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## THE BIOLOGY AND SYSTEMATICS OF THE PINFISH, *LAGODON RHOMBOIDES* (LINNAEUS)


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# THE BIOLOGY AND SYSTEMATICS OF THE PINFISH, *LAGODON RHOMBOIDES* (LINNAEUS)

DAVID K. CALDWELL[1]

## TABLE OF CONTENTS



[1]The work reported on here was submitted to the Graduate School, University of Florida, in partial fulfillment of the requirements for the Doctor of Philosophy. The author, who has two other papers appearing in this volume of the BULLETIN, is now associated with the U.S. Fish and Wildlife Service, Brunswick, Georgia. Manuscript received 25 May 1957.—ED.

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Aside from the above, I have tried to give credit for particular aid at the appropriate place within the body of the text. However, the names of many have been omitted completely. To these people I offer my apologies and sincere thanks, for without them this study could not have been completed.

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## Introduction

The range of the pinfish, *Lagodon rhomboides* (Linnaeus), extends in the shallow littoral waters of the Atlantic from Cape Cod, Massachusetts, to Yucatan, Mexico. It is also found in Bermuda. The pinfish is apparently the most common member of the family Sparidae in the waters of the southeastern United States; and in vegetated, inshore, open marine habitats in this part of its range it is also probably the most frequently encountered of any nonpelagic fish species. In spite of this, and as is often the case with ultracommon organisms, there have been only a few papers furnishing more than random notes on its biology. These data have been included in more general works by Hildebrand and Cable (1938), Reid (1954, 1956), Kilby (1955), Gunter (1945), Hildebrand and Schroeder (1928), Smith (1907), Jordan and Evermann (1898), Holbrook (1860), and Eigenmann and Hughes (1888).

Since no detailed study of the pinfish had been undertaken that encompassed the many interrelationships found when all aspects of the biology of that organism were examined as a unit, it was felt that such a study, involving one of the most abundant and widespread of western North Atlantic shore fishes, and one which through sheer numbers must be a particularly important factor in the total ecology of an area, would thus not only be a marked contribution to the biology of that species, but would serve also as a pattern for similar studies on other organisms.

The advantages of attempting to cover in a single study many facets of the biology of an organism have become apparent in exploring the biology of this species. The various facets are quite intertwined, and a knowledge of each is thus important for a truly clear and meaningful understanding of the others. Therefore, an effort should be made to consider as many as possible of them simultaneously, rather than concentrating on one aspect alone. Actually these facets are so inseparably involved that to separate one from the other, though often attempted, is really impractical, often even impossible.

Although I have made an effort to touch on several of the major phases of the biology of the pinfish, many problems remain incomplete, or even unbegun. It is hoped, therefore, that this study will serve as a summary of the known biology of this interesting species, and that it can act as a point of departure for future workers. More important, however, I hope that it will act as a stimulus to others to do similar comprehensive studies of the biology of other organisms—not only fish. In this way the interrelationships or total ecology of all organisms will become more obvious and the structure of our environment more meaningful.

Although during this study an attempt was made to examine all the literature which referred to the pinfish, I have not attempted to include all such papers in the form of an annotated synonymy. Actually, however, most of these papers have been cited in this paper.

Unless otherwise stated, for the purposes of this paper the common name "pinfish" should be considered synonymous with *Lagodon rhomboides*.

## METHODS

Pinfish were collected by almost every available means at some time during this study. However, the common methods of procuring them were by seine, trawl, and hook and line. The collections at Cedar Key were made mostly with a small (15-foot mouth) otter trawl, made of 1-inch-stretched mesh, operated at a speed of approximately 3 miles per hour from a small inboard motor boat. The net was dragged from 75 to 100 feet behind the boat, depending on the depth, and was on the bottom for five minutes on the flats and channel edge, and for ten minutes in the channels. A 10- or 25-foot bag seine with ½-inch-stretched mesh was used at the protected flat station during the summer months, and a 4-foot common sense minnow seine with a marquisette inner liner was used at the two beach stations. Hook-and-line, using a small hook, was used for obtaining many of the large pinfish. In other regions, collecting was done primarily with seines and hook-and-line, although traps and rotenone were sometimes used. All of the offshore collections, with the exception of one collection made at the surface with a cast net, were made with large commercial shrimp trawls with various large-sized meshes drawn by large vessels at slow speeds. Half-meter plankton nets were tried at the surface at Cedar Key without success, though this method has produced larval pinfish elsewhere. It should be noted that postlarvae of species other than pinfish, and smaller than the minimum size of that species taken at Cedar Key, were caught there with the gear used. These fish became entangled in vegetation and detritus, and it can be assumed that small pinfish, if present, would have been taken.

Most of the fish were preserved in the field by dropping them alive into a 10 percent solution of formaldehyde and the majority of these are deposited in the University of Florida Collections.

Water samples were brought into the laboratory and salinities were calculated from density data obtained through the use of a hydrometer. Water temperatures are surface temperatures taken with the thermometer held about 10 inches below the surface.

McBee Keysort Cards were used to record field data. Data so recorded was then coded and punched into the cards, thus permitting their rapid recovery by mechanical means. Annotated bibliographic citations were treated in the same manner.

Unless otherwise stated, all lengths are standard length, which was considered as being the uncurved length as measured with dividers from the tip of the snout—with the mouth firmly closed—to the base of the middle rays of the caudal fin (end of hypural plate). Head length was taken in the same manner, from the tip of the snout to the greatest posterior extension of the opercle. Body depth was the vertical distance taken with dividers from the insertion of the pelvic fins to the base of the dorsal fin. Other proportional measurements, also made with dividers, are described in table 6.

Pored lateral-line scales, unless damaged, were counted on the left side from the origin of the lateral line near the upper angle of the opercle to the fold made at the end of the hypural plate when the tail is bent upwards. Scales above the lateral line were counted in an anteriorly directed oblique line to the origin of the dorsal fin, and those below, in a posteriorly directed oblique line to the origin of the anal fin.

All gill rakers, including rudiments, were counted on the first right gill arch. The raker at the angle of the arch was considered as belonging to the lower limb.

Each dorsal and anal fin spine or soft-ray base was counted as one. In instances where two or more branched from a common base—as is always the case in the last elements of these fins—they were counted as one. Pectoral fin ray counts include unsegmented rays; caudal fin counts include only branched rays. In the pelvic fins, spines and segmented soft-rays were counted separately.

## Material Examined

The sources of specimens examined, the abbreviation for the collections, and the persons to whom I am grateful for permitting me to examine the materials are: United States National Museum (USNM), through Leonard P. Schultz; University of Michigan, Museum of Zoology (UMMZ), through Reeve M. Bailey; University of Florida Collections (UF); Tulane University, Department of Zoology (TU), through Royal D. Suttkus; Chicago Natural History Museum (CNHM), through Loren P. Woods; Florida State University, Department of Zoology (FSU), through Ralph W. Yerger; Academy of Natural Sciences of Philadelphia (ANSP), through James Böhlke; Charleston Museum (CM), through E. Milby Burton and Albert Schwartz; American Museum of Natural History (AMNH), through Francesca LaMonte; University of Georgia, Department of Zoology (UG), through Donald Scott; University of Miami, Department of Zoology (UM), through Luis R. Rivas; Institut Royal des

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In addition to these, I am also indebted to the following persons who examined other collections for me and found that there were either no pinfish or that the specimens in the collection only duplicated large series already studied from the same locality. They, and the collections they examined, are: Margaret Storey (Stanford University Natural History Museum), William Schroeder (Museum of Comparative Zoology at Harvard), Walter Auffenberg (Carnegie Museum), and Donald deSylva (Cornell University).

Specimens which I collected during this study from numerous localities in Florida are now in the University of Florida Collections. Those used in the study of geographical variation are catalogued and are included in the following list of materials examined. Most of those not used in the geographical study are deposited uncatalogued in the Collections.

MASSACHUSETTS: Woods Hole, 1 (UMMZ 65109), 1 (USNM 24483), 1 (USNM 58927), 1 (AMNH 2239), 1 (USNM 31528), 1 (USNM 83507); Hadley Harbor, 1 (USNM 58890).

RHODE ISLAND: Newport, 1 (USNM 25721); Sakonette Point, 1 (USNM 41011).

NEW YORK: Fire Island Beach, 1 (USNM 36002); Massapeque, (USNM 108658).

NEW JERSEY: Sea Bright, 1 (CNHM 1642); Beesley's Point, 2 (USNM 45134); off Cape May, 1 (ANSP 69130, holotype of *Salema atkinsoni* Fowler).

VIRGINIA: Norfolk, 1 (USNM 143990); Fort Monroe, 3 (USNM 143894); Cape Charles, 1 (USNM 42487), 1 (USNM 42489), 1 (USNM 43157), 2 (USNM 143992).

NORTH CAROLINA: Cape Lookout, 3 (USNM 155377), 1 (USNM 134269); Beaufort, 1 (USNM 51870), 1 (USNM 118916), 3 (USNM 61461), 1 (USNM 116696), 5 (USNM 64004), 4 (CNHM 40344); mouth of Cape Fear River, 1 (USNM 25594); Fort Macon, 1 (USNM 132298), 13 (USNM 19686); Onslow Beach, 1 (UM 324); off North Carolina, 3 (USNM 163702).

SOUTH CAROLINA: Magnolia Beach, 2 (CM 34.239.31); Pawley's Island, 2 (UMMZ 136065); Porcher's Bluff, 1 (CM 31.196.13); Caper's Inlet, 3 (CM 31.207.14); Charleston, 1 (CNHM 37949), 1 (USNM 25415), 1 (USNM 24685), 1 (USNM 25597), 1 (USNM 155378), 1 (USNM 25623); off Stone Inlet, 1 (CM 31.190.12).

GEORGIA: Brunswick, 2 (USNM 118149), 3 (USNM 127460), 10 (UF 5534).

FLORIDA: St. Johns River near Orange Park, 3 (UF 7669); St. Johns River, 1 (USNM 154780), 2 (USNM 21280); Vilano Beach, 6 (UF 3311); St. Augustine, 2 (UF 3020), 1 (UMMZ 136490); Matanzas River near Matanzas Inlet, 3 (UMMZ 139401); Ponce de Leon Inlet, 6 (USNM 133293); New Smyrna, 1 (USNM 65348), 1 (USNM 53336); Edgewater, 3 (UM 970); Mosquito Lagoon, 3 (UMMZ 139381); Indian River near Melbourne, 2 (UMMZ 139356); Vero Beach, 10 (UF 7823), 1 (UF 1300); Ft. Pierce, 2 (UF 7815); Jensen Beach, 6 (UF 4276); Miami, 15 (USNM 53368), 1 (USNM 57232), 4 (UM 328); off Cape Florida, 1 (AMNH 15229); Cutler, 1 (UM 325); Biscayne Bay, 20 miles south of Homestead, 2 (UF 5008); Broad Creek, 1 (USNM 57264); Tavernier Creek, 1 (USNM 57219); Tavernier, 1 (UF 7819), 7 (UF 7817), 7 (UM 331); Blackwater Bay, 1 (USNM 104972); Upper Matecumbe Key, 2 (UF 7820); Snake Creek near Islamorada, 4 (UMMZ 136568); Bahia Honda, 1 (USNM 57297), 1 (UM 326); Big Pine Key, 1 (UF 7026); Summerland Keys, 1 (USNM 57163); Big Coppitt Key, 10 (UF 7818); Key West, 1 (UF 7821), 6 (USNM 38671), 2 (USNM 143979), 1 (USNM 130826), 1 (AMNH 2628), 2 (USNM 93854), 1 (USNM 65387), 1 (USNM 132227); Tortugas, 3 (UMMZ 147721), 2 (UMMZ 147682), 2 (UG 196), 1 (CNHM 6915), 4 (USNM 117286), 1 (USNM 117285), 1 (USNM 88101); 15–20 miles off Tortugas, 1 (IRSNB 10.911, holotype of *Lagodon mercatoris* Delsman); Sawyers Key, 1 (USNM 57373); Knights Key, 5 (USNM 62746), 5 (USNM 62601); Florida Keys, 1 (USNM 57376); Flamingo, 1 (uncataloged, sent to IRSNB for deposit); off Cape Sable, 1 (USNM 39879); between Whitewater and Oyster Bays, 1 (UM 971); Bonita Beach, 8 (UF 3412); Pine Island Sound, 1 (TU 7637); Captiva Pass, 1 (CNHM 541), 1 (CNHM 542), 1 (CNHM 573); Placida, 10 (UF 7812); Pass-a-Grille Beach, 1 (UMMZ 154890), 1 (UMMZ 154092), 3 (UMMZ 154939), 1 (UMMZ 153776); Clearwater, 1 (UF 1445); Bayport, 3 (UF 2528), 6 (UF 2525); Cedar Key, 3 (UF 7813), 7 (UF 7814), 6 (UF 2531); Alligator Harbor, 4 (FSU 625), 6 (FSU 775), 1 (FSU 408); Apalachicola, 4 (UM 973); off Cape San Blas, 1 (UM 972); latitude 28° 56′ N., longitude 85° 18′ W., 29 (UF 7817); Panama City, 1 (UF 5421), 5 (UF 5378); Destin, 1 (UF 4430); Santa Rosa Sound at Camp Navarre, 3 (UMMZ 135907), 2 (UMMZ 135914); Pensacola, 3 (UMMZ 136518), 3 (UF 1787), 22 (TU 6394).

ALABAMA: Latitude 29° 33′ N., longitude 87° 58′ W., 7 (TU 12751); latitude 29° 56′ N., longitude 88° 29′ W., 7 (TU 2738); Gulf Shores State Park, 2 (UMMZ 123990).

MISSISSIPPI: Latitude 29° 15′ N., longitude 88° 48′ W., 1 (CNHM 46531); Ocean Springs, 3 (TU 1940).

LOUISIANA: Lake Pontchartrain, 10 (TU 6412); Chandeleur Sound off Mitchill Key, 7 (TU 8287); Southwest Pass outside of Vermillion Bay, 1 (TU 8400).

