shaped" origins on the carapace and run anteriorly to insert on two pairs of large apodemes and on other parts of the protocephalon. The largest apodeme, upon which the ventral-most part of the protocephalon attractor muscles inserts, arises from the ventral surface of the antennular foramen, broadening posteriorly into a large vertical sheet of cuticular material. Slightly antero-dorsal to the antennular apodeme, in the same parasagittal plane, is an apodeme which invaginates from the ventral floor of the basal segment of the eyestalk and projects through the ventro-lateral side of the eyestalk foramen into the thoracic hemocoel. This apodeme, like that near the antennule, broadens vertically. By virtue of apodemal position,

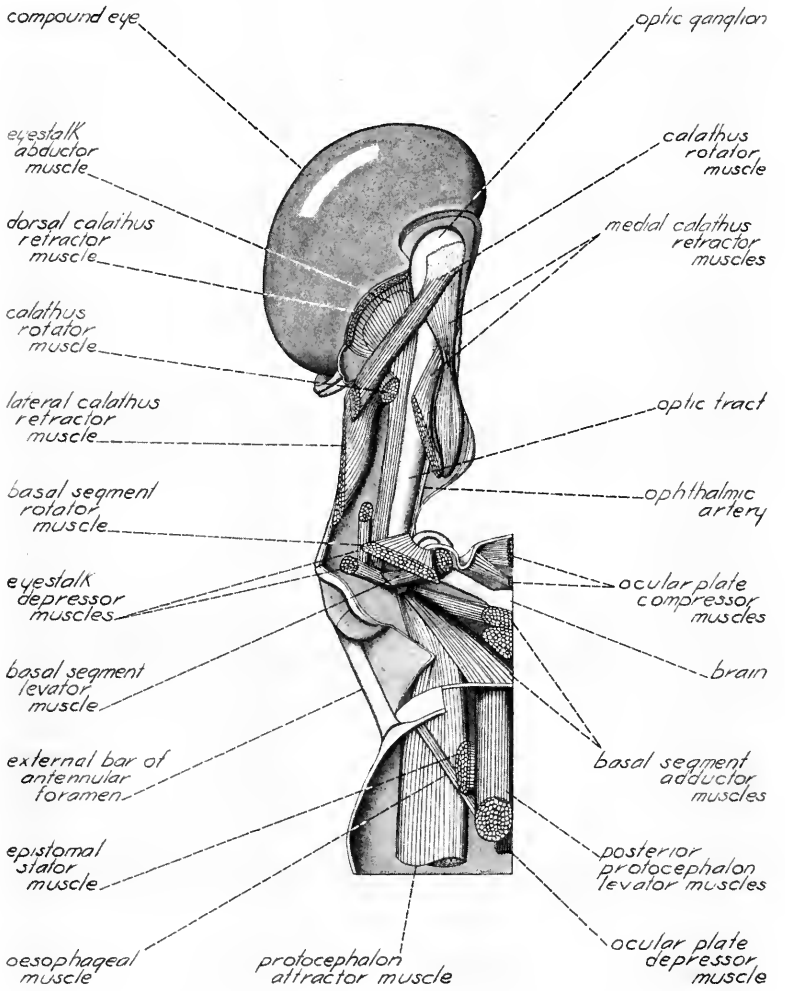

Figure 3. ***Penaeus setiferus.*** **Dorsal view of left eyestalk. Dorsal cuticle and carapace removed to show muscles.**

that part of the protocephalon attractor muscle attaching upon the eyestalk apodeme is somewhat longer than is the part inserting on the antennular apodeme.

The longest and most dorsal part of the protocephalon attractor muscle extends anteriorly beyond the antennular and eyestalk apodemes, to insert slightly laterad in connective tissue at the ventral surface of the basal segment of the eyestalk (figs. 4, 5).

To these comparatively huge protocephalon muscles we may ascribe at least two functions, namely, (1) attraction of the protocephalon, and (2) adduction of the eyes. The largest of the three inserting bodies of the muscle is the ventral-most part inserting on the antennular apodeme, described above. From a study of the points of articulation between the carapace and the protocephalon, dorsally, and the mandibular segment and the protocephalon, ventrally, the primary result of contraction of the ventral muscle body would be to draw the protocephalon directly posterior. The same muscle has been called a protocephalon depressor by Grobben (1917). When studying a European penaeid, this worker so described the muscle in a morphological discussion of the crustacean protocephalon. The point of Grobben's discussion, that the protocephalon is movable on the gnathal tagma, is not changed by a difference in opinion over the function of the muscle under consideration.

