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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         | <i>Fundulus olivaceus</i> |    |    |     |      |                 |
|---------------------|---------------------------|----|----|-----|------|-----------------|
|                     | Number of Dorsal Rays     |    |    | M   |      |                 |
|                     | 9                         | 10 | 11 | N   | s    | 2s <sub>M</sub> |
| Mo. R., Mo.         | —                         | 7  | —  | 7   | 10.0 | —               |
| Southern Ill.       | 6                         | 23 | 2  | 31  | 9.9  | .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  | .45  | .18             |
| Eastern La.         | 7                         | 20 | 2  | 29  | .54  | .20             |
| Total Miss. Valley  | 18                        | 78 | 8  | 104 | 9.9  | .10             |
| Biloxi R., Miss.    | 6                         | 6  | —  | 12  | 9.5  | .30             |
| Ala. R.             | 34                        | 4  | —  | 38  | 9.1  | .10             |
| Pensacola Bay Dr.   | 14                        | 6  | —  | 20  | .47  | .21             |
| Choctawhatchee R.   | 7                         | 3  | —  | 10  | 9.3  | .31             |
| Chattahoochee R.    | 2                         | —  | —  | 2   | 9.0  | —               |
| Total Ala. and Fla. | 57                        | 13 | —  | 70  | 9.2  | .09             |
| Populations         | <i>Fundulus notatus</i>   |    |    |     |      |                 |
|                     | Number of Dorsal Rays     |    |    | M   |      |                 |
|                     | 8                         | 9  | 10 | 11  | 12   | 2s <sub>M</sub> |
| Northern Ill.       | 2                         | 44 | 16 | —   | 62   | .13             |
| Marion Co., Ill.    | —                         | 5  | 3  | —   | 8    | —               |
| Meramec R., Mo.     | —                         | 2  | —  | —   | 2    | —               |
| Western Tenn.       | —                         | 8  | 1  | —   | 9    | —               |
| Tombigbee R., Ala.  | —                         | 3  | 1  | —   | 4    | —               |
| Total               | 2                         | 62 | 21 | —   | 85   | .10             |
| Galveston Bay Dr.   | 1                         | 1  | 8  | 7   | 1    | .47             |
|                     |                           |    |    |     | 18   | 1.03            |
|                     |                           |    |    |     | 10.3 | .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 procurent 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         | <i>Fundulus olivaceus</i> |    |    |     |      |      |
|---------------------|---------------------------|----|----|-----|------|------|
|                     | Number of Anal Rays       |    |    |     |      |      |
|                     | 11                        | 12 | 13 | N   | M    | s    |
| Mo. R., Mo.         | —                         | 5  | 2  | 7   | 12.3 | —    |
| Southern Ill.       | 9                         | 17 | 5  | 31  | 11.9 | .67  |
| 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  |
| Eastern La.         | —                         | 23 | 6  | 29  | 12.2 | .41  |
| Total Miss. Valley  | 11                        | 69 | 24 | 104 | 12.1 | .57  |
| Biloxi R., Miss.    | 3                         | 7  | 2  | 12  | 11.9 | .67  |
| Ala. R.             | 21                        | 17 | —  | 38  | 11.5 | .50  |
| Pensacola Bay Dr.   | 8                         | 12 | —  | 20  | 11.6 | .50  |
| Choctawhatchee R.   | 7                         | 3  | —  | 10  | 11.3 | .48  |
| Chattahoochee R.    | 1                         | 1  | —  | 2   | 11.5 | —    |
| Total Fla. and Ala. | 37                        | 33 | —  | 70  | 11.5 | .63  |
|                     |                           |    |    |     |      | .15  |
| Populations         | <i>Fundulus notatus</i>   |    |    |     |      |      |
|                     | Number of Anal Rays       |    |    |     |      |      |
|                     | 11                        | 12 | 13 | 14  | N    | s    |
| Northern Ill.       | 7                         | 51 | 4  | —   | 62   | 11.9 |
| 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 |
| Galveston Bay Dr.   | —                         | 3  | 15 | 1   | 19   | 12.9 |
|                     |                           |    |    |     |      | .46  |
|                     |                           |    |    |     |      | .10  |
|                     |                           |    |    |     |      | .21  |