TEXAS: Galveston, 5 (USNM 118563), 1 (USNM 118562), 2 (USNM 31052), 1 (USNM 143828), 1 (USNM 46285), 1 (UMMZ 164992), 1 (UF 7801); Rio Brazos, 1 (UMMZ 160243); Matagorda Bay, 3 (USNM 63656); off St. Joseph Island, 1 (UF 7808); east of Port Aransas jetty, 1 (UF 7806); Aransas Pass at Port Aransas, 17 (UF 7810); southeast of Port Aransas, 1 (UF 7807); within 50 miles of Corpus Christi, 1 (CNHM 40238); Brazos, 3 (USNM 731); latitude 26° 10′ N., longitude 96° 54′ W., 1 (UF 7804); latitude 26° 10′ N., longitude 96° 25′ W., 1 (UF 7816).

MEXICO: Punta Piedras in Laguna Madre, 11 (UF 7809); 100 miles south of Port Isabel, Texas, 4 (UF 7805); latitude 24° 12′ N., longitude 97° 17′ W., 1 (CNHM 45514); 35 miles north of Tampico, 2 (UMMZ 157327); off Point Morros, Yucatan, 1 (UF 1285); latitude 19° 48′ N., longitude 91° 20′ W., 1 (CNHM 46532); off Campeche, Yucatan, 1 (UF 7803), 10 (CNHM 46530), 2 (UF 7802); latitude 20° 18′ N., longitude 91° 48′ W., 4 (CNHM 45515); latitude 21° 09′ N., longitude 91° 41′ W., 2 (UF 7811).

BERMUDA: Flatts Inlet, 4 (CNHM 48728); no other data, 4 (USNM 21359).

[?]CUBA: no other data, 1 (USNM 9838).

"BAHAMAS?": no other data, 7 (USNM 6108).

## SYSTEMATICS

The systematic status of *Lagodon rhomboides* may be summarized as follows:

Genus *Lagodon* Holbrook

*Lagodon* HOLBROOK, 1855, p. 56 (type species *Sparus rhomboides* Linnaeus, 1766, by subsequent designation of Eigenmann and Hughes, 1888, p. 66).

The characters which serve to distinguish the genus *Lagodon* from the other members of the family Sparidae are briefly stated as follows: The mouth has a single row of incisor teeth which are triangular in anterior aspect above their base; those in the anterior part of the mouth almost always have a single notch (fig. 19), the posterior ones are with or without the notch. Several series of rounded molariform teeth lie behind the incisors. Occipital and temporal crests of the skull are nowhere coalescent; the interorbital area is not swollen, its bones are thin and concave in transverse section.

More detailed characteristics of the genus may be found by referring to Holbrook (1855:56), Eigenmann and Hughes (1888:66), Jordan and Fesler (1893:518), Jordan and Evermann (1898:1357), and Fowler (1940:2).

With the exceptions noted below in the synonymy of *Lagodon rhomboides,* most authors have agreed that the genus *Lagodon* is monotypic. However, it is of interest to present the following quotation from Holbrook (1860:63) who, in completing his description of *Lagodon rhomboides,* states: "I have, therefore, established for it [*rhomboides*] the genus Lagodon to which must also be referred the *Sargus unimaculatus* of Cuvier and Valenciennes." Holbrook gives no explanation for this action; subsequent authors have apparently ignored the statement, and investigations since his writing have shown the species *unimaculatus* of Bloch [=*rhomboidalis* of Linnaeus] to be allied more closely with the genus *Archosargus* Gill than *Lagodon* (see Eigenmann and Hughes, 1888:66), though some authors (Jordan and Evermann, 1896a:390; Jordan, Evermann, and Clark, 1930:338; and Fowler, 1940:3) place it in a third genus, *Salema* Jordan and Evermann, all in the family Sparidae. In no instance have I found another author who considered this species to be a member of the genus *Lagodon.*

## *Lagodon rhomboides* (Linnaeus)

*Sparus rhomboides* LINNAEUS, 1766, p. 470 (Charleston, South Carolina). Shaw, 1803, p. 447.

*Sargus rhomboides* (Linnaeus). VALENCIENNES, *in* Cuvier and Valenciennes, 1830, p. 68, pl. 143 (New York, Carolinas, New Orleans). DEKAY, 1842, p. 93 (New York). STORER, 1846, p. 81. GUENTHER, 1859, p. 447.

*Lagodon rhomboides* (Linnaeus). HOLBROOK, 1855, p. 56, pl. 8, fig. 1 (South Carolina) [pagination copied from Gill, 1864, p. 93]. EIGENMANN AND HUGHES, 1888, p. 66. JORDAN AND EVERMANN, 1898, p. 1358; 1900, fig. 552. JORDAN, EVERMANN, AND CLARK, 1930, p. 337. FOWLER, 1945, pp. 148, 204, 308.

*Diplodus rhomboides* (Linnaeus). JORDAN AND GILBERT, 1882, p. 558.

*Lagodon rhomboidalis* (Linnaeus). GOODE AND BEAN, 1886, p. 194 (*non* Linnaeus).

*Salema atkinsoni* FOWLER, 1940, p. 2, figs. 1-4 (off New Jersey).

*Lagodon mercatoris* DELSMAN, 1941, p. 70, fig. 9 (off Tortugas, Florida).

Since *Salema atkinsoni* Fowler and *Lagodon mercatoris* Delsman have apparently never previously been considered synonyms of *Lagodon rhomboides,* and since the use of the specific name *rhomboides,* as opposed to the older and possibly applicable Linnean name *rhomboidalis,* has not been clarified, though followed, I present my reasons for these actions below.

Goode and Bean (1886:194, 201), after examining and verifying Linnaeus' (1766:470) type specimen (a half skin collected by Alexander Garden, at Charleston, South Carolina, and located in the Linnaean Society of London) as the form presently recognized as *Lagodon rhomboides,* concluded that since the Linnaean synonyms for *Perca rhomboidalis* Linnaeus (1758:293) were the same as those he later gave for *Sparus rhomboides* Linnaeus (1766:470), the two names should be synonymous, and the correct name for the pinfish should thus be *Lagodon rhomboidalis* (Linnaeus), the older name having priority. The two sparids, *Lagodon rhomboides* and *Archosargus rhomboidalis* [=*A. unimaculatus* (Bloch)], as now recognized, are very similar in general appearance; however, since Linnaeus (1758:294) listed the habitat of "*rhomboidalis*" as "America," and since he apparently based his description only on the works of Catesby (presumably 1754:4) and Browne (1756:446) rather than on actual specimens, and since his description can be applied to either species—but to no other sparid—it cannot be said with certainty that he was describing *L. rhomboides,* as Goode and Bean (1886:194, 201) believed. Though Catesby's plate (t. 4—top) shows the interorbital area to be elevated and swollen as in *A. rhomboidalis,* and though Edwards (in the 1771 edition of Catesby) used *Sparus rhomboides* in applying

Linnaean names to Catesby's fishes, it is now apparent, based on the present knowledge of the ranges of the two species, that the fish referred to by Catesby may be either species, since both occur on the mainland coast of Atlantic North America. Neither species is known from the Bahamas. Shaw (1803:447) also expressed doubt as to the true identity of Catesby's species. Jordan (1885b:191) suggested that Catesby's fish was in reality the form presently known as *Anisotremus virginicus* (Linnaeus). Jordan based his assumption on the fact that the present common name of this haemulid, "porkfish," was used by Catesby for his fish also, and concluded, therefore, that Catesby's form should not be considered in reference to the two sparids discussed above. He also noted, in assigning *A. virginicus* to Catesby's fish, that Browne's species was also apparently misplaced by Linnaeus in establishing the synonymy of *Perca rhomboidalis.* Common names are poor criteria for attempting to establish identities in fishes, and it seems unlikely that even Catesby's poor illustrations would not have included the prominent black bars through the eye and postopercular region so characteristic of *A. virginicus.* Thus Jordan was almost certainly in error in making his assumptions, and in even considering the porkfish in the discussion of the two sparids noted above. Apparently Browne, in Jamaica, was referring only to *A. rhomboidalis*—there is considerable doubt *L. rhomboides* is a member of the Jamaican fauna (see section on geographical distribution). Furthermore, Linnaeus (1766:470) furnishes a more complete diagnosis which permits a reasonably certain identification of his 1766 species as the pinfish, and he also notes that this species was collected by Dr. Garden—thus from South Carolina where the pinfish is common, and almost certainly not *A. rhomboidalis* since this latter species is not regularly found north of Miami, Florida, though Fowler, 1952a:130, reports a specimen from New Jersey. Since this is the first description with which the pinfish surely can be recognized, the name *rhomboides* must be applied to it.

Since Linnaeus' 1758 description of *Perca rhomboidalis* apparently can refer only to the two sparids, *L. rhomboides* and *A. rhomboidalis,* and since one of these, the pinfish, has been assigned the trivial name "*rhomboides*" in the twelfth edition (1766) of Linnaeus (see above), the specific name "*rhomboidalis*" is made available for the other of these two sparids and thus must be applied to the form named "*unimaculata*" by Bloch (1792:75, pl. 308). Thus *Archosargus unimaculatus* (Bloch) must become *A. rhomboidalis* (Linnaeus) [=*Salema rhomboidalis* (Linnaeus) of authors] by the laws of priority. Jordan, Evermann, and Clark (1930:338) and Fowler (1940:3) apparently have arrived at this conclusion previously, but they did not clarify their action.

Through the courtesy of James Böhlke of the Academy of Natural Sciences of Philadelphia, I had the opportunity to study the holotype and only recorded specimen of *Salema atkinsoni* Fowler (ANSP 69130).

Other than the presence of an obvious outer row of incisor like teeth in each jaw posterior to the large, notched, anterior incisors characteristic of the genus, 19 obvious rows of scales from below the lateral line to the spinous anal origin, and minor proportional differences, this specimen falls within the variation expected in *Lagodon rhomboides*. The specimen is much larger (328 mm. in length) than usually reported (up to approximately 150 mm., rarely to 250 mm.) for *L. rhomboides* and the differences mentioned above apparently can be attributed to ontogenetic change. A study of both small and large examples of *L. rhomboides* (up to 239 mm. in length) in the University of Florida Collections and the United States National Museum shows that while the "compressed cuneiform teeth with truncate ends" described and figured by Fowler are not obvious as such in the small pinfish they may be there. They often appear molar like, and develop in varying numbers in the large-sized fish, like the one named by Fowler. They develop immediately posterior to the expanded, anterior, notched incisors characteristic of the genus. Unfortunately only a few pinfish above 180 mm. in length—and none between 239 and 328 mm.—have been available to try to trace this development accurately, though enough material is at hand to show that it does take place. Poey (1866:314) alluded to this form of incisorlike molar tooth in describing the dentition of a specimen which he notes was nine inches long.

The number of scales from below the lateral line to the spinous anal origin is usually given as 17 for *L. rhomboides*. However, this count is difficult to make accurately since the scales in the immediate vicinity of the anal origin are small and crowded. As the length of the fish increases, however, these scales enlarge to a point where an accurate count can be made, and 19 rows of scales may be seen in most of the large specimens of *L. rhomboides*. The other counts and subjective descriptions given by Fowler for *S. atkinsoni* fall well within the range of variation found in *L. rhomboides*. The few proportions which are at variance, particularly the ratio of eye in head, may be attributed to ontogenetic change, and, in fact, this tendency is shown in the smaller specimens of pinfish available to me.

In describing *S. atkinsoni,* Fowler apparently overlooked the possibility that his specimen might be *L. rhomboides*—a fact possibly obscured by the large size of his specimen and the related ontogenetic differences noted above—and he erected a new subgenus *Sphenosargus* of the genus *Salema* Jordan and Evermann [=*Archosargus* Gill] for it. The characters he used to distinguish this new subgenus from the subgenus *Salema,* however, are those that are of primary importance in the separation of *Lagodon* from *Archosargus* (Fowler, 1940:2). In each instance these characters—body shape, tooth structure, number of gill rakers, and lateral-line scales—are like *Lagodon,* and unlike *Archosargus* as exhibited in specimens of *A. rhomboidalis* (L.) and *A. probatocephalus* (Walbaum) examined in the University of Florida Collections. The condition of the interorbital area—a major character in distinguishing *Lagodon* and *Archosargus*—in the holotype of *S. atkinsoni* is not elevated and greatly swollen as in *Archosargus* (Fowler, 1940:1), but is only slightly swollen and unelevated as in *Lagodon.*

Very large specimens of *L. rhomboides* are frequently taken in late spring and early summer in waters adjacent to Long Island, New York. These large pinfish were reported, and a photograph presented, by Alperin (1955). Irwin Alperin, Aquatic Biologist (Marine), with the New York State Conservation Department, writes me that he has caught these large specimens and notes that he is familiar with the species from fishing in Florida. Apparently the fish are generally not distinguished from the common porgy of the area, *Stenotomus chrysops* (Linnaeus), though some fishing captains, especially those who fish in the South during the winter, do distinguish it as the "banded porgy." Alperin kindly has made available definite records of such pinfish which reached 234 mm. standard length (260 mm. fork length) and notes that others have been measured which exceeded 300 mm. fork length. The original negative of the photograph used by Alperin of one of these large pinfish was made available to me through the kindness of the photographer, Warren Rathjen, and it is reproduced in this paper (fig. 1), since the "Conservationist" is not generally accessible to ichthyologists. *S. atkinsoni,* taken off Cape May, New Jersey, in April, is apparently one of these large pinfish. It should be stated, though, that although this northern area apparently has produced more actual records of large *L. rhomboides* than other regions, large individuals are known from elsewhere. Schroeder (1924:28) lists a 13-inch specimen which he collected at

Key West, Florida. There are also specimens in the United States National Museum from Beaufort, North Carolina; in the Chicago Natural History Museum from Captiva Pass (near Fort Myers), Florida; and in the University of Florida Collections from Vero Beach, Florida; all of which exceed 200 mm. in length, and one in the Chicago collection from the vicinity of Corpus Christi, Texas, measures 185 mm.