Furthermore, these muscles are not antennular in any way, having, as brought out by Snodgrass (1951), origins on the carapace. They are also not antennal, for the simple reason that they do not go to the antennae. Although it is possible that the protocephalon attractor muscles in *Penaeus brasiliensis* Latreille 1817, may be widely differnet from those in *P. setiferus,* the statement of Knowles (1953) that the two muscles lying just beneath the antero-lateral side of the carapace are antennal is probably in error. From his figures the external-most muscle is properly a depressor of the antennal scale, while the large inner muscle is the protocephalon attractor muscle.

The two antero-dorsal parts of the protocephalon attractor muscles which find insertions in the eyestalks have, in addition to attraction, the function of eyestalk adduction. Upon contraction of the whole muscle, these dorsal fibers in the eyestalk draw the ocular plate and attached eyestalk segments posteriorly toward the carapace. The posterior side of the basal segments makes contact with a condylic thickening on the anterior edge of the carapace, at a point known as the *orbital angle* (fig. 1), thereby swinging the eyestalks forward in a horizontal plane into the ocular depressions on the antennules. As suggested in the introduction, the movement is a quick one, much faster than the return of the eyes to the spread position. In *Penaeus setiferus* other muscles exist which function to adduct the eyes, but their effect is negligible when compared to that of the much larger protocephalon attractor muscles.

The protocephalon attractor muscles appear in *Pandalus,* designated by Berkeley (1928) as the depressor muscles "c" of the antennae, on grounds of their attachment to the basipodites of those structures. At the same time this worker ascribes to the depressor muscles "c" the function of adduction and rotation, rather than depression of the antennae. Berkeley's name for the muscles obviously was taken from the work of Schmidt (1915) on *Astacus,* in which form the antennal

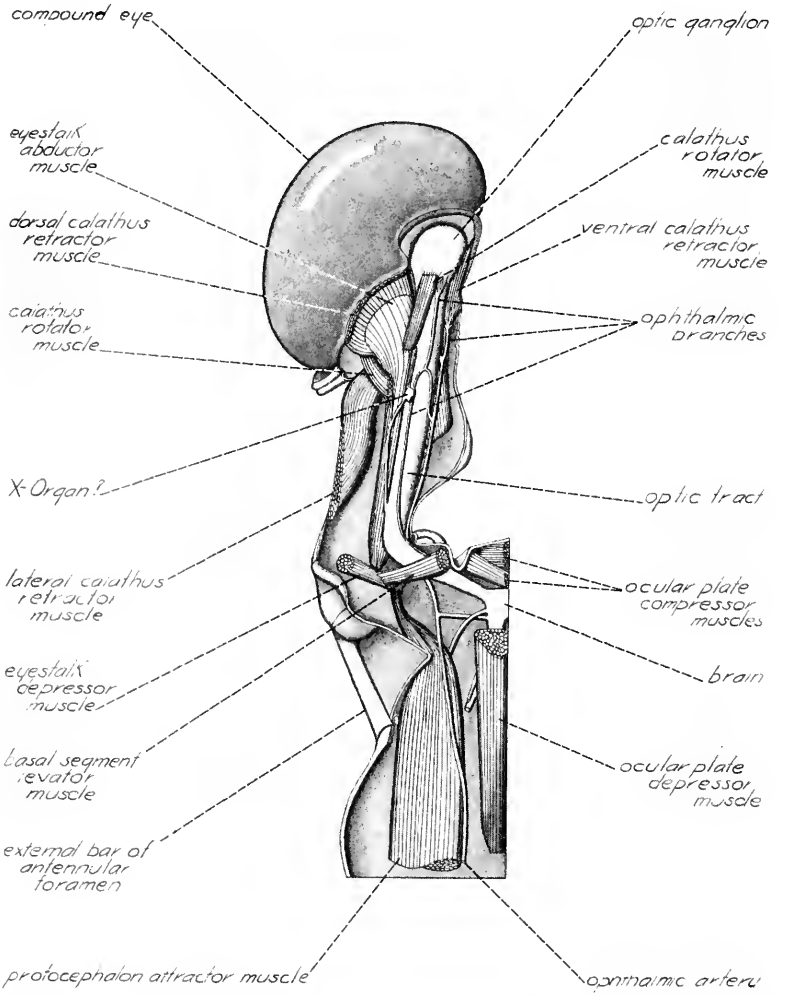

Figure 4. *Penaeus setiferus.* Dorsal view of left eyestalk. Dorsal muscles removed to show branches of nerves and arteries.