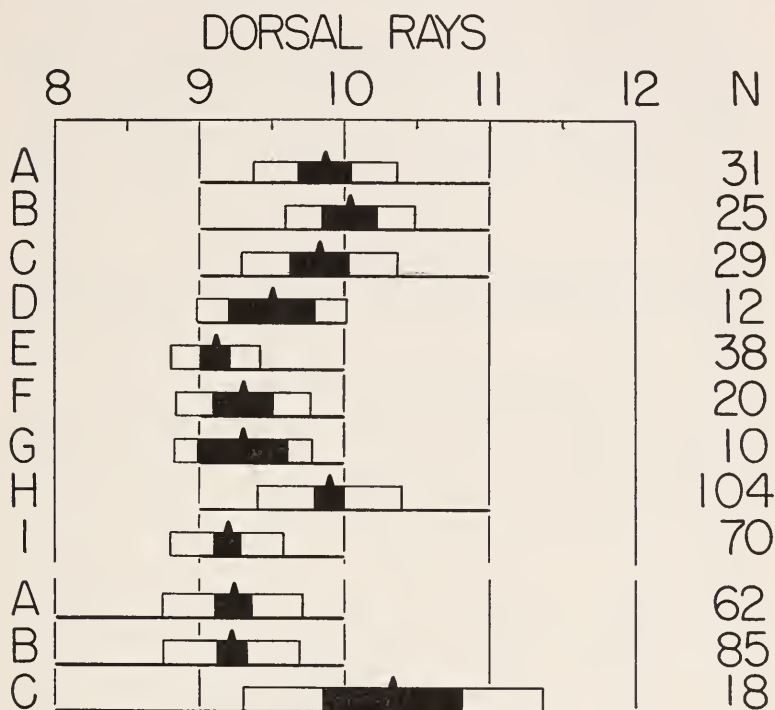


Figure 1. Dorsal ray counts. *Fundulus olivaceus*: A. Southern Illinois; B. Arkansas River, Ark.; C. Eastern Louisiana; D. Biloxi River, Miss.; E. Alabama River; F. Pensacola Bay drainage; G. Choctawhatchee River; H. Total Mississippi Valley and Louisiana; I. Total Alabama River to Chattahoochee River. *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        | Number of Lateral-Line Scales |    |    |    |    |     |      | <i>Fundulus olivaceus</i> |                 |  |  |
|--------------------|-------------------------------|----|----|----|----|-----|------|---------------------------|-----------------|--|--|
|                    | 32                            | 33 | 34 | 35 | 36 | N   | M    | s                         | 2s <sub>M</sub> |  |  |
| 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        | Number of Lateral-Line Scales |    |    |    |    |    |      | <i>Fundulus notatus</i> |                 |  |  |
|--------------------|-------------------------------|----|----|----|----|----|------|-------------------------|-----------------|--|--|
|                    | 32                            | 33 | 34 | 35 | 36 | N  | M    | s                       | 2s <sub>M</sub> |  |  |
| 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  $1\frac{1}{2}$  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

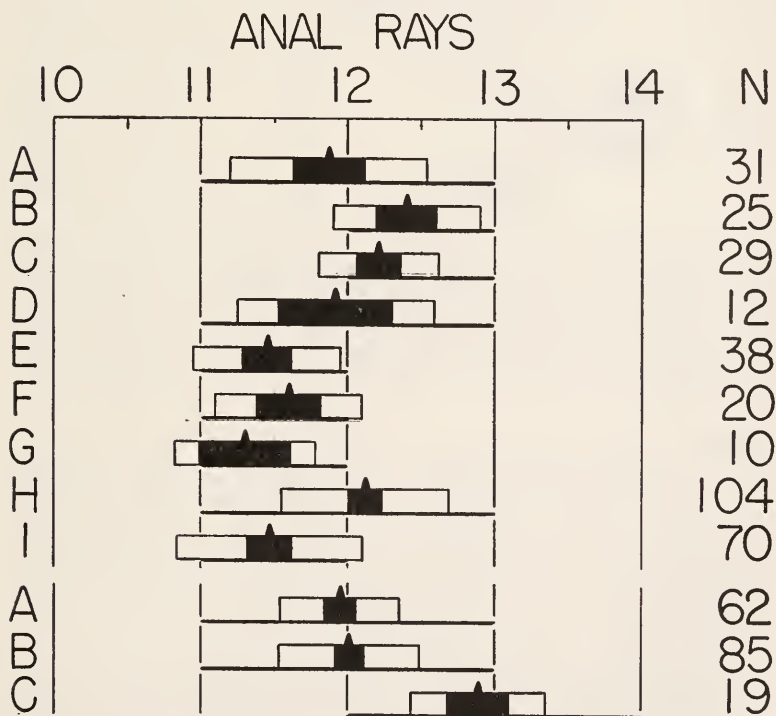


Figure 2. Anal ray counts. *Fundulus olivaceus*—A.-I. same as fig. 1. *Fundulus notatus*—A.-C. same as fig. 1.