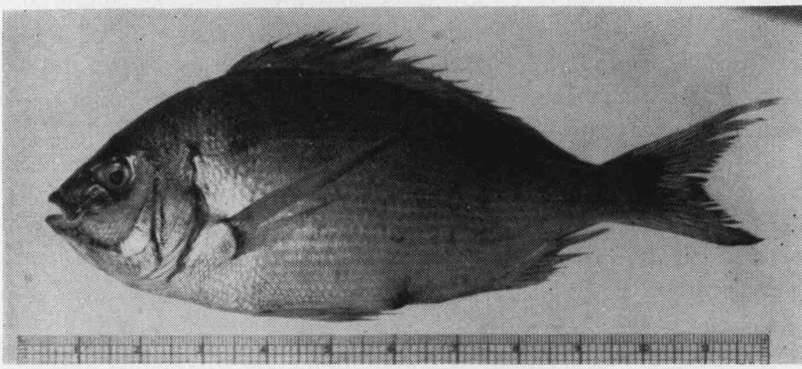


Figure 1.–Large *Lagodon rhomboides* (L.) from Great Peconic Bay, New York.

Based on the evidence presented above, I do not hesitate in placing *Salema atkinsoni* Fowler in the synonymy of *Lagodon rhomboides* (Linnaeus).

The primary basis for the erection of the species *Lagodon mercatoris* by Delsman appears to be a reduced number of dorsal spines, and several proportions using particular dorsal spines or the region of these spines. The holotype of *L. mercatoris* has only nine dorsal spines, while *L. rhomboides* usually has twelve, rarely thirteen.

Through the efforts of Max Poll of the Royal Belgian Congo Museum, the holotype and only specimen of *L. mercatoris* (IRSNB 10.911) was made available to me for study from the Royal Institute of Natural Sciences of Belgium. A comparison of this specimen with *L. rhomboides* of the same size from the vicinity of the type locality of *L. mercatoris*–off Tortugas, Florida–revealed no differences except those involving the size and number of dorsal spines and the appearance of the region of the anterior dorsal spines. Though this region is completely scaled on the holotype of *L. mercatoris,* the scales are in disarray, and close examination suggests the presence of a healed but scarred wound. Furthermore, only nine rows of scales are present above the lateral-line in this anterior region in contrast to the ten rows which are generally found between the lateral-line and the origin of the dorsal fin in *L. rhomboides*. Posterior to this the expected number of scale rows are present between the dorsal fin and the lateral-line. The first row of scales normally below the dorsal fin apparently has been utilized to cover the surface where the dorsal spines are normally borne. X-ray photographs of the holotype of *L. mercatoris* and of a normal *L. rhomboides* show that the normal structural bases and their internal pterygiophores are present for each of the supposed missing spines in *L. mercatoris* (fig. 2).

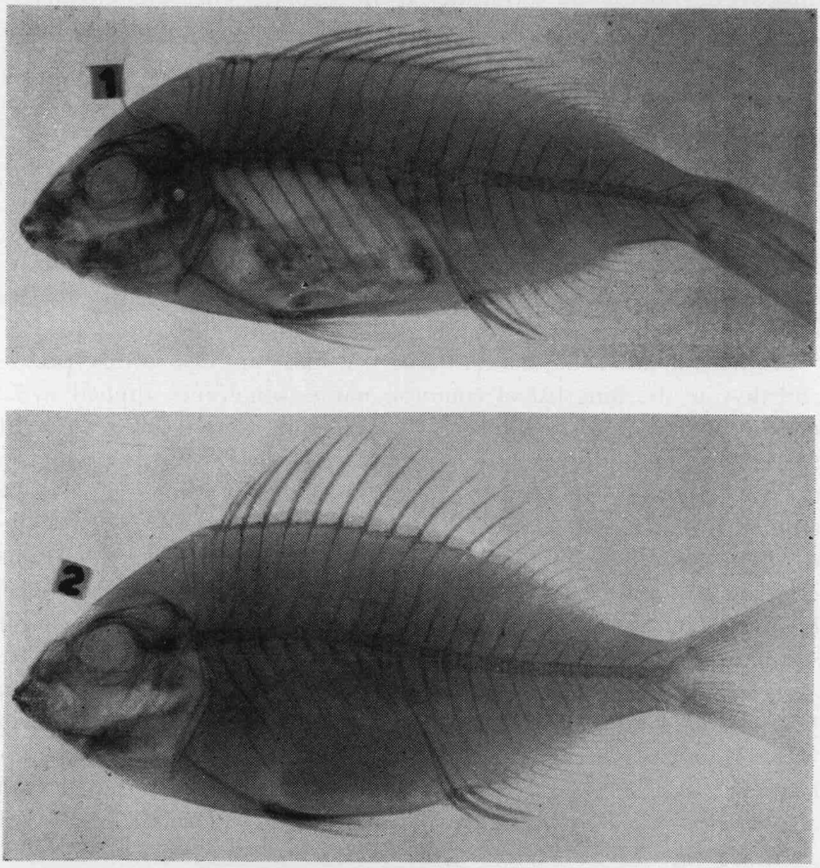



Figure 2.—X-ray photographs of *Lagodon rhomboides* (L.). Above, the holotype of *L. mercatoris* Delsman from off Tortugas, Florida, IRSNB 10.911. Below, a normal specimen from Flamingo, Monroe County, Florida. Original X-ray photograph by Betty J. Bradburn, University of Florida Infirmary; prints by Robert L. Hay, University of Florida College of Medicine. Film exposed at 50 milliamps, 32 kilovolts, at 20 inches, for 1/4 second.

Similar anomalies are occasionally found in *L. rhomboides* from other areas; fin-rays may be missing, and once, the entire caudal fin and peduncle was missing, and yet the area apparently completely healed and is normally scaled. Furthermore, if Delsman's proportions involving various dorsal spines are made so that the fourth dorsal spine of a normal pinfish is used as the first, the fifth as the second, etc., they are found comparable with those presented for *L. mercatoris*. Similarly, the proportion involving the distance between the antrose spine and the second dorsal spine becomes comparable when the fifth spine in *L. rhomboides* is considered the second. The other characters given by Delsman for *L. mercatoris* fall easily within the range of variation for *L. rhomboides*.

I therefore do not hesitate in placing *Lagodon mercatoris* Delsman into the synonymy of *Lagodon rhomboides* (Linnaeus).

## Common Names

Though the American Fisheries Society (1948:369) lists "pinfish" as the approved common name for *Lagodon rhomboides*, this species is known by a large assortment of other common names.

In most areas, a single local name is usually applied to this species, and despite the long list of common names sometimes applied to *L. rhomboides*, the name "pinfish" is used surprisingly often by local fishermen and biologists. In some areas, however, "pinfish" applies to other species. At Cedar Key, Florida, for instance, "pinfish" is applied to the grass porgy, *Calamus arctifrons* Goode and Bean, while *L. rhomboides* is called "shiner." Although there are local variations in usage, in general, *L. rhomboides* is called pinfish, sailor's choice, bream (especially in the Florida Keys), or chopa spina, in the Gulf states, and pinfish or sailor's choice on the Atlantic seaboard. There are certain generalized local variations to this, such as fair-maid in Virginia, salt-water bream in South Carolina, piggy-perch in certain western parts of the Gulf of Mexico, and sargo in some areas, for example, the Florida Keys, where this species is often confused with *Archosargus rhomboidalis*. In Bermuda it is known as pinfish or spanish porgy.

The following is a list of common names known to have been applied to *Lagodon rhomboides*. Most have been gathered from the literature, but since there is so much repetition among authors, I have not attempted to credit names to any one writer. These names are: banded porgy, bastard margaret, bream, brim, canadian bream, chopa, chopa espina, chopa spina, fair-maid, hogfish, perch, pinfish, pin-fish, pigfish, pisswink, porgy, rhomboidal porgy, robin, ronco blanco, ronco prieto, sailor's choice, salt-water bream, sand perch, sargo, scup, sea bream, shiner, shiny scup, spanish porgy, spot, squirrelfish, thorny-back, and yellowtail.

## Geographical Distribution

*Lagodon rhomboides* has been recorded in the literature from the entire coast of Atlantic North America from Cape Cod to Texas (for example, Jordan and Evermann, 1902:440; Jordan, Evermann, and Clark, 1930:337; Storey, 1937:21; and Longley and Hildebrand, 1941: 133); from the Campeche Banks off the Yucatan Peninsula, Mexico (Hildebrand, 1955:211; Springer and Bullis, 1957:85); from Bermuda (Goode, 1877:292); from Cuba (Poey, 1856–58:367; from Green Turtle Cay, Bahamas (Lee, 1889:671); and from Kingston, Jamaica (Fowler, 1939:14). Of these noncontinental records, only the one from Bermuda appears to be based on a permanent population; the others apparently are based on accidentals, imports, or misidentifications.

Based on present material and recent field work, the geographical range of the pinfish probably would be more correctly stated as extending from the south side of Cape Cod in the vicinity of Woods Hole, Massachusetts, southward along the Atlantic coast to include the Florida Keys, and throughout the Gulf of Mexico; it is also present in Bermuda (fig. 3).

Since this range is at variance with that noted above as being found in the literature, an explanation for it is presented below.

Apparently the most northern record for *L. rhomboides* is from the south shore of Cape Cod in the vicinity of Woods Hole, Massachusetts (Smith, 1898:101; Sumner, Osburn, and Cole, 1913:758). Bigelow and Schroeder (1953) do not record it from the Gulf of Maine and state (1953:1) "that the temperature of the Gulf and its fauna are boreal, and that its southern and western boundaries [north side of Cape Cod] are the northern limit to common occurrence of many southern species of fishes and of invertebrates." The effects of the southward flowing cold Labrador Current, the northward flowing warm Gulf Stream, and the deflective action of the Cape on them, seem to be responsible for this line of demarcation which is followed by the pinfish.

The recorded range of *L. rhomboides* continues unbroken south-

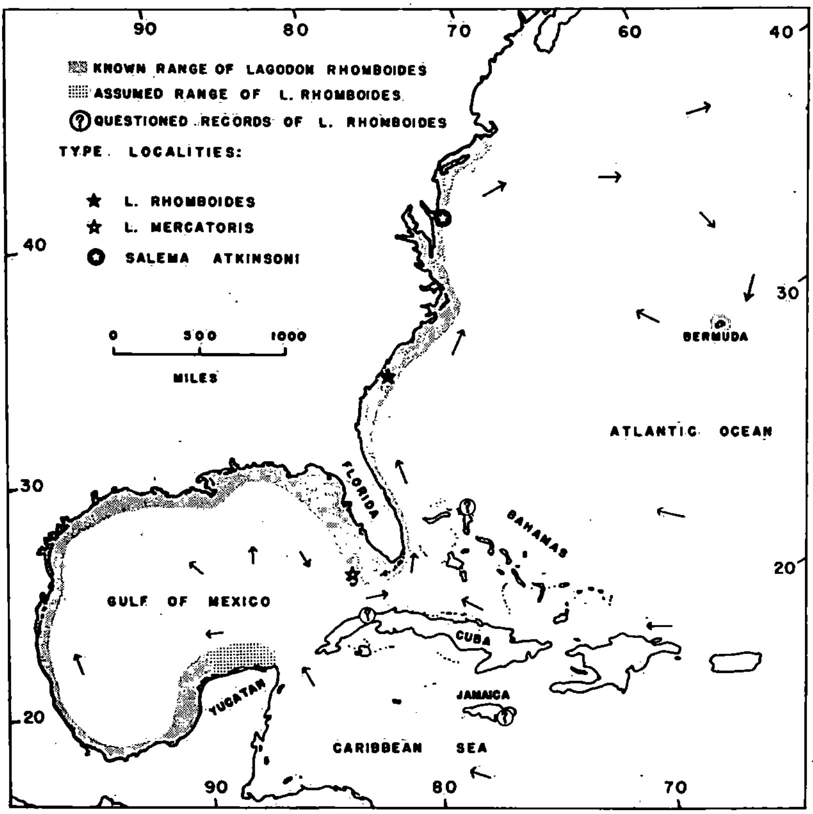



Figure 3.—Geographical distribution of *Lagodon rhomboides* (L.). The arrows indicate the general directions of major ocean currents.

wards from Woods Hole along the Atlantic continental coast of the United States to Brazos Santiago, Texas (Girard, 1858:16; Evermann and Kendall, 1894:93, 116). Investigations by the staff of the *Oregon*, research vessel of the United States Fish and Wildlife Service, have also shown pinfish to occur farther south in deeper water off the coast of Mexico at latitude 24° 12′ N., longitude 97° 17′ W., at *Oregon* station 662 (Springer and Bullis, 1957). Henry H. Hildebrand and J. L. Baughman both inform me that pinfish occur in the Mexican Laguna Madre to approximately the same latitude as the offshore record from the *Oregon* (see section on material examined). Other than the Campeche records cited below, records of the occurrence of pinfish on the coast of Mexico beyond the Laguna Madre are practically nonexistent. I have been able to uncover only two, both apparently previously unpublished. The first of these consists of two specimens in the University of Michigan Museum of Zoology (UMMZ 157327) from 35 miles north of Tampico, 6 miles northeast of Morón, Tamaulipas, Mexico, at approximately latitude 22° 50′ N., some 80 miles south of the *Oregon* record noted above. The second is based on a specimen (125 mm. in total length) which Henry Hildebrand writes he collected at Anton Lizardo, a village near Veracruz, some 250 shoreline miles south and east of the record from near Tampico. The next records are those from the Campeche Bank, the nearest to Veracruz being approximately 350 shoreline miles to the east and north.

Springer and Bullis (1957) and Hildebrand (1955) record a number of localities at which *L. rhomboides* has been taken on the Campeche Banks off Yucatan. These localities extend from approximately latitude 19° 40′ N., longitude 91° 04′ W., (off Point Morros on the western side of the Yucatan Peninsula and represented by specimens in the University of Florida Collections [UF 1285]) to latitude 22° 27′ N., longitude 89° 59′ W., (*Oregon* station 646, off the northern end of the Yucatan Peninsula). Hubbs (1936) did not list the pinfish from the inshore waters of Yucatan, but it should be expected to occur on its western and northern coasts. However, the narrowness of the continental shelf at the northeastern tip of Yucatan, and the strong northward flow of the Gulf Stream through the Yucatan Channel near this point, would seem to make the occurrence of the relatively shallow-water-living *L. rhomboides* south of this point unlikely. I have postulated (Caldwell, 1955b:233) a similar limit of distribution in this region for another continental-shelf-living porgy, *Stenotomus caprinus* Bean.