depressor muscles "c," while small nonetheless depress the antennae. Although proof must wait upon a study of the nerves in *Penaeus* and *Pandalus,* Berkeley has homologized the so-called depressor muscles "c" of *Pandalus* and *Astacus* on the basis of their dorso-lateral origins on the carapace and their insertions on the medio-dorsal edge of the antennal basipodite (in *Pandalus*) and coxopodite (in *Astacus*). That the depressor muscles "c" in *Pandalus* and the protocephalon levators

in *Penaeus* are homologous seems fairly certain, in spite of the apparent change of insertion in the former. A review of cleared and stained exoskeletons of *Pandalus* might show multiple insertions of the muscle as in *Penaeus*. The homology of the protocephalon attractor muscles in *Penaeus* with the depressor muscles "c" in *Astacus* is less certain. In *Callinectes*, Cochran (1935) figures a pair of ocular attractor muscles which originate on the carapace. Their phylogenetic relation to the protocephalon attractor muscles in *Penaeus* is unlikely.

Epistomal Stator Muscles
(figs. 2, 3)

Originating on the dorsal surface of the carapace, lateral to the posterior protocephalon levator muscles, and converging on the anterior side of the epistomal invagination are a pair of small muscles which are named in the present work, the *epistomal stator muscles* (figs. 2, 3). The name derives from the fact that contractions of the muscles would appear to hold the epistomal invagination in position during the contraction of other muscles in the area. The epistomal stator muscles are homologous with the musculus oculi basalis posterior in *Pandalus* and *Astacus* and probably in *Callinectes*.

Oesophageal Muscles
(figs. 2, 3)

The last of the muscles in the anterior region of the gnathothorax to be treated is a pair of *oesophageal muscles* (figs. 2, 3) which originate on the antero-lateral surfaces of the carapace, dorsal to the protocephalon attractor muscles, and converge upon the anterior surface of the oesophagus. They function to dilate the oesophagus. Dorsal oesophageal muscles are not shown in the works of *Astacus, Pandalus,* or *Callinectes,* although Cochran (1935) figures several ventral oesophageal dilators in the latter form.

Ocular Plate Muscles

Arising in the ocular plate or post-ocular region dorsal to the brain are several pairs of muscles and a muscle group. Some of these muscles insert inside and some outside of the ocular plate.

Ocular Plate Compressor Muscles
(figs. 3, 4)

Attached about the shallow antero-dorsal groove of the ocular plate is a group of muscles which runs to the lateral wall of the ocular lobe (figs. 3, 4), the *ocular plate compressor muscles*. They function to draw the sides of the head lobe and ocular plate mesad, and to depress slightly the center of the ocular plate.

Anterior Basal Segment Adductor Muscle
(fig. 3)

The *anterior basal segment adductor muscle* originates on the ocular plate dorsal to the brain and attaches to connective tissue and apodemal