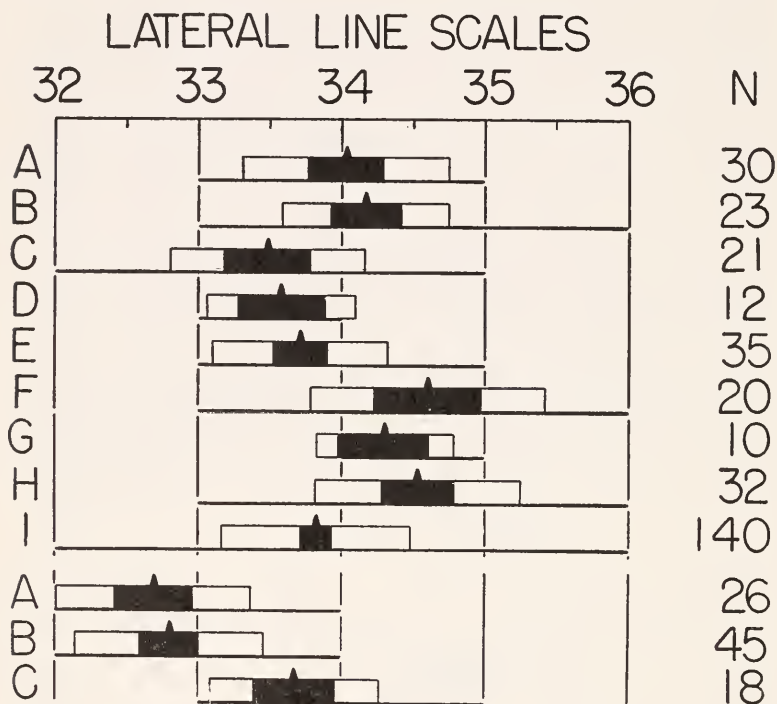


Figure 3. Lateral line scale counts. *Fundulus olivaceus*—A. Southern Illinois; B. Arkansas River, Ark.; C. Eastern Louisiana; D. Biloxi River, Miss.; E. Alabama River; F. Pensacola Bay drainage; G. Choctawhatchee River; H. Total Pensacola Bay to Chattahoochee River; I. Total Mississippi Valley and East 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        | <i>Fundulus olivaceus</i>        |    |    |    |    |    |      |      |      |      |   | N | M | s | 25 <sub>M</sub> |
|--------------------|----------------------------------|----|----|----|----|----|------|------|------|------|---|---|---|---|-----------------|
|                    | Number of Caudal Peduncle Scales |    |    |    |    |    |      |      |      |      |   |   |   |   |                 |
|                    | 14                               | 15 | 16 | 17 | 18 | 19 | 20   |      |      |      |   |   |   |   |                 |
| 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        | <i>Fundulus notatus</i>          |    |    |    |    |    |      |      |      |      |   | N | M | s | 25 <sub>M</sub> |
|                    | Number of Caudal Peduncle Scales |    |    |    |    |    |      |      |      |      |   |   |   |   |                 |
|                    | 16                               | 17 | 18 | 19 | 20 |    |      |      |      |      |   |   |   |   |                 |
| Northern Ill.      | 4                                | 14 | 7  | 0  | 1  | 26 | 17.2 | —    | —    | —    | — | — | — | — | .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             |