As in the case of *S. caprinus,* the discontinuity in the range of the pinfish in the lower Gulf of Campeche is almost certainly an apparent rather than real one (Caldwell, 1955b:232). There is no evidence that conditions of habitat, or oceanographic factors, are not suitable for the occurrence of the pinfish there (Galtsoff, 1954), even though Jordan and Dickerson (1908) failed to report it in small collections of fishes from Tampico and Veracruz, and Hildebrand (1954:340) did not get it in trawling off Obregon. I also made a brief but unsuccessful attempt to catch pinfish by hand-line in the polluted harbor at Veracruz in the summer of 1954, and I did not see them at the one fish market visited. However, I did not consider the results of my efforts to be a fair indication of their presence or absence there since the harbor presented unsuitable conditions of habitat—even for the wide tolerance of pinfish—and I visited the market late in the morning after most of the fish had been sold or cleaned beyond recognition; few panfish were seen. In the two papers cited above, Jordan and Dickerson failed to report pinfish from Tampico, which is near the southernmost record cited earlier, and Hildebrand (1954) did not report *L. rhomboides* at localities where they are known to occur —this is often the case in reports on trawling operations. Thus, although the two apparent wide breaks in the range of the pinfish in the lower Gulf of Campeche, and its apparent absence from the north coast of Yucatan, are likely due to inadequate collecting, the following remarks written to me by Henry Hildebrand in May 1957, may be significant. In discussing the abundance of pinfish in the southeastern Gulf of Campeche, he wrote:

> Last year, I thought the rarity of Pinfishes might have been due to the red tide. There is a big difference in the number of reef fishes this April over what I found last April. I am now convinced it is a very rare fish. Without consulting all my notes, I remember seeing only one caught, and possibly four or five small ones in the market. I have visited all the accessible fishing towns from Tampico to Tonala on the Tabasco border [some 150 shoreline miles east of Veracruz]. My collecting has all been sporadic, but I don't recall seeing any Pinfish and I know I didn't collect any.

Despite the records cited at the beginning of this section (Cuba, Jamaica, and the Bahamas), and although *L. rhomboides* is included in the fauna of the West Indies by authors (for example, Goode, 1879:46, 1880:27; Rivas, 1949:17), the results of this and other studies indicate that it does not occur within that area.

There is a specimen in the United States National Museum (USNM 9838), with no date or definite locality, which is cataloged as having been collected in Cuba by Poey—two other specimens in this collection (USNM 38741) listed as having been collected in Havana by Stimpson, prove to be *A. rhomboidalis*. Poey (1856–1858: 358, 367) listed the pinfish definitely from Havana, basing his record on a large ("forte") specimen. In later describing what is clearly this species, Poey (1866:314) noted that the specimen in hand was nine inches long ("largo nueve pulgados"). Since the specimen in the National Museum is only approximately five inches in standard length (6½ inches in total length), Poey clearly saw more than one pinfish from Cuba. However, in his earlier work, Poey (1856–1858:367) remarks that the pinfish in Cuba is a "sp. dubia" and notes (1856-1858:395) that fishes so designated, unless it is otherwise stated, have not been taken in Cuba since the first record of its occurrence there. Thus even Poey seemed to have doubts about its regular appearance in Cuba. Whether the later listing of pinfish from Cuba (Poey 1868: 310) was based on new material is not made clear, though he cites the 1866 work, perhaps thus basing the new record on the old. Luis R. Rivas tells me that he understands many of the fishes studied by Poey were obtained in the Havana fish market, and though Poey may have understood in good faith that the pinfish he was studying had come from Cuban waters, it is possible, and even likely, that it did not. In Poey's time it was often the practice of Cuban fishermen to visit the Florida Keys or Campeche and return with live fish in the live-wells of their vessels, and thus Poey's pinfish may well have reached Havana in this manner from a locality within the natural range of the species, rather than having been caught in Cuban waters. It is even conceivable that since so many foreign fish came into Cuba alive at that time that some pinfish escaped and were subsequently re-taken under natural conditions, though they were not native there and never became established as a permanent population. Since the residence of the pinfish in Cuba was in such doubt, despite Poey's specimen and remarks, an effort was made during this study to verify or deny it. In the fall of 1954, Archie Carr, Leonard Giovannoli, and I made a concerted but unsuccessful effort to collect pinfish at Playa Baracoa (just west of Havana) in habitats which in Florida would be considered perfect for this species. We were equally unsuccessful in finding *L. rhomboides* at Batabano on the south coast of the island, and in several trips to the main Havana fish market where fishes of all sizes and descriptions are brought in from points all around the coast of the island. Nichols (1912:189) did not report pinfish from this market either, but as we did there and in our field observations, he found *A. rhomboidalis* to be relatively common at all times. Archie Carr again interviewed many fishermen at numerous Cuban seacoast towns in the summer of 1955 and found no evidence of pinfish. As we had discovered on our earlier trip, he found that when shown pictures or specimens of both species, the Cubans do not distinguish *L. rhomboides* and *A. rhomboidalis*. Thus if shown only a pinfish, they would undoubtedly say it occurs in Cuba, and would thus compound the error of its occurrence there. I also visited the fish collection of the Museo Poey at the University of Havana and found no specimens of *L. rhomboides*. It becomes apparent, therefore, that despite Poey's material, the true origin of which can never be positively known, the pinfish does not now occur in Cuban waters, if it ever did so. The literature reports since the time of Poey are seemingly based on his records, (for example, Jordan and Evermann, 1896a:390, 1898:1358; Jordan, Evermann, and Clark, 1930:337; Breder, 1948:185; Gabrielson and LaMonte, 1950:58; LaMonte, 1952: 113; and Sanchez-Roig and Gomez de la Maza, 1952:69).

Like the Cuban record, the only Jamaican record (Fowler, 1939: 14) is based on a market specimen from Kingston. Though Fowler notes that the specimen is deposited in the collections of the Academy of Natural Sciences at Philadelphia, several efforts by James Böhlke (one as late as December 1956) have failed to produce the specimen for verification. Since the pinfish is unreported from other nearby West Indian localities, and since it is so often confused at first glance with *A. rhomboidalis,* a species which does occur in Jamaica (Bean and Dresel, 1885:158; Jordan and Rutter, 1898:112), but which Fowler did not include in his list, this record must be viewed with doubt until the provenance and identification of the specimen is verified, or others are taken there.

Since this manuscript was prepared, I was fortunate to be able to visit Jamaica. In mid-June 1957, a time of year when pinfish in continental waters are especially abundant inshore, I (with the valuable cooperation of Walter Auffenberg, R. P. Bengry, Peter Drummond, and C. Bernard Lewis) made extensive collections in excellent pinfish habitat on both the north and south shores of the island. I also observed commercial seiners as they worked grass flats in Kingston harbor, and visited numerous Kingston fish markets where fishes of all sizes and varieties are sold. No pinfish were seen or collected, though *Archosargus rhomboidalis* was common, especially on the flats. Material in the fish collection at the Institute of Jamaica in Kingston labeled *"Lagodon rhomboides"* proved to be *A. rhomboidalis.* No specimens of either species were found in the small fish collection at the University College of the West Indies near Kingston. As a result of these observations, I am now convinced that the pinfish should not be expected in the Jamaican fauna.

During this visit to Jamaica, it was found that a certain amount of fresh fish is now being imported from Miami, Florida, and is being sold in the markets side by side with the local fish. While the shipment I discovered consisted entirely of cigarfish, *Decapterus* sp., and the vendors when queried knew which of their fish were from Miami, it is not inconceivable that an occasional specimen of another species—pinfish, for example—might be placed in the box at Miami, be shipped to Jamaica (or any other port outside the range of that fish), and on arrival be sorted from the "special" imported fish species and sold with the local fish.

Like the records from Cuba and Jamaica, the record of *L. rhomboides* from the Bahamas must be viewed with extreme doubt. There is at present no available specimen with which the Green Turtle Cay, Bahamas (Lee, 1889:671), record can be confirmed or denied. It was reportedly collected by a group of students from Johns Hopkins University, but B. H. Willier, chairman of the zoology department there, wrote me in 1955 that, though a number of collecting trips had been made to such areas in the late nineteenth century by Johns Hopkins students, there was no reference to these fish in the records of those expeditions, and that he knew no specimens from the Bahamas had been at the University since he took over the chairmanship of the department in 1940. To my knowledge there are no pinfish in collections listed as being definitely from the Bahamas, though the United States National Museum contains seven specimens (USNM 6108) labeled only "Bahamas?" with no date of collection, collector, true locality, or reason as to why they are so labeled. Giles Mead of the United States Fish and Wildlife Service kindly checked the fish catalog of the Museum and has been unable to shed further light on this question. Bean (1905), in listing fishes collected in the Bahamas, did not include pinfish, nor was it included by Nichols (1921), Breder (1927), Parr (1930), or Fowler (1944) in their various studies on fishes of the islands. I have collected in the Nassau area in good pinfish habitat and have, on a number of days, visited the market there, where small fishes from most of the "Out Islands" are sold, and did not find it. James Böhlke and Charles C. G. Chaplin tell me they have not obtained the species in their extensive collecting for their forthcoming handbook of Bahamian fishes. C. M. Breder, Jr., Louis Krumholz, and Don McCarthy; Donald deSylva and Marshall Bishop; and F. G. Wood have all informed me that neither they nor their immediate associates know of any records for pinfish in the Bahamas, at Bimini, or at Grand Bahama, respectively. In view of this evidence and the lack of a specimen for verification, the single record of pinfish from the Bahamas must have been based on a misidentification or stray specimen, and the species is not expected to regularly occur there, if at all.

Further evidence for the absence of *L. rhomboides* from the West Indies, and actually from the entire Caribbean, is given by citing several important faunal lists which cover many Caribbean and West Indian localities and which fail to include pinfish. Some of these are: Evermann and Marsh, 1902 (Puerto Rico); Metzelaar, 1919 (Dutch West Indies), 1922 (Lesser Antilles); Meek and Hildebrand, 1925 (Panama); Fowler, 1928 (Bahamas, Haiti, Puerto Rico, St. Lucia, Dominica), 1944 (numerous Antillean islands and banks, Central America, Cayman Islands), 1952b (Hispaniola), 1953 (Colombia); Beebe and Tee-Van, 1928 (Haiti), 1935 (Haiti, Santo Domingo); Nichols, 1929 (Puerto Rico, Virgin Islands); Herre, 1942 (Antigua, Barbados); Schultz, 1949 (Venezuela); and Erdman, 1956 (Puerto Rico). In addition, Dudley Wiles, J. L. Baughman, Leonard Giovannoli and Larry Ogren, Gaston Blanche, Frank J. Mather, III, and Archie Carr have told me that they could give no records of its being found in the respective localities of Barbados, Central America, Costa Rica, Martinique, the Virgin Islands, and numerous Caribbean localities.

Other than the questionable records from Jamaica and the Bahamas, and the specimens from Cuba and the "Bahamas?" previously discussed, I have found no mention of extracontinental specimens of *L. rhomboides* other than from Bermuda.

Though Goode (1876) did not include pinfish in his catalogue of Bermuda fishes, he did list it the following year (1877:292); and in 1884 (p. 393) he noted that it was not uncommon in the Bermudas, though Beebe and Tee-Van (1933:161) stated that it was known there only from a published record [presumably Goode's]. It is apparently rare there; Louis Mowbray, Director of the Government Aquarium at Flatts, and a frequent and excellent field observer and collector, wrote me in 1954 concerning them: "I have seen both the adult and half-grown (3") fish here on rare occasions . . . . I doubt whether I have seen them ten times in the past 25 years, so they are anything but common." In 1956 he told me that when caught by hook-and-line or in traps, they are usually taken only one at a time. There are a few specimens from the islands in collections (see section on material examined). The currents which form a barrier to the dispersal of *L. rhomboides* to the West Indies seem also to account for its presence in Bermuda. As shown by Sverdrup, Johnson, and Fleming (1942:chart VII), there are large swirls or eddies from the Gulf Stream which bathe the Bermudas, and because of these currents a few pinfish, most likely stray postlarvae or young traveling with floating weed, are apparently able thus to reach the islands from the continent. Louis Mowbray wrote further in 1954: "It would appear that they might arrive here while quite young while sheltering under sargassum weed, as do so many other young fish when 'lost.' I think that is the only way in which they would ever reach the islands."

Following Matthew (1939:32), it can be assumed that *L. rhomboides* had an origin in North American continental waters. This is certainly its center of abundance today, and fossil evidence indicates that it or a closely related ancestor has existed in these waters at least since the middle Miocene. The barrier to its spread to the Antilles and Bahamas is apparently the deep water gap which has existed since the Pliocene (Schuchert, 1955) and which is now actively represented by the deep channel and relatively fast-flowing current of the Gulf Stream. This barrier to dispersal to the islands today seems to be related primarily to two major factors. Probably the most important of these is depth. The Stream reaches hundreds of fathoms close to its edges, while pinfish, including pelagic larvae, are unknown from more than 40 fathoms, despite numerous trawl stations and plankton tows made in deeper water by various research vessels. The other factor is one of current. Even though the larvae seem to be hatched offshore (see section on spawning), they, older young possibly sheltering under floating weed, or even adults, finding themselves misplaced into the deep fast-flowing Stream, would almost certainly not be able to swim or be carried across to the islands of the West Indies before being swept north of them. The general directions followed by these currents are outlined by Sverdrup, Johnson, and Fleming (1942:chart VII), Galtsoff (1954:29), and Leipper (1954: 121-122), and it may be seen from these charts that there are apparently no countercurrents which originate in continental waters and flow to the Antilles, Bahamas, or the Caribbean in general, and which could carry *L. rhomboides* to those areas.

As already noted, it is apparently the effects of the Gulf Stream which can account for the presence of pinfish in Bermuda and for their occurrence as far north as Woods Hole in continental waters. Furthermore, it is the loss of the warming properties of that current, brought about by the presence of the cold Labrador Current, which seems to prevent the successful dispersal of this species north of Cape Cod.

## Geographical Variation

Although its range includes some 23 degrees of latitude, *L. rhomboides* shows a marked lack of geographical variation, based on the morphometric characters examined during this study.

Though a number of meristic and proportional characters were examined, only the number of lateral-line scales was found to show any tendency toward geographical variation. Though other characters varied, they seemed to do so essentially to the same degree throughout the range of the pinfish—on a mean as well as a range of variation basis—and this variation in general could be attributed to normal genetic variation expected in any population, or to ontogeny, or to physical factors of the environment, though unknown factors not related to these may have been in operation.