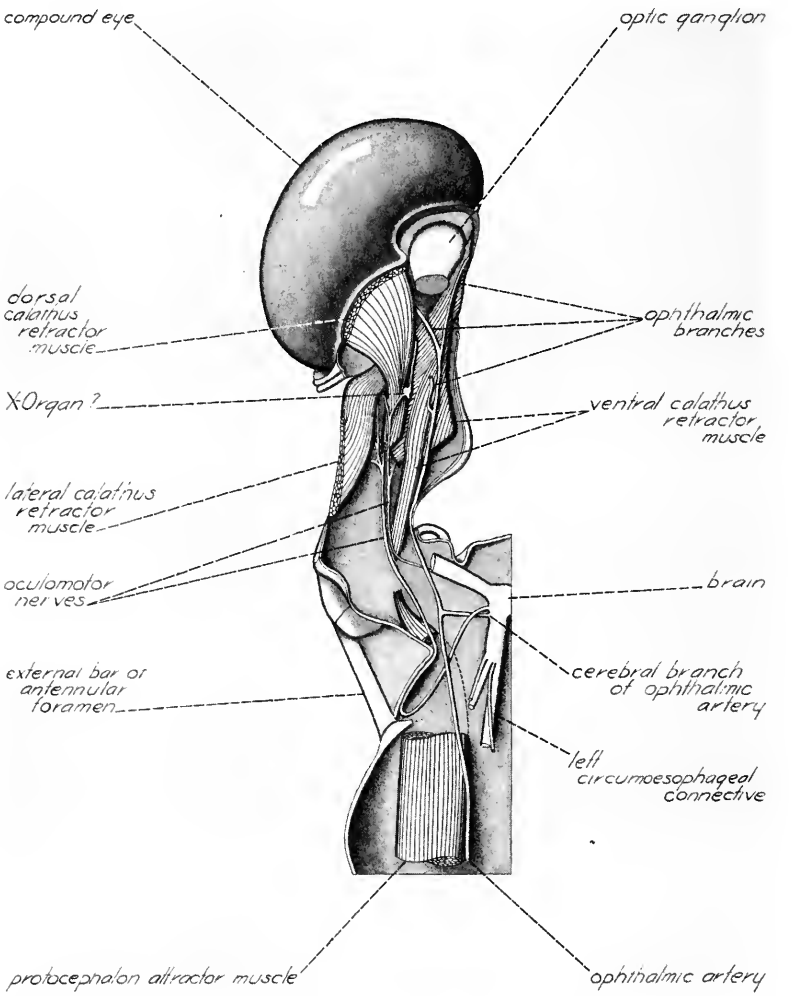

Figure 5. *Penaeus setiferus.* Dorsal view of left eyestalk. Dorsal muscles and optic tract removed to show ventral muscles and branches of nerves and arteries.

material in the ventral part of the basal segment (fig. 3). Contractions of the muscle turn the basal segment toward the ocular plate in a horizontal plane.

Posterior Basal Segment Adductor Muscle
(fig. 3)

The *posterior basal segment adductor muscle* inserts in the basal

segment at the same point as the anterior basal segment adductors, but originates on the anterior side of the vertical transverse plate posterior to the post-ocular region (fig. 3). It, too, draws the anterior edge of the basal segment toward the ocular plate. The origins of these muscles are so widely separated that we may conclude that they have never been the same muscle. How the basal segment adductors may be homologized with the situation in *Pandalus* and *Callinectes,* in which forms no knowledge of muscle innervations exists, will be speculation. The ocular adductor muscles of *Astacus* and *Pandalus* may well be the homologues of the anterior adductor muscles of *Penaeus,* but hardly with the ocular adductors of *Callinectes,* in which animal the muscles are located in the distal end of the long stalk segment. Phylogenetic relationships of the posterior basal segment adductor muscle are even more uncertain, although possibly it is the same muscle as the ocular attractor muscle in *Pandalus* and *Astacus.* The basal segment adductor muscles do not appear in *Callinectes.*

Basal Segment Levator Muscle
(fig. 3)

The *basal segment levator muscle* originates at the antero-dorsal corner of the ocular plate and runs ventrally to the connective tissue and apodemal cuticle on the ventral surface of the basal segment (fig. 3). In the normal spread condition of the eyestalk, contraction of the muscle tends to raise the basal segment and with it the extended eyestalk.

Basal Segment Muscles

In the functional descriptions of the muscles which follow, the eyestalks will be considered as if in their lifelike, lateral positions.

Basal Segment Rotator Muscle
(fig. 3)

The *basal segment rotator muscle* is a short, broad structure originating on the antero-dorsal edge of the basal segment and inserting on the antero-ventral edge of the same segment. Upon contraction, the muscle pulls the dorsal surface of the basal segment anteriorly, thus rotating the entire eyestalk forward.

Eyestalk Depressor Muscle
(fig. 3)

Two very small muscles, the *eyestalk depressor muscles,* one slightly lateral to the other (fig. 3), function to draw the eyestalk ventrally. After a review of the literature, the present writer concludes that neither of these muscles, the basal segment rotator or the eyestalk depressor muscle, has been previously described.

Eyestalk Muscles

Eyestalk Abductor Muscle
(fig. 3)

All of the muscles of the eyestalk and optic calathus are associated with retraction and rotation of the optic calathus on the eyestalk, except for the long *eyestalk abductor muscle* (fig. 3). The proximal end of the eyestalk abductor muscle is attached in connective tissue in the ventral region of the basal segment. The muscle runs the length of the eyestalk to insert in connective tissue near the dorsal calathus retractor muscle. Contraction of the muscle swings the eyestalk horizontally to a lateral position. The eyestalk abductor muscle of *Penaeus setiferus* is very likely homologous with the abductor muscle described for *Astacus* and *Pandalus,* and possibly with the lateral branch of the ocular abductor muscle in *Callinectes.*

Calathus Retractor Muscles

The muscles in *Penaeus setiferus* which retract the optic calathus appear to be clearly represented by the retractor muscles of the eyes of *Astacus, Cambarus, Pandalus,* and *Callinectes.* Phylogenetically, the situation in *Penaeus setiferus* is somewhat more generalized than in the other forms which we are considering, in that several of the calathus retractor muscles in *Penaeus* have more than one part. In addition, *Penaeus* has a number of apparently independent rotator muscles, none of them previously described, which function to twist the optic calathus about a longitudinal axis through the eyestalk.