## SCALES AROUND CAUDAL PEDUNCLE

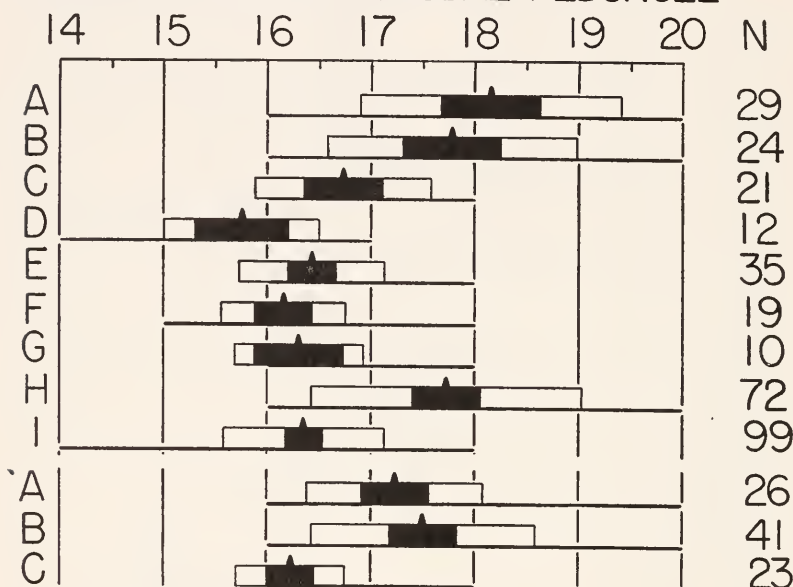


Figure 4. Scales around caudal peduncle. *Fundulus olivaceus*—A. Southern Illinois; B. Arkansas River, Ark.; C. Eastern Louisiana; D. Biloxi River, Miss.; E. Alabama River; F. Pensacola Bay drainage; G. Choctawhatchee River; H. Total Mississippi Valley; I. Total Gulf Coast. *Fundulus notatus*—A. Northern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

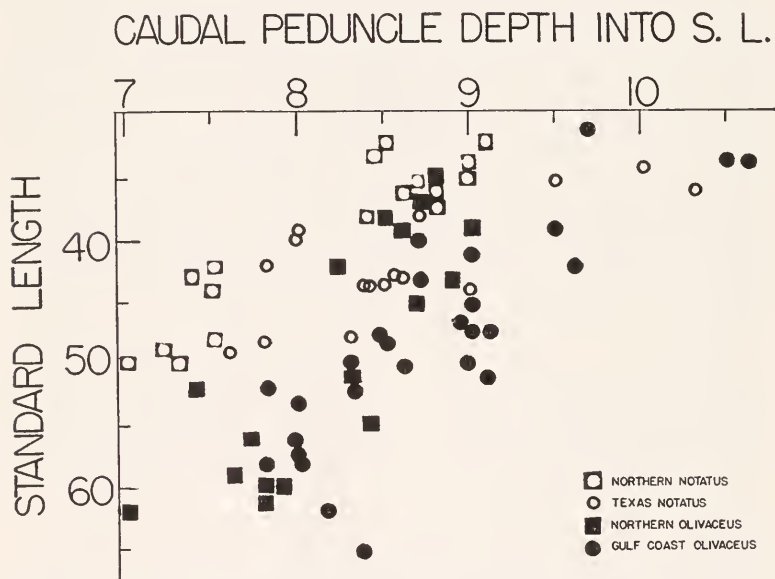


Figure 5. Caudal peduncle depth in relation to standard length in males of northern and southern populations of *Fundulus notatus* and *Fundulus olivaceus*.

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                                                      | <i>olivaceus</i>                                                                | <i>notatus</i>                                                                  |
|----------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| 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 north-eastern 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

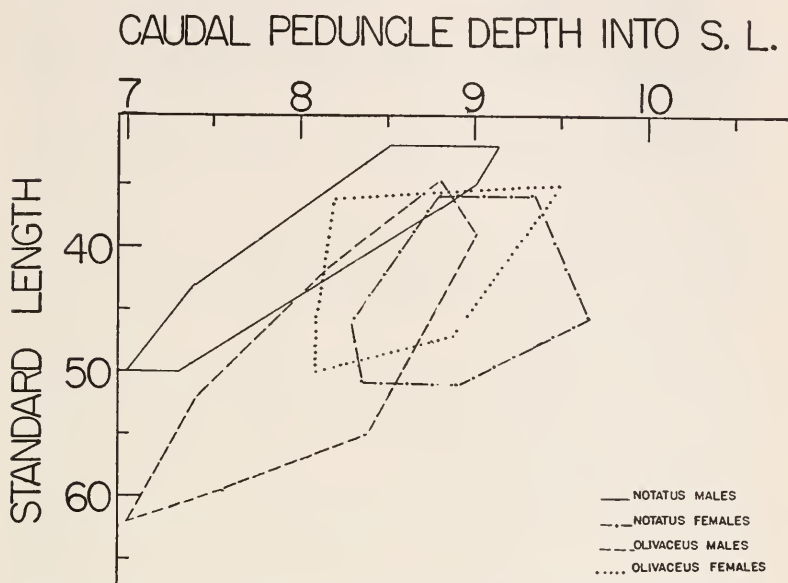


Figure 6. Sexual dimorphism of caudal peduncle depth in relation to standard length in Illinois and Missouri populations of *Fundulus notatus* and *Fundulus olivaceus*. Number of specimens: *F. notatus* ( $\delta = 17$ ,  $\phi = 10$ ), *F. olivaceus* ( $\delta = 17$ ,  $\phi = 21$ ). The polygons encompass 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.

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