Since large samples of pinfish from any one locality are not generally available in collections, the data obtained were lumped to include large geographical areas which seem reasonably termed single biological populations, and by doing so, I was able to obtain samples more valid for statistical analysis. Numerous localities are represented within each area, and in the process of grouping it was assumed that all segments of the large population groups were included.

Since some of the fishes of the Atlantic seaboard have been shown to differ from those of the Gulf of Mexico (Ginsburg, 1952:99; Evermann and Kendall, 1900:44), all of the material from Cape Cod, Massachusetts, to Fort Lauderdale, Florida (lower peninsular east coast), was included as one group. Those from the Gulf of Mexico proper, from Cape Romano, Florida (lower peninsular west coast), along the Gulf coast to Veracruz, Mexico, were considered as a second group. Since the Florida Keys—from Biscayne Bay to Tortugas—are considered by many (for example, Ginsburg, 1952:99) to be faunistically different from the rest of the waters of Florida—being more tropical than temperate—the specimens from this area plus those from Florida Bay were included as a third group. Though there seems to be no real ecological basis for it (see section on geographical distribution), the pinfish of the Campeche Bank are seemingly isolated, and they were thus included as a fourth group, though only a small sample was available. Bermuda specimens are considered as the fifth group.

The frequency distributions of lateral-line scales from these five groups, as well as that of all data combined, are given in table 1. These same data are graphically compared in figure 4, using a format suggested and discussed in detail by Hubbs and Hubbs (1953). In each diagram, the mean is represented by a vertical line at the midpoint of the body of the diagram. The blackened bar indicates two standard errors of the mean on each side of the mean. One-half of each black bar, plus the white bar at either end, shows one standard deviation on each side of the mean. The solid horizontal line indicates the observed range of variation. The small vertical lines near the extremes of this horizontal line indicate three standard deviations on each side of the mean. If the three standard deviations exceed the observed range on either side of the mean, this is so indicated by a dashed line (Cazier and Bacon, 1949; Dickinson, 1952). The standard deviation is a measure of dispersion; the standard error of the mean is one of reliability. As shown by Hubbs and Hubbs (1953), the statistical significance of the difference between the samples thus graphed can be analyzed without further calculations.

TABLE 1

FREQUENCY DISTRIBUTION OF LATERAL-LINE SCALES OF *Lagodon rhomboides*

| Number of lateral-line scales | All data | Bermuda | Atlantic seaboard | Gulf of Mexico | Florida Keys | Campeche Bank |
|---|---|---|---|---|---|---|
| 53 | 1 | | | 1 | | |
| 54 | 3 | | | 1 | | 2 |
| 55 | 2 | | | | 2 | |
| 56 | 2 | | 1 | | 1 | |
| 57 | 13 | | 2 | 1 | 9 | 1 |
| 58 | 15 | | 5 | 3 | 6 | 1 |
| 59 | 26 | | 5 | 8 | 12 | 1 |
| 60 | 48 | | 8 | 21 | 15 | 4 |
| 61 | 78 | 3 | 22 | 32 | 18 | 3 |
| 62 | 90 | 2 | 24 | 47 | 14 | 3 |
| 63 | 99 | 3 | 37 | 42 | 15 | 2 |
| 64 | 60 | | 15 | 36 | 9 | |
| 65 | 24 | | 5 | 14 | 4 | 1 |
| 66 | 8 | | 3 | 4 | | 1 |
| 67 | 1 | | | 1 | | |
| 68 | 1 | | | 1 | | |
| Mean | 61.78 | 62.00 | 62.04 | 62.24 | 60.78 | 60.42 |
| Standard error of mean | 0.10 | 0.31 | 0.17 | 0.13 | 0.23 | 0.68 |
| Standard deviation | 2.18 | 0.87 | 1.89 | 1.94 | 2.33 | 2.98 |
| Sample size | 471 | 8 | 127 | 212 | 105 | 19 |

Even though there is only a small sample, the material from Bermuda is not statistically different from that of the Atlantic seaboard and the Gulf of Mexico proper. Though it is unknown if a breeding population is present in the islands, there is apparently enough recruitment from the mainland populations to prevent any incipient speciation.

Likewise, there is no significant difference between the groups of pinfish from the Atlantic seaboard and the Gulf of Mexico proper. It was found, however, that there is a tendency for some variation of the mean between local areas in these two large groups. However, these ranges of variation almost completely overlap and the local mean differences showed no statistical significance, even when samples from the extremes of latitude were compared. Similar clines were found by DeSylva, Stearns, and Tabb (1956) in their study of the scales of members of local populations of the black mullet, *Mugil cephalus* L., in Florida, though they found a greater mean scale

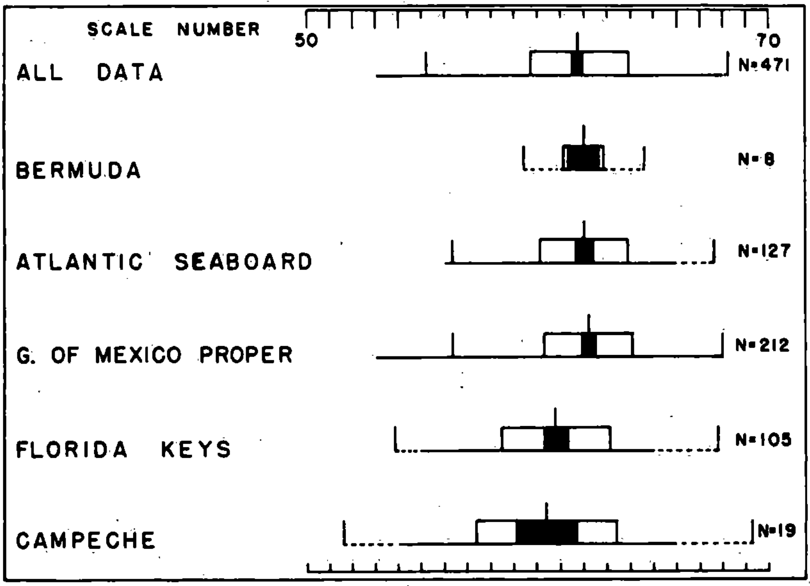



Figure 4.—Geographical variation in the number of lateral-line scales of *Lagodon rhomboides* (L.). See text for explanation of the figure and for exact delineations of geographical groups.

count in lower latitudes, while pinfish showed a tendency toward a lesser mean scale count. These authors also present an excellent summary of earlier studies showing intrapopulation clines based on other morphological characters. They have further suggested that it is probable that the cline in the number of mullet scales is due to phenotypic manifestations related to physical factors—primarily temperature—of the environment. They have cited a number of experimental studies in which temperature has been shown to be operative in modifying characters which are often used by ichthyologists as supposedly useful tools for demonstrating variations with taxonomic significance. It has been further shown that this environmental modification can often take place late in the development of the individual. Thus genetic differences may not be wholly responsible for the variation in the number of variants in a meristic character. Studies summarized by DeSylva, Stearns, and Tabb (1956) have shown that the number of scales apparently is fixed during the development of the postlarvae, and that temperature is an important factor in this process.

Pinfish apparently spawn offshore, and it must be assumed that the larvae are widely distributed by currents, and even that adults from diverse areas may meet offshore while spawning. There thus must be a wide exchange of genes each spawning season and with it little possibility for permanent genetic isolation. These assumptions are corroborated by the lack of geographical variation noted above. It can be assumed further, that the only character showing a tendency to form clines, the lateral-line scale count, is probably related to some physical factor of the environment rather than to genetic factors. DeSylva, Stearns, and Tabb (1956) cited various experiments which have shown that the exact number of variants in a meristic character in fishes can be affected, within genetic limits, by environmental factors. Such a relationship apparently exists between the number of lateral-line scales on pinfish and the temperature of the inshore waters where the postlarvae, as defined by Hubbs (1943:260), develop.

That pinfish are spawned offshore and then move inshore to undergo much of their postlarval and later development was first suggested by Hildebrand and Cable (1938:524) and this idea has been given added support by the results of the present study.

Scales are apparently first formed on pinfish of about 15 mm. (late postlarvae). The young, scaleless fish first arrive in inshore waters when about 11 mm. long. Thus, assuming temperature is an important factor in determining the number of lateral-line scales, and assuming the scale number is fixed shortly before the scales are formed, the pinfish would have moved into the shallow inshore waters and would thus be under the influence of the temperature there at just about the time in development when the scale number is fixed. Since the waters of any local area would have approximately the same temperature each year during the spawning and early development season, the young pinfish developing in that area each year would show consistently a mean number of lateral-line scales characteristic of that general area. This number would be related to the predictable temperature of that area during the season of development, but the fish would still remain genetically indistinct from members of a neighboring population. With this in mind, it was found that the number of lateral-line scales can be correlated with the temperature of the waters in which the fish develop, with fewer scales on fish from warmer water. Thus the long spawning season of the pinfish may account in part for the wide variation in scale number from any given locality, with the mean number of scales being fixed by the temperature when spawning is at its peak, and the range being due to temperature variation as well as the genetic limits of the character. This range of variation may be modified by the movements of the adults from one area to the next, either by simple along-shore movements, or during their offshore-inshore movements (see section on ecology) in which an individual might move offshore at one angle to the coastline and then return to the inshore waters at an opposing angle and thus find itself at a considerable shoreline distance from its original point of departure. It would be desirable, then, to treat the scale number of large samples of young (0-year class)—and thus fish which have not yet migrated—from many areas but from the same month, preferably one early in the season. An early month would tend to eliminate the effects of accumulation of representatives of past months of different temperatures. Such a study might show narrower limits of variation of scale number in local populations, and such limits could be even more closely correlated with the water temperature of the area.

Though the ranges of variation widely overlap, there is a statistically significant difference between the mean number of lateral-line scales in the specimens from the Florida Keys group as compared to the mean numbers of groups from the Atlantic seaboard, Gulf of Mexico proper, and Bermuda (fig. 4). However, since this difference is not reflected in the other characters examined, and since the Keys feel the full force of the warming Gulf Stream—without the counter cooling effects of cold air temperature and cool countercurrents—and are thus more tropical than temperate (Ginsburg, 1952:100), the mean lateral-line scale count would be expected to be consistently low in that region. This relationship of scale number and water temperature during postlarval development has been discussed above. It was found that the mean of the scale count of the specimens from the upper Keys (Biscayne Bay southwest to Marathon, and Florida Bay) was almost identical with that of the sample from the lower Keys, though the two areas are sometimes considered faunistically different. All of the Keys can be considered as a group since this tendency for a low lateral-line scale count is distributed throughout the island group, though no taxonomic significance is presently attributed to it.

Though the sample from Campeche is small, the group is significantly different from that of the Gulf of Mexico proper (fig. 4), although it is not significantly different from the groups from the Atlantic seaboard and Bermuda. It is like the Keys group in character. Like the Keys, the Campeche area receives a strong warming influence from the Gulf Stream, especially during the months of pinfish spawning and postlarval development (Galtsoff, 1954:29; Leipper, 1954:122). Furthermore, the distribution of currents in the Gulf of Campeche during the time of year pinfish spawn tends, apparently, to keep the temperature of the Campeche Bank area higher than the Florida Keys (Leipper, 1954:128). Thus, an even lower scale count should be expected for pinfish from Campeche than for those from the Keys, and this is the tendency.

## Morphological Variation with Water Depth

Since it had been suggested to me that the pinfish from deep water offshore might be different morphologically from those of shallow inshore waters, a comparison was made between the number of lateral-line scales of specimens trawled at forty fathoms in the northeastern Gulf of Mexico and the number of scales on specimens from the northeastern Gulf which had been taken inshore, from waters of five fathoms or less. The frequency distribution of the scales of these samples is presented in table 2 and statistical diagrams (as described in the section on geographical variation) are given as figure 5. It may be seen from these diagrams that no statistically significant difference exists between the two samples.

Actually, the lack of significance between the two samples is not surprising. Not only is it apparent that all pinfish postlarvae develop inshore, and thus are subject to the same factors of temperature during their development, but there is also an unbroken range of depths at which pinfish have been taken, and thus a continuous population seems to exist from inshore to the forty-fathom extreme.

Although the specimens from the one large series compared above, taken at forty fathoms in the northeastern Gulf, tended to be dark in color and shallow in body depth, a few specimens taken from forty fathoms elsewhere were more normally colored (lighter) and

TABLE 2

FREQUENCY DISTRIBUTION OF LATERAL-LINE SCALES OF Lagodon rhomboides FROM THE NORTHEASTERN GULF OF MEXICO

| | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | Mean | Standard error of mean | Standard deviation | Sample size |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inshore waters (5 fathoms or less) | | | | | | | | | | | | | |
| | 3 | 4 | 6 | 8 | 9 | 9 | 4 | 2 | 1 | 62.63 | 0.28 | 1.92 | 46 |
| 40 fathoms | | | | | | | | | | | | | |
| | | 3 | 4 | 8 | 4 | 6 | 2 | 2 | | 62.69 | 0.31 | 1.66 | 29 |

were deep bodied. Thus in these and other characters—fin-ray counts and body proportions—the material examined from forty fathoms falls, as a whole, within the range of variation for any local inshore population.

## MORPHOLOGY

Though various authors have given rather detailed descriptions of the morphological characters of *L. rhomboides,* many of the characters vary more than these writers have indicated, and such variations

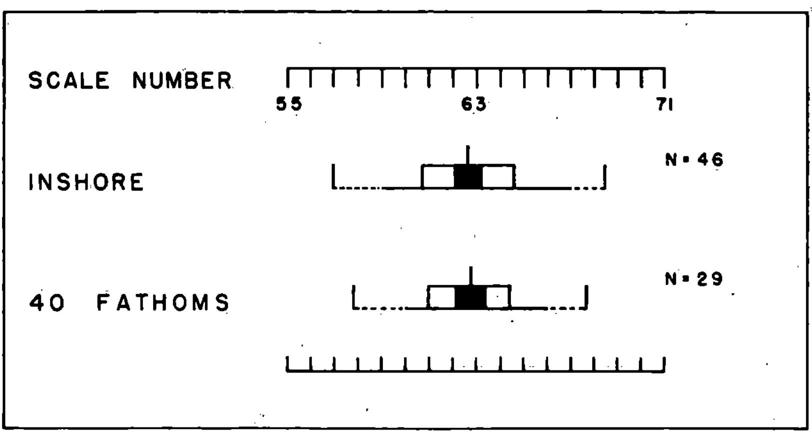



Figure 5.—Variation with water depth in the number of lateral-line scales of *Lagodon rhomboides* (L.), from the northeastern Gulf of Mexico. See text for explanation of the figure.

will be discussed below. Of these previously published descriptions, that given by Holbrook (1860:59) is particularly complete. However, since this work is rare, the reader is referred also to Jordan and Evermann (1898:1357-58), Smith (1907:299), Eigenmann and Hughes (1888:66), and Hildebrand and Schroeder (1928:265).