Dorsal Calathus Retractor Muscle
(figs. 3, 4, 5)

The *dorsal calathus retractor muscle* arises in connective tissue near the ventral surface of the eyestalk and attaches to the dorsal edge of the calathus.

Lateral Calathus Retractor Muscle
(figs. 3, 4, 5, 6)

The *lateral calathus retractor muscle,* really the posterior retractor, originates on sclerotized material along the lateral, or actually posterior, blood sinus running the length of the eyestalk. The larger portion of this muscle attaches on the lateral edge of the calathus, the lesser part turning ventrally and running across the ventral edge of the calathus, just dorsal to the ventral retractor muscles (fig. 6). When this muscle contracts it not only retracts the calathus, but rotates the calathus about an axis longitudinal to the eyestalk.

Ventral Calathus Retractor Muscle
(fig. 6)

The *ventral calathus retractor muscle* originates on several sclerotized regions on the ventral surface of the eyestalk. One part of the muscle is long and slender, while the others are short and arise from broad

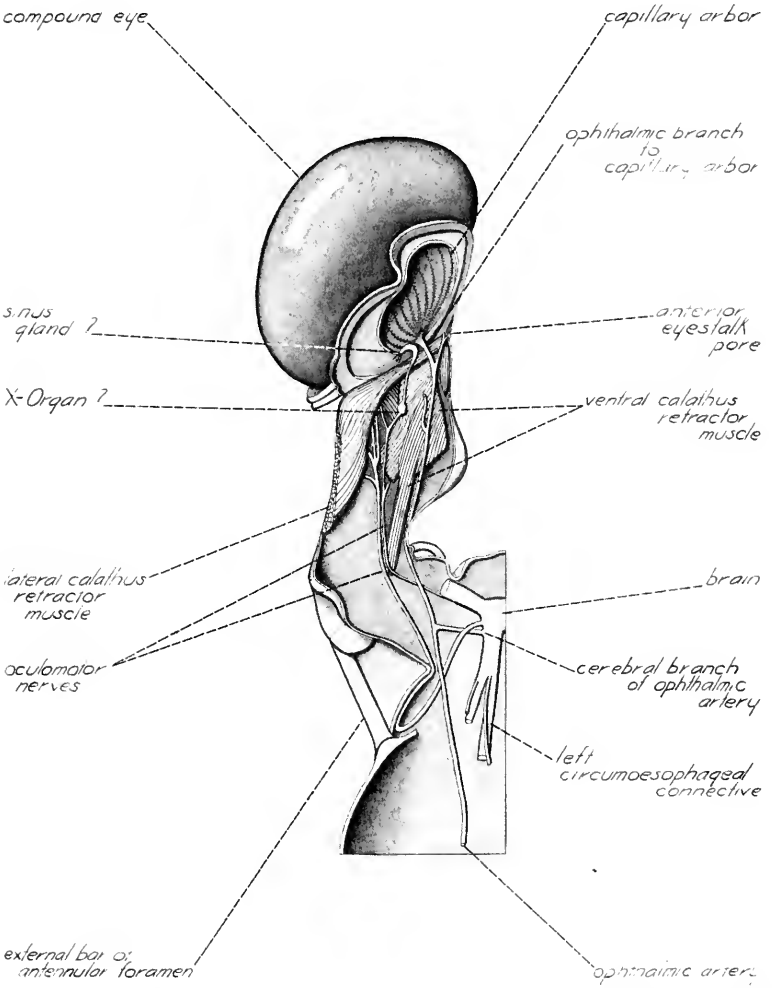

Figure 6. *Penaeus setiferus.* Dorsal view of left eyestalk. Dorsal muscles and optic tract removed to show brain, branches of nerves, arterial capillary supply to distal optic ganglia, neurosecretory glands, and location of anterior eyestalk pore.

origins (fig. 6). The muscle is inserted over a wide area on the ventral edge of the calathus.

Medial Calathus Retractor Muscle
(fig. 3)

The *medial calathus retractor muscle* orignates on two points in

the region of the median tubercle, and actually is comprised of two muscles (fig. 3). The larger muscle originates in the median tubercle and inserts in connective tissue dorsal to the distal optic ganglionic mass. The smaller muscle originates dorsal to the larger muscle, crosses over the optic tract beneath the larger muscle and inserts on a ventro-medial point on the calathus. The contraction of both muscles results in medial retraction of the calathus; functioning in opposition, the muscles retract the calathus in a vertical plane, reinforcing the action of the dorsal and ventral retractor muscles.

Calathus Rotator Muscles
(figs. 3, 4)

At least three *calathus rotator muscles* may be seen in the eyestalk of *Penaeus setiferus*. Rotator muscles of this type have not been described for *Pandalus, Astacus, Cambarus,* or *Callinectes*. The calathus rotators bear a certain similarity to one another, in that they are all superficial in position and originate and insert in the heavy connective tissue underlying the thick cuticle of the calathus.

Eyestalk Vascular Supply
(figs. 4, 5, 6, 7)

Blood is pumped to the eyestalk in the vessel described by Huxley (1906) as the *ophthalmic artery*. From the anterior end of the heart, the ophthalmic artery runs forward dorsal to the gastric region, turns ventrally and laterally through dorso-lateral muscle origins to the protocephalon attractor muscle, with which muscle it enters the eyestalk, giving off a large branch to the brain in passing. Once in the eyestalk, the artery runs medially along the optic tract and divides into several branches at the distal end of the eyestalk. The most proximal branch bifurcates on the dorsal surface of the optic tract (figs. 4, 7), sending a short vessel to and apparently through a small gland on the optic tract here designated as the X-Organ described by Hanström (1948) and about which more will be said below. A small part of the arterial branch to the gland continues proximally along the dorsal surface of the optic tract and has not been traced beyond the connective tissue of the basal segment. The larger part of the proximal ophthalmic branch runs distally into the distal optic ganglionic mass (figs. 4, 7).

Distally, the ophthalmic artery divides into two large branches, one of which (figs. 5, 6) carries blood into a highly-branched, dendritic structure embedded deeply among the optic ganglion cells (fig. 6). The organ has been named the *capillary arbor,* since it appears to distribute blood to ganglionic cells. Nothing similar has been found in the literature of the arthropod eye.

The other, and most-distal ophthalmic branch, repeatedly divides to form a vascular plexus on the medial surface of the eyestalk, just beneath a heretofore undescribed pore to the exterior (figs. 6, 7).

The pore is designated as the *anterior eyestalk pore.* Its function is unknown.

Circulation to the eyestalk of *Penaeus setiferus,* like that to some of the other appendages, is made up of a closed afferent system which is subdivided into capillaries in muscles, ganglia, and other organs. Venous returns of the blood to the heart is carried out in an open system, by means of sinuses in to the hemocoel. To what extent the closed-arterial, open-venous blood vascular system is representative of the Crustacea must wait upon further study (Calman, 1909).

Eyestalk Nerves
(figs. 5, 6, 7)

By far the largest nervous element in the eyestalk of *Penaeus setiferus* is the optic tract, a part of the brain, which rises from the anterolateral region of the brain, runs distally in the eyestalk, increasing in diameter, and enters the calathus. Within the calathus the optic tract enlarges to incorporate the various distal optic ganglia and makes contact with the nerves from the ommatidia (figs. 6, 7). If the distal optic ganglionic mass is pulled away from the dioptric elements of the eye, the tearing is confined to natural lines of weakness representing a deep concavity. Lining the concavity so produced will be found the capillary arbor described above (fig. 6).

Along the lateral side of the optic tract, and embedded in the perineurium in the proximal region of the optic tract, is a small nerve which branches out of the perineurium distal to the basal segment. This nerve puts out several tiny branches to muscles and then enters a glandlike structure for which the name *X-Organ* (Hanström, 1948) is proposed (fig. 7). From the X-Organ a nerve continues along the optic tract distally to enter another, and larger, glandlike organ here termed the *sinus gland* (fig. 7). The sinus gland lies against and sends branches into the optic ganglionic mass at the distal end of the optic tract. It should be emphasized that the identification of the X-Organ and the sinus gland is made on doubtful grounds, since no supporting histological or experimental evidence is presented.