## Meristic Counts

Various meristic characters were investigated in the course of the study of geographical variation. While the ranges of variation in these do not show significant geographical differences, they do give a better indication of the morphological variation in this species as a whole than do the works of the authors cited above.

FIN RAYS.—The postlarval development of the fin rays has been discussed by Hildebrande and Cable (1938). Once the fins have completely developed in an individual, there is apparently no further ontogenetic change in the number or character of the elements.

*Vertical fins.*—The vertical fin ray counts for the specimens examined are presented in tables 3 and 4. It may be seen that most individuals possess a dorsal count of twelve spines (expressed as XII) and eleven branched soft rays (expressed as 11). The anal fin count is III, 11 in almost all of the specimens examined. It may further be seen in the tables that the dorsal fin is more apt to show a divergence from the modal count than the anal. Usually when one of these two fins showed a divergence, the other did not. In only three of the thirty cases in which the dorsal fin showed a count other than XII, 11 did the anal show other than the modal number of elements. In two of these instances the dorsal count was XIII, 10, while the anal was III, 12, and IV, 10. In the third case the dorsal was XII, 12, and the anal III, 12. The other eight times the anal showed a divergent count; the dorsal count was XII, 11, as expected.

In some instances, a reduced number of elements in the dorsal fin obviously was due to injuries to the first spines. However, since it could not always be ascertained externally with any degree of certainty whether the reduced number of spines was due to genetic or environmental factors, all specimens examined were included in table 3. It has previously been shown in this paper that Delsman (1941:70), with a single specimen which showed such an aberrant condition, described a new species (*mercatoris*) of the genus *Lagodon*.

There is normally no break in the membranes between the first

TABLE 3

VARIATION IN DORSAL FIN RAY COUNTS IN *Lagodon rhomboides*.

| | VIII | IX | X | XI | XII | | | XIII | |
|---|---|---|---|---|---|---|---|---|---|
| | | 11 | | | 10 | 11 | 12 | 10 | 11 |
| Atlantic seaboard | | | 1 | 1 | 6 | 132 | | 1 | 1 |
| Gulf of Mexico proper | | 1 | | 1 | 5 | 203 | 1 | 3 | |
| Florida Keys | 1 | 1 | | 2 | | 97 | 1 | 3 | 1 |
| Campeche Bank | | | | | | 15 | | | |
| Bermuda | | | | | | 8 | | | |
| All data | 1 | 2 | 1 | 4 | 11 | 455 | 2 | 7 | 2 |

spine and the last ray of the dorsal and anal fins. The last soft ray of these fins is split to the base and thus has a characteristic appearance as compared to the other soft rays of the fins. It was thus assumed that unless there was an obvious traumatic blank between the first spine and the last, typically split, soft ray, the fin behind the first spine was normal. In one case a specimen was found which had an anal count of III, 7. In this instance the complete membrane seemed to be present, but the last four rays were missing, thus leaving a large

TABLE 4

VARIATION IN ANAL FIN RAY COUNTS IN *Lagodon rhomboides*.

| | III | | | | IV |
|---|---|---|---|---|---|
| | 7 | 10 | 11 | 12 | 10 |
| Atlantic seaboard | | 3 | 137 | 1 | 1 |
| Gulf of Mexico proper | | | 217 | 3 | 1 |
| Florida Keys | 1 | | 103 | 1 | |
| Campeche Bank | | | 14 | | |
| Bermuda | | | 8 | | |
| All data | 1 | 3 | 479 | 5 | 2 |

sheet of rayless membrane at the posterior end of the fin. In several fish it was noted that not only was the last anal soft ray split to the base as normally expected, but the next adjacent ray originated at this same base instead of at its own which was missing. This then resulted in a reduced soft ray count, since the bases of the elements were counted rather than the elements themselves. It should be noted, however, that all low soft ray counts were not due to this condition, but rather, the fin had a low number of elements as well as fewer bases. In no case was the last soft ray found to be missing in either fin due obviously to injury.

The infrequently occurring divergent counts not obviously attributable to injury in later development may be either the result of abnormalities in early embryological development—such as the development as a spine of an element normally expected to be a soft ray, or the failure of an element to develop at all—or they may be true genetic mutants.

*Pectoral fins.*—While as few as 14 and as many as 17 elements were rarely counted in the material examined, the pectoral fin ray count was usually 16, occasionally 15. Furthermore, though the count was usually the same for each side of the fish, some individuals showed different values on the two sides in almost every combination of the above numbers.

*Pelvic fins.*—All pelvic fins examined, 143 pairs, showed a count of I, 5.

*Caudal fin.*—All caudal fins examined, 143, showed a count of 15 branched rays.

SCALES.—

*Lateral-line scales.*—The lateral-line scales have been discussed in detail in the section on geographical variation. A range in scale number from 53 to 68 was found for all the material examined (table 1), and it was found that water temperature during early development is probably important in determining the exact number of scales, within genetically controlled limitations.

*Scales above and below the lateral line.*—While the number of scales between the lateral line and the origin of the dorsal fin is easily determined and is always 10 (except in injured specimens), the count of scales below the lateral line is difficult to make (especially in small specimens) due to the crowding of the scales near the origin of the anal fin. Most authors (for example, Jordan and Evermann, 1898:

1358) give it as 17, though in large specimens, in which the scales become larger and more distinct, it often proves to be 18 or 19.

GILL RAKERS.—The counts of gill rakers are given in table 5. A wide range of combinations of uppers and lowers was found to exist on the first arch, though the combination of 7 uppers and 13 lowers was by far the most common, and 6 uppers and 13 lowers frequently was encountered. The other combinations were rare.

TABLE 5

VARIATION IN GILL RAKER COUNTS ON THE FIRST GILL ARCH IN *Lagodon rhomboides*.

| | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|
| Upper limb | 47 | 107 | 6 | 2 | | | | | | |
| Lower limb | | | | | 1 | 1 | 18 | 150 | 21 | 1 |

## Body Proportions

Means and ranges of variation for a number of body proportions are given in table 6. Hildebrand and Cable (1938) have discussed in detail the early ontogenetic changes in these proportions in the postlarval fish, and the results of my study of larger fish seem to corroborate their findings. The following characters were studied in detail since they had been suggested as showing the most promise for demonstrating significant geographical variation between local populations, although this is shown later not to be the case. These general tendencies were found:

With increase in body length, the eye becomes proportionately smaller; the snout becomes longer; the head shorter; and the interorbital width broader. In fish under 60 mm. there is a tendency for the length of the pectoral fin to be shorter in smaller fish. In fish larger than 60 mm., however, the proportional length of this fin, while widely varying, tends to remain relatively constant on a mean basis. It is somewhat surprising to find that the mean and range of variation in the relationship of body depth to length remains constant in fishes from 14 to 328 mm. in length. Pinfish in nature are often apparently separable into two groups, deep- and shallow-bodied individuals. However, it is now evident that the extremes

TABLE 6

SELECTED BODY PROPORTIONS OF *Lagodon rhomboides* 14 TO 328 MILLIMETERS IN STANDARD LENGTH.

| Standard length/character specified | Mean | Range | Sample size |
|---|---|---|---|
| Body depth | 2.4 | 1.7- 3.5 | 222 |
| Pectoral fin length | 3.0 | 2.1- 4.8 | 115 |
| Head length | 3.2 | 2.6- 3.7 | 95 |
| Least depth of caudal peduncle | 9.1 | 7.6-10.6 | 31 |
| Tip of snout to origin of dorsal fin | 2.6 | 2.3- 3.1 | 29 |
| Insertion of dorsal fin to base of caudal fin | 6.1 | 5.3- 6.8 | 31 |
| Origin of anal fin to tip of lower jaw | 1.5 | 1.4- 1.7 | 31 |
| Insertion of anal fin to base of caudal fin | 6.0 | 5.3- 6.8 | 31 |
| Insertion of pectoral fin to tip of snout | 3.0 | 2.5- 3.5 | 31 |
| Insertion of pectoral fin to base of caudal fin | 1.5 | 1.4- 1.6 | 31 |
| Posterior edge of bony orbit to posterior edge of opercle | 7.3 | 5.6- 8.3 | 31 |
| Length of dorsal fin base | 1.8 | 1.6- 1.9 | 48 |
| Length of anal fin base | 4.0 | 3.6- 4.7 | 50 |
| Length of pectoral fin base | 15.0 | 12.4-17.8 | 26 |
| Origin of dorsal fin to base of caudal fin | 1.4 | 1.3- 1.5 | 30 |
| Tip of snout to insertion of dorsal fin | 1.2 | 1.1- 1.2 | 31 |
| Origin of anal fin to base of caudal fin | 2.4 | 2.3- 2.6 | 30 |
| Tip of snout to insertion of anal fin | 1.2 | 1.1- 1.4 | 31 |
| Ventral fin length | 4.6 | 3.4- 6.4 | 30 |
| **Head length/character specified** | **Mean** | **Range** | **Sample size** |
| Snout length | 3.0 | 2.5- 4.0 | 37 |
| Diameter of bony orbit | 3.6 | 2.8- 5.2 | 97 |
| Width of bony interorbital | 3.8 | 2.9- 5.2 | 37 |

are noted and remembered by the observer but that intermediates usually occur regularly, at least in large samples. Since one sometimes finds individuals all of one type, some ecological factor at some stage of development may function to bring about this condition, or the sexes may segregate. Sexual dimorphism, as yet undemonstrated, has been suggested as being relative to this phenomenon; but small samples of specimens of known sex have not yet borne this out, though further study may prove that it is actually the case.

A constant straight-line relationship was found to exist between standard, fork, and total length in specimens measuring 15 to 328 mm. in standard length. Since measurements of pinfish are, in addition to the more widely used standard length, sometimes given as total or fork length, the following factors are given for easy, approximate conversion from one length to another. To convert total length to standard length, multiply by 0.79; fork length to standard length, by 0.86; standard length to total length, by 1.26; and standard length to fork length, by 1.16.

## Color

The basic life colors and color patterns have been described by Jordan (1885a:128), Jordan and Evermann (1898:1358), Smith (1907:299), and Holbrook (1860:59), and figured in color by Holbrook (1860:pl. 8) and LaMonte (1952:pl. 46), and the patterns in black and white by Jordan and Evermann (1900:fig. 552). The colors are quite consistent, though they do vary considerably in intensity. Often the yellows, oranges, and blues of the body and fins are rather brilliant. However, at other times, often depending on the habitat occupied, the live fish are pale, almost completely silver—though the vertical bars usually persist—or are dark in overall color. These variations of tone usually disappear after preservation so that the basic pattern of stripes and bars alone remains.

A few individuals, from shallow as well as deep water, were found to be melanistic, with large dark areas, especially around the head region, persisting after preservation.

The development of the basic color pattern in the postlarvae from North Carolina has been previously described by Hildebrand and Cable (1938). These writers have further shown that this development toward the color pattern of the adult does not take place until the young fish reach the inshore weedy areas, and that it is thus not necessarily a function of size. This was also found to be the case at Cedar Key, Florida. Since these authors do not give the colors of their young fish, but only patterns of melanophores, the following color notes which I made from a group of 16 to 17 mm. live fish from a grassy flat at Cedar Key are of interest:

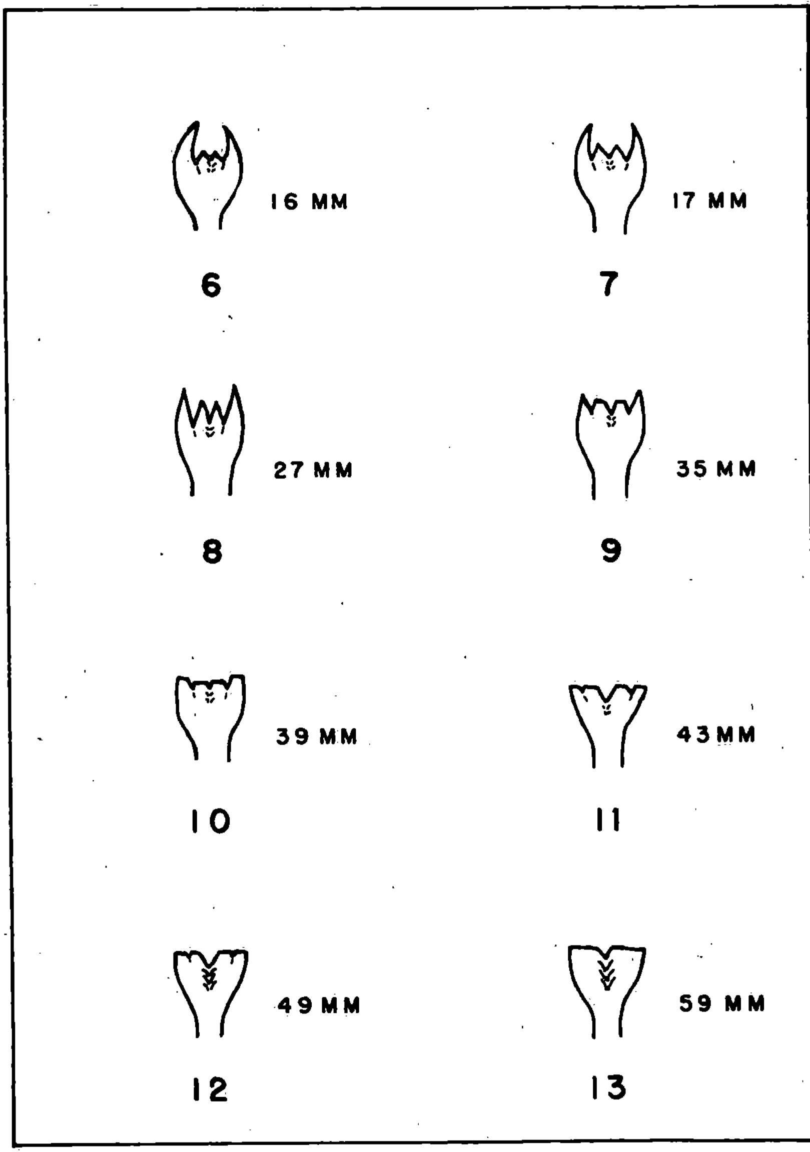
Dorsal and anal fin membranes tipped with brick red, smeared to the base of the fin, particularly so on the spinous portion (and especially so on the spinous dorsal).