On the other hand, certain anatomical information lends support to the identification of the above-mentioned glandlike structures as the X-Organ and sinus gland. The support is to be found in the literature of neurosecretory experiments. The illustrations in some works of this literature are, to say the least, circumscribed (Passano, 1953), and useless to the morphologist. However, Welsh (1941) has taken pains to illustrate clearly his experiments on retinal pigment migration in *Cambarus bartoni.* From his figures, indicating careful anatomical work on the nerves of the eyestalk of *C. bartoni,* the locations and innervations of the X-Organ and the sinus gland appear to be similar to the glandlike structures in *Penaeus setiferus.*

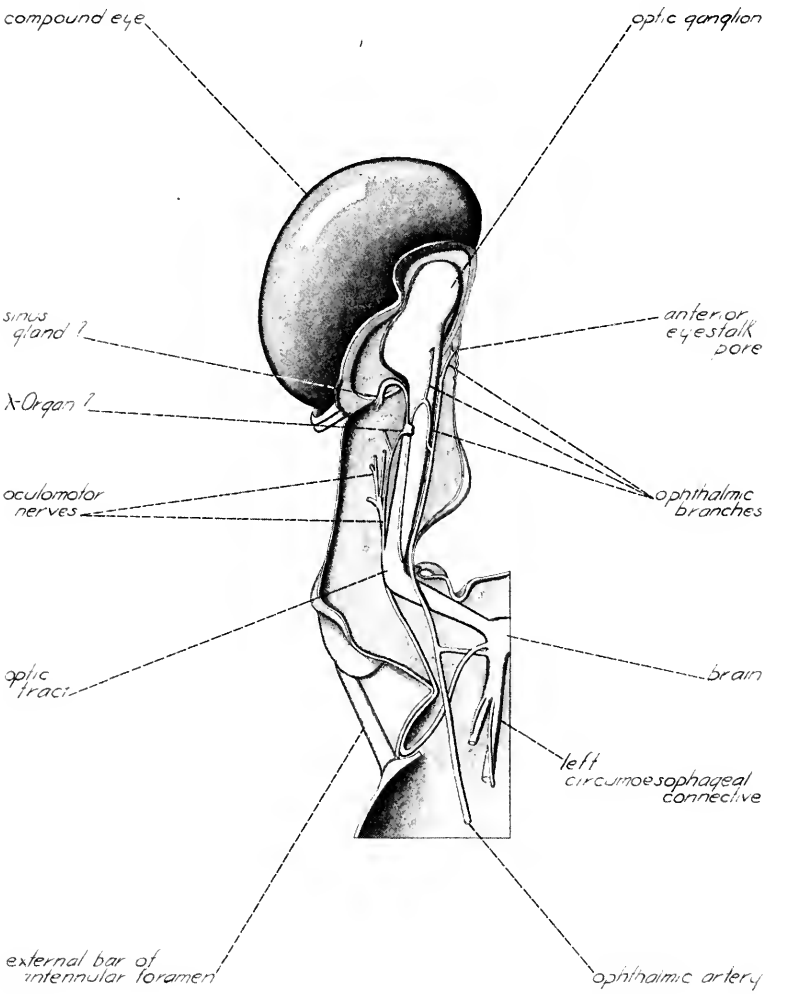

Figure 7. *Penaeus setiferus*. Dorsal view of left eyestalk. Muscles removed to show optic tract, oculomotor nerves, neurosecretory glands, and branches of ophthalmic artery.

Keim (1915) in his account of the nerves in *Astacus* does not illustrate the structures.

The eyestalk nerve to be considered last in the present account originates on the lateral side of the brain, slightly posterior to the optic tract, and, beginning ventrally describes an almost complete loop around the protocephalon attractor muscles (figs. 5, 6, 7). The nerve

procedes to the dorso-lateral region of the muscle, between the muscle and the outer epidermis. From the latter position, the nerve turns sharply anterior and runs into the eyestalk, giving off branches to various of the muscles. The nerve in *Penaeus* is the same as the eye muscle nerve, or *oculomotor nerve* described by Keim (1915) in *Astacus.*

Regrettably, very little can be said of homologies between the eyestalk nerves of the various Crustacea, since so little information exists on the subject. Certainly, the optic tracts and the oculomotor nerves in *Penaeus, Astacus,* and *Cambarus* are homologous structures. Further anatomical information on the nerves will have to be provided before the compartive morphology of the Crustacea Decapoda will be in any way a satisfactory story.

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Summary and Conclusions

1. The eyestalks of the white shrimp, *Penaeus setiferus,* are discussed briefly in connection with its natural history.

2. The earlier observation that the ommatidia are square in *Astacus* is also true in *Penaeus setiferus* as borne out by a study of longitudinal and cross sections of the eye.

3. The name, optic cup, for the sclerotized hemisphere containing the dioptric elements of the stalked crustacean eye is changed to optic calathus, or basket, to end confusion with the optic cup of the vertebrate embryo.

4. The eyestalk of *Penaeus setiferus* is compared to that of *Pandalus danae, Astacus astacus, Cambarus bartoni,* and *Callinectes sapidus.*

5. Seventeen muscles associated with the eyestalk of the white shrimp are discussed and figured. Several of them have not been previously described.

6. The vascular supply of the eyestalk is treated, including an undescribed circulatory structure, the capillary arbor.

7. A previously unknown pore, the anterior eyestalk pore, on the anterior or leading edge of the eyestalk segment is described.

8. The neural elements of the eyestalk are considered, including possible identifications of the neurosecretory glands, the X-Organ and sinus gland.

References Cited

Anderson, William W. and Milton J. Lindner 1945. A provisional key to the shrimps of the Family Penaeidae with especial reference to American forms. *Trans. Amer. Fish. Soc.*, 73: 284-319.

Berkeley, A. A. 1928. The musculature of *Pandalus danae* Stimpson. *Trans. Roy. Canad. Inst.*, 16: 181-321.

Bernhards, H. 1916. Der Bau des Komplexauges von *Astacus fluviatilis*. *Zeitschr. Wiss. Zool.*, 116: 649-707.

Calman, W. T. 1909. Appendiculata, Part VII, Crustacea, Third Fascicle. In *A Treatise on Zoology*, ed. by Sir Ray Lankester. Adam and Charles Black, London, pp. 1-346.

Cochran, Doris M. 1935. The skeletal musculature of the blue crab, *Callinectes sapidus* Rathbun. *Smithson. Misc. Coll.*, 92 (9): 1-76.

Grobben, K. 1917. Der Schalenschliessmuskel der dekapoden Crustaceen, zugleich ein Beitrag zur Kenntnis ihre Kopfmuskulatur. *Sitzungsb. Kais. Akad. Wiss., Wien*, Abt. 1, 126: 473-494.

Hanström, B. 1948. The brain, the sense organs, and the incretory organs of the head in the Crustacea Malacostraca. *Bull. Biol. de France et de Belge.*, 33: 98-126.

Huxley, T. H. 1906. *The Crayfish.* 7th ed., Kegan Paul, Trench, Trubner & Co., Ltd., London, pp. 1-371.

Keim, W. 1915. Das Nervensystem von *Astacus fluviatilis* (*Potamobius astacus* L.). *Zeitschr. Wiss. Zool.*, 113: 485-545.

Knowles, F. G. W. 1953. Endocrine activity in the crustacean nervous system. *Proc. Roy. Soc., B*, 141: 248-267.

Passano, L. M. 1953. Neurosecretory control of molting in crabs by the X-organ sinus gland complex. *Physiol. Comp. et Oecol.*, 3: 155-189.

Perkins, E. B. 1928. Color changes in crustaceans, especially in *Palaemonetes*. *Jour. Exp. Zool.*, 50: 71-105.

Ramadan, M. M. 1952. Contribution to our knowledge of the structure of the compound eyes of Decapoda Crustacea. *Acta Univ. Lund.*, (N.S.) 48: 1-20.

Schmidt, W. 1915. Die Muskulatur von *Astacus fluviatilis* (*Potamobius astacus* L.). *Zeitschr. Wiss. Zool.*, 113: 165-251.

Snodgrass, R. E. 1935. *Principles of Insect Morphology.* McGraw-Hill Book Company, New York, pp. 1-667.

---------- 1951. *Comparative Studies on the Head of Mandibulate Arthropods.* Comstock Publishing Co., Inc., Ithaca, New York, pp. 1-343.

Voss, Gilbert L. 1955. A key to the commercial & potentially commercial shrimp of the family Penaeidae of the western North Atlantic & the Gulf of Mexico. *Mar. Lab. Univ. Miami, Tech. Ser.*, No. 14: 1-23.

Welsh, John H. 1941. The sinus glands and the 24-hour cycles of retinal pigment migration in the crayfish. *Jour. Exp. Zool.*, 86: 35-49.

TULANE STUDIES IN ZOOLOGY
VOLUME 3

INDEX TO AUTHORS AND SCIENTIFIC NAMES

(New species and genera in boldface)