Lemon yellow to orangeish chromatophores over most of the body, concentrated where the black melanophores are least numerous. Black humeral spot developed. Eye iridescent, bluish. Under magnification the yellow chromatophores seem to develop without pattern but in association with the melanophores, while the red chromatophores appear as definite bars.

## Incisor Teeth

While the incisor teeth of adult fish are discussed and figured later in this paper (see fossil record) and are mentioned in the discussion of *Salema atkinsoni* earlier, a description of the change in their form in young fish has not previously appeared. As shown by the series of outline drawings (figs. 6 to 13), the familiar and diagnostic single-notched incisor tooth of large pinfish is the result of a series of modifications from a quite different postlarval form.

The first incisor teeth were noted in specimens 16 mm. long. There were only two in each jaw. These were at the most anterior point and were of the form shown in figure 6. Specimens 14 mm. long had no incisors, but were well equipped with a series of long, sharply pointed, erect, conical teeth around the whole of each jaw. The developing incisors apparently appear on the outside of this row of conical teeth and gradually replace them. In a 17 mm. specimen, the outer horns of the incisors (fig. 7) became shorter in proportion to the rest of the tooth and less hooked, while the two inner peaks became blunter and more obvious. By 20 mm. the conical teeth were all lost and replaced by the adult number of incisor teeth, eight, in each jaw. At 27 mm., the outer peaks were no longer hooked, though still proportionately longer than the inner ones (fig. 8). The inner peaks of the incisors of a 35 mm. specimen (fig. 9) had flattened, and the outer peaks continued to become proportionately shorter, though remaining pointed. By 39 mm. these side peaks too were flattened (fig. 10). Incisor teeth of a 43 mm. individual had progressed in their development so that the center notch was much more obvious than the two side ones (fig 11). By 49 mm. (fig. 12), the side notches were almost obscured, and the final notched appearance, as found in the teeth of a 59 mm. specimen (fig. 13), was almost complete. The exact size at which these changes occur varies, of course, though the sizes cited seem to be approximately typical, especially for the smaller fish. The developmental sequence, at least to the stage shown in figure 13, always seems to occur as indicated. Throughout the development of the tooth, each notch has a dorsoventral groove extending basally from its apex. On the teeth of large fish, this groove becomes more obvious as the areas on each side of it thicken and swell (figure 17). Also, as a function of size, the in-




Figures 6-13.—Change in form with growth of incisor teeth from the most anterior part of the mouth of *Lagodon rhomboides* (L.). Teeth are drawn diagramatically, not to scale. Lengths refer to the standard length of the fish.

cisors become proportionately thicker in their anteroposterior dimension. The posterior incisors that are not notched (fig. 19) are assumed to go through, and then beyond, the development outlined above, since all the incisors of very young pinfish observed showed that multinotched condition. Furthermore, in some incisor teeth seen in larger pinfish, the side notches persist to some slight degree and thus give the cutting edge of the tooth a somewhat serrate or rough appearance obviously not due to chipping.

## Internal Anatomy

Since Holbrook's (1860:62) description of the internal organs (other than gonads) of the pinfish is extremely accurate, as well as detailed, there seems to be no need to elaborate on his remarks. Due, however, to the general unavailability of that publication, his description is quoted verbatim here:

> The peritoneum is silvery, but with numerous small, dusky spots, that give the whole a dark colour; the liver is large and trilobate; the left lobe is irregularly three-sided, and extends nearly to the vent; the middle lobe is thick above, and joined to the left, without a distinct fissure, but does not extend more than half as far back; the right lobe is thick, and about half as long as the middle lobe; both right and left lobes project into the hypochondria. The gall bladder is a long tube, reaching nearly to the vent, and is very slightly enlarged behind. The stomach is rather small, though long, sub cylindrical, and pointed behind in the undistended state; when full, it fills much of the abdominal cavity; the pyloric portion begins at the posterior fourth, and is small, though rather long; there are four large coecal appendages. The small intestine runs half way to the vent, then returns to the base of the pylorus, whence it is reflected, after one or two short convolutions, to end in the rectum. The spleen is very small, oblong, and flattened. The air-bladder is large, broad before, and narrow behind, where it terminates in two horns. There is no urinary bladder, though the kidney is tolerably thick.

He does not mention the gonads, and this omission agrees closely with the apparent absence of these structures in the generally completely sexually immature pinfish found inshore (see section on spawning). Actually, however, the paired gonads lie immediately dorsal to the intestine in the body cavity, and lie more or less between the lobes of the liver, which form a sort of cradle for them as they develop. They are attached anteriorly with mesentaries near the origin of the liver lobes. When first showing signs of development, their body begins at a point about the level of the posterior end of the short right lobe of the liver. It is assumed however—though no fully ripe ones were seen—that full-ripe gonads essentially fill most of the available space in the body cavity, as do those of most fishes.

This tendency was being shown in the few near-ripe examples examined. As would be expected, on nearing ripeness the ovaries become yellowish and the testes chalky white. Goode (1884:394) notes that the "spawn is pale blue." It is assumed, however, that individual, fully ripe eggs were being described thusly. *Archosargus probatocephalus*, for example, a closely related sparid, has eggs which are clear when ripe (Rathbun, 1892:lix), and these might well appear blue in certain lights even though they did not contain blue pigment. The entire fully ripe ovary probably appears yellow, however, as it does in other fishes.

### Skeleton

The characters of the pinfish skeleton have been described in detail by Eigenmann and Hughes (1888).

## Spawning

### Place of Spawning

Though it is not yet known for certain, all evidence gathered during this and previous studies indicates that pinfish spawn in the open ocean, and often a considerable distance offshore. This distance is probably determined by the depth of the water or its temperature, which in turn may be associated with the depth. This is postulated on a number of major items of evidence. First, mature adults are rarely seen in inshore waters. Second, there is a definite offshore movement of large pinfish with the onset of fall and winter. Third, the smallest specimens of pinfish have been taken well offshore. Fourth, no larvae are reported inshore.

Conversations with numerous commercial and sport fishermen with long experience, and with biologists, in widespread parts of the range of the pinfish have resulted in the almost universal reply of, "I don't remember ever having seen a pinfish with roe." The only exception to this will be discussed below. Equally common is the statement that the larger pinfish move offshore with the coming of fall and winter. This movement begins before the spawning season, and the fish do not return to inshore waters in any numbers until spring, after the spawning season. A compilation of pinfish catch records (Springer and Bullis, 1957) of the *Oregon*, United States Fish and Wildlife Service exploratory fishing vessel, trawling in the

Gulf of Mexico at numerous localities and depths and during all seasons, suggested an increase in that species in deeper waters in the winter months. This relationship was also indicated by Hildebrand (1955:211). Springer (1957:170) reported several schools of pinfish, estimated to number 1000-2000 individuals, at the surface in the Gulf of Mexico on 17 September 1952, over 21 fathoms of water at latitude 29° 33′ N., longitude 87° 58′ W. Of several fish taken from these schools, six were males and one was a female, and it was reported that the female and one of the males was gonadally in a nearly ripe condition. Though the fish were at the surface, they may not have been there purely voluntarily, since they were apparently being fed upon by groups of spotted porpoise, *Stenella plagiodon* (Cope), (Springer, 1957:170; Siebenaler and Caldwell, 1956:127).

Since the youngest fish have been taken in plankton tows at or near the surface (Hildebrand and Cable, 1938:525; and a specimen collected by George Grice, 3 miles off Alligator Harbor, Florida, see below), it is assumed that they are normally pelagic. Though pinfish eggs in the natural free state are seemingly unknown today, it is assumed that they too are pelagic. Rathbun (1892:lix) reported floating eggs for the closely related *Archosargus probatocephalus,* and Kunz and Radcliff (1917:102) report them for another sparid, *Stenotomus chrysops.* It is assumed likely, therefore, that the spawning takes place somewhere near the surface.

There seems to be little doubt that in most places pinfish spawn well offshore. Hildebrand and Cable (1938:524) suggest a distance greater than 13 miles, off North Carolina. Springer (1957:170) also suggests an offshore spawning for this species based on the schools of near-ripe fish he reports. In the vicinity of Vero Beach, Indian River County, Florida (lower Atlantic coast), local fishermen are familiar with ripe pinfish in winter in the Indian River (actually a long bay protected by a barrier island). Mature pinfish were also reported from an unnamed locality in the Indian River by Goode (1884:394). In this study, large, nearly mature pinfish were taken at Vero Beach in late November, during the expected spawning season. Local fishermen reported to me that they have taken fully ripe specimens there. Since the waters of the Atlantic off the east coast of Florida are deep quite close inshore, the maturing pinfish, found in the deep channels and associated holes in the River, may be strays from the nearby deep waters harboring the main breeding population. The gently shelving coasts elsewhere may place the optimum minimal depth for spawning too far offshore for the members of the spawning population to occur inshore with any regularity. Gunter (1945:64) suggests that in Texas waters pinfish spawning takes place near the passes, though in the open Gulf. Relatively deep water is found inshore off Texas also. The areas in which spawning far offshore has been postulated are also regions with gently shelving bottoms, where really deep water over the continental shelf is well offshore. Inshore areas in which well-matured pinfish have been taken are likewise closely associated with fairly deep open water, and it is suspected that closer examination of specimens from such areas near deep water would produce more individuals with well-matured, though not necessarily ripe, gonads. Thus the place of pinfish spawning seems to be more closely related to depth than with distance offshore. The necessary depth is apparently far enough offshore so that fully mature fish are not usually taken inshore, and so that the fry reach a late postlarval stage of development before appearing inshore. Or, this phenomenon is quite possibly one of temperature—most likely associated with depth—rather than one of depth alone. The maturing pinfish at Vero Beach, for instance, may appear inshore because the water is warm enough—due to the Gulf Stream—close enough inshore for a spill-over from the main population to find sanctuary in the deep holes and channels of the Indian River, while at Cedar Key, on the other hand, there are no immediate warm current effects which might encourage such winter inshore habitation. The fish probably seek the more constant—and in winter, somewhat warmer—temperatures found in deep water as compared to the almost daily fluctuating, air-temperature-controlled ones found in shallow inshore waters. Other factors, such as pressure and light, may be operating, of course, either alone or associated with temperature, particularly if the adults spawn near the bottom in deep water.

Assuming pinfish do spawn in or over a given depth offshore, the larvae would be hatched at varying distances offshore, depending on various local topographic conditions. The sizes of small young appearing in sheltered inshore waters might thus be expected to vary, with smaller ones appearing in areas where the deep water is nearer the coast—such as the lower Florida east coast—than in regions where the deep water is further offshore—such as the Cedar Key region. This is not the case. The smallest non-plankton-caught fish taken inshore are almost invariably the same size everywhere (11 to 12 mm.). Postlarvae this size are even found well upstream from the mouth in saline rivers (McLane, MS:317; and specimens taken during this study several miles up the North Fork of the St. Lucie River, near Stuart, Florida). A possible explanation for this phenomenon might be as follows: The smallest larvae probably lack any self-directing powers, and though at the mercy of currents, they may not be swept shoreward at a rate fast enough for them to appear inshore in differential sizes in different regions. Therefore, assuming the larvae and postlarvae remain offshore until they reach a size at which they do possess self-directing powers, they may then be able to complete their inshore movement in such a short time that not enough growth occurs to show an interarea differential, even though various distances may be involved. On the other hand, the growth rate at this developmental stage may be slow enough so that even a considerable time differential for the trips might be ineffective in causing a difference in the smallest size found in different areas. A slow growth by pinfish in the first months of life has been shown by Hildebrand and Cable (1938:526).

## Time of Spawning

The postlarvae (11 mm.) first appeared inshore at Cedar Key in early December (1953), and specimens this small continued to be taken there until late April (1954). This would seem to indicate that spawning is initiated in the late fall and early winter in the Cedar Key region, and the prolonged appearance of the smallest postlarvae seen there (fig. 14) would indicate a long spawning season, probably from mid-October to March, with a December and January peak. Hildebrand and Cable (1938) found a similar situation in North Carolina. Reid (1954:44) in 1950-51, and Kilby (1955:233) in 1948, found the same sized fish at the same time of year at Cedar Key, and Kilby also reported them from Bayport, Hernando County, Florida. Postlarval specimens collected during this study in January and February (1954) at various other localities in Florida (St. Marks, upper northeastern Gulf coast, Wakulla Co.; Estero Island, near Fort Myers, Lee Co.; and Matanzas Inlet, Flagler Co., near St. Augustine) were all of the same size range as those collected during those months at Cedar Key. A large sample of 12 to 14 mm. specimens (USNM 118914) was taken in St. George Sound at Carrabelle, Franklin County, Florida, on 15 January 1913. Specimens taken by E. Deubler, J. Higham, and J. Huntley at Beaufort, North Carolina, from late December through early February are of this size also. Though too late in the year for postlarvae to be found, small specimens were col-

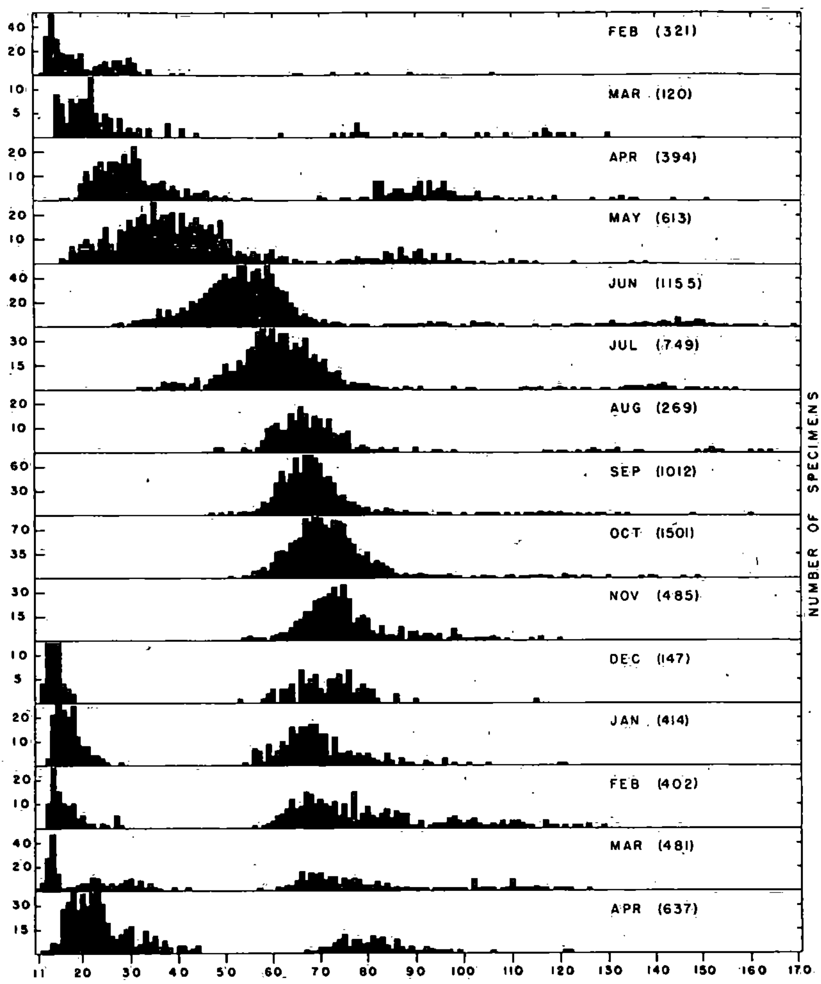



Figure 14.—Standard length-frequency data for *Lagodon rhomboides* (L.) at Cedar Key, Florida, during 1953 and 1954. Numbers of specimens are shown in parentheses. Due to collecting errors, only approximate seasonal abundance should be estimated from these data.

lected during this study at numerous other localities in Florida, in Texas, Mississippi, and Georgia. Small specimens were seen in collections from most of the other states within the range of the pinfish. All of these compared favorably, in their respective months of capture, with those from Cedar Key, and it was thus assumed that they had been spawned at a similar time as those at Cedar Key. Slight variations to this association might well be correlated with differences in growth rate brought about by differentials in food, habitat, etc. Various writers other than the above have postulated a winter spawning season for the pinfish. Some of these are: Smith (1907:300), South Carolina; Goode (1884:394), Gulf coast; Gunter (1945:64), Texas; and Hildebrand and Schroeder (1928:266), North Carolina. Joseph and Yerger (1956:135) suggest a much later spawning season during 1952 at Alligator Harbor (near St. Marks, Florida). They report young fish as small as 17 mm. from late May to July. Those caught in May well could have been spawned late in the expected winter spawning season—such 17 mm. fish appeared at Cedar Key in 1953 until May (fig. 14). The reported presence of fish this small as late as July is surprising. In view of the data presented above, and particularly the material collected near St. Marks and Carrabelle, and the fact that the smallest pinfish I have seen from the Gulf (9.5 mm.) was taken off Alligator Harbor in December 1954 (by George Grice), the suggestion of a later spawning season for Alligator Harbor alone must be questioned.

Further evidence for a late fall and winter spawning of the pinfish can be based on the few adults with ripening gonads which I found during this study or which are reported in the literature. The first pinfish I took at Cedar Key which showed any gonadal development was a female taken on 2 August 1953. The gonads were small, about stage 2 (as described by Vladykov, 1956:821). Another female, taken there on 3 October had gonads somewhat more developed (about early stage 3). No other fish with developing gonads were seen there during this study, though Reid (1954:44) reported seeing a male there whose gonads showed some development in September. Specimens with well-developed, but not mature, gonads (at least late stage 3, possibly early stage 4) were collected in late November and early December at Vero Beach, Florida, and local fishermen stated that they often caught them there with full roe at about that season, though no "running ripe" (stage 5) ones were mentioned. A series of large specimens (approximately 145 mm. in length) taken at Port Canaveral, Brevard County, Florida (middle Atlantic coast), in April 1954, showed, in the fresh state, gonads which seemed to be spent (stage 6). The gonads were flaccid, rather than showing the developing condition of the ones taken in the fall. Workers at Marine Studios (near St. Augustine) tell me that they believe they have seen pinfish with developing gonads in that region in late summer. The few mature or maturing specimens reported in the literature also corroborate a fall and winter spawning season for the pinfish. Smith (1907:300), in South Carolina, reported a pinfish with ovarian eggs on 6 August and a fully ripe male on 20 November. The general disappearance of large pinfish from inshore waters in the fall and winter, noted above, also corroborates a spawning during this season.

## Egg Production and Egg Size

Only one female was taken which had ovarian eggs far enough developed (about stage 3 or 4) to make even an approximate estimate of the number of eggs produced by a single individual. This fish was 157 mm. long and was taken at Vero Beach in late November. Using the volumetric method for determining the approximate number of eggs in an ovary (Lagler, 1952:79), an estimate of 90,000 eggs was made for the combined ovaries of this specimen. Vladykov (1956) has shown that the number of eggs per fish, in trout, can vary positively with increase in fish length and negatively with increase in degree of development of the gonad. Such a condition may well exist in other fishes, and the estimate of 90,000 eggs for the pinfish should be taken only as an order-of-magnitude number for that species.

The largest eggs in the specimen noted above averaged about one-half millimeter in diameter. Goode (1884:394) notes that the eggs of pinfish are about the size of mustard seed—approximately 1.0 to 1.5 mm. in diameter.

## Size and Age at Spawning

Hildebrand and Cable (1938:526) have suggested that pinfish first spawn in their second year, though they reported no specimens with developing gonads on which to base this suggestion. The smallest pinfish taken at Cedar Key with developing gonads was a female 146 mm in length, taken in October. Ones as small as 128 mm. and as large as 157 mm. were taken at Vero Beach in November. Interpolating from the length-frequency diagrams of fish from June 1953 from Cedar Key (fig. 14)—this is the only month in which a good series of large fish (with smaller ones for comparison) was obtained—these fish were probably in their third year, though the 157 mm. specimen from Vero Beach could have been older. The small fish showed a gonadal development of about stage 2, the 157 mm. one, a development of late stage 3 or early stage 4. Vladykov (1956) has suggested that once a development to stage 2 is reached during the spawning season, the fish will spawn that season, though one showing a development of stage 0 or stage 1 may not. Since maturing specimens small enough to be in only their second year have not been taken—in fact, gonads in fish this size are essentially indistinguishable—it seems almost certain that pinfish do not spawn before their third year, but that they can at that age. Unfortunately, scale studies have not yet been made to attempt to corroborate this estimate of spawning age.

## Ecology

### Physical Factors of the Environment

The pinfish is amazingly ubiquitous in its ecological distribution. It is found associated with wide ranges of temperature, salinity, depth, bottom type, current, and other ecological conditions, and this tolerance of the species to wide ranges of physical factors permits it to exist in many types of habitats.

Salinity.—Pinfish have been recorded from waters with salinities ranging from approximately 0.1 to 37.2 parts per thousand. McLane (MS:317) recorded this species from salinities as low as 0.116 parts per thousand in the St. Johns River in Florida. Another low-salinity locality in Florida was the Homosassa River, Citrus County. I collected a single specimen of *L. rhomboides*, UF 7822, 136 mm. long, in a cove just below the "Fish Bowl," one of the main spring boils providing the head waters of the river, on 6 March 1953. The salinity of the water in the cove, 0.8 parts per thousand, was determined by H. T. Odum by first obtaining the chlorinity by titration and converting that result to approximate salinity. This method was used since the hydrometers in use would not register such a low value with accuracy. Other pinfish were taken at this cove on other trips, but no water samples were taken with them, however, the water was "fresh" to the taste. Herald and Strickland (1950:106) recorded one specimen of *L. rhomboides* from the "Fish Bowl," and William Sloan of the University of Florida told me that on 24 April 1953, he had seen a large group of pinfish (each estimated to be about 75 mm. long) in the "Fish Bowl." Gunter (1942a:315) also lists the species from this spring and from Six-mile Creek near Tampa, Florida (based on the notes of Archie Carr). The highest salinity at which I found

*L. rhomboides* was that recorded in a small tide pool on Sanibel Island, Lee County, Florida, where, on 3 February 1954, I collected several postlarvae from water which registered a salinity of 37.0 parts per thousand. Gunter (1945:63) took pinfish in Texas in salinities ranging from 2.1 to 37.2 parts per thousand. Kilby (1955:242–43) reported this species at salinities from 4.5 to 26.1 at Cedar Key (he says the former should read 15.4 in his table 6 on page 242), and between 1.4 and 15.8 at Bayport. I found pinfish at Cedar Key in salinities ranging from 18.4 to 31.8 parts per thousand during this study. On the basis of these data, and as previously suggested by various writers, *L. rhomboides* is obviously indifferent to this environmental factor, and at whatever salinity it is found, it is usually present in good numbers. Gunter (1957) has suggested that of the marine fishes which invade fresh water, it is the younger individuals that do so. This tendency is shown by pinfish, with the exception that the young larvae and postlarvae, which, since they are known only from well offshore, have been found only in the relatively high salinities of the open sea. The largest pinfish which are regularly found inshore also invade fresh water, and the apparent tendency for the majority of the invaders to be small individuals is likely a phenomenon related more to depth than to salinity. As is shown in the section on ecology, on reaching inshore waters the small pinfish are generally found in shallow waters—in salinities equal to or higher than those found offshore—and thus they are more readily available for freshwater invasion than are the larger individuals which remain farther offshore.

Reid (1954:85) found that pinfish were among the most conspicuous of fishes killed at Cedar Key as a result of a hurricane of 4–6 September 1950. He noted that the salinity of the bay water dropped from 23.5 to 9.7 parts per thousand during a period of four days. Though pinfish have just been shown to exist successfully in much lower salinities, this sudden drop may have contributed to their death. Greatly increased turbidity in the bay waters may have also been a factor contributing to this mortality.

TEMPERATURE.—Although pinfish have been taken in waters with a wide range of surface temperatures, this environmental character seems to have some importance as a limiting factor. Its effect on limiting northern distribution has already been discussed in the section on geographical distribution, and it has been shown in the section dealing with spawning that the time and place of spawning may be related to temperature and thus to the distribution of the large fish.

In inshore waters at Cedar Key, I took pinfish in waters with surface temperatures ranging between 18.9° and 36.9° C., the greatest range which I found anywhere. In Texas, Gunter (1945:63) found pinfish in inshore water in which temperatures varied from 9.1° to 34.9° C. Records at *Oregon* stations at which pinfish were found (Springer and Bullis, 1957) show that this species is recorded more often during the cold months offshore where temperatures are warmer and more constant that those found inshore. Actually, since pinfish have been taken in wide extremes of temperature, their general movement offshore in winter is quite possibly a function of the constancy of temperature there, rather than the acutal degree of temperature itself. *L. rhomboides* frequently has been described as being able to withstand cold well, better than many species living in the same area with it (Hildebrand and Cable, 1938:518; Storey, 1937:21; Storey and Gudger, 1936:641), though pinfish have been reported killed by low temperatures in North Carolina, Texas, and Florida (Hildebrand and Cable, 1938:518; Gunter, 1941a:198, 1941b:203–4; Gunter and Hildebrand, 1951:732; Storey and Gudger, 1936:647). Gunter (1941b:204) notes that there were large numbers of cold-killed pinfish at Aransas Pass, Texas, on 24 January 1940, and that a few more were still swimming at the surface in a dazed condition in water whose temperature was 4.7° C. Whether this temperature is thus near the critical point for the survival of the species in Texas—and thus probably so elsewhere—is not known. The above authors, particularly Storer and Gudger (1936:645), Gunter (1941b:208), and Hildebrand and Cable (1938:518), note that they believe the deaths due to cold are more the result of sudden drops in temperature, or are due to the entrapment of the fish in shallow pools where they cannot escape to deeper water, rather than to the lowness of the temperature alone.

Gunter (1950:302), in correlating maximum size of shore fishes with water temperature, found that pinfish in Texas grew larger than those in Chesapeake Bay and noted that this was in opposition to the situation found in most of the other shore fishes so compared. However, in view of the size of the largest pinfish now known, from New York (Alperin, 1955) and off New Jersey (Fowler, 1940), this tendency for a positive correlation between cold water and large size actually appears to exist with pinfish, though very large specimens are known from very warm latitudes (see discussion of *Salema atkinsoni* in section on systematics).

DEPTH.—Pinfish have been taken at widely varying depths, ranging from a few inches of water inshore to 40 fathoms offshore, and almost all intermediate depths are represented by records. Though there are individual exceptions, there seems to be a positive relationship between the size of the fish and the depth of its occurrence, with the larger fish being taken in deeper water. The major exception is that the youngest, and thus smallest, have been taken well offshore. However, these larvae and postlarvae seem to occur in the upper layers rather than near the bottom, and so are still found in "shallow" water as related to the surface. The general relationship of depth to size is shown throughout the early life of the pinfish from the time it reaches inshore waters (see detailed discussion of the ecological development of the 0-year class, below), and it apparently continues throughout life, since the largest specimens have been taken in or near deep water offshore and similar sized ones only rarely are taken in inshore shallow waters. When large specimens are taken inshore, they seem to occur in deep channels and holes. Such a distribution of size groups was remarked upon by Goode (1884:394).

BOTTOM MATERIAL.—The results of collections made during this and other studies indicate that occurrence of pinfish cannot be related to any particular type of bottom material. This was found to be true in inshore waters, and the station records of the *Oregon* (Springer and Bullis, 1957) indicate that it is also true offshore. Pinfish have been taken at numerous depths on mud, coral, sand, and rock bottoms, and on bottoms combining these materials.

CURRENTS AND WAVE ACTION.—Few really fast currents—such as freshwater stream rapids—occur in marine habitats, except locally as tidal currents between islands and through channels. Thus current is not usually considered an important factor for consideration in marine ecological studies—except of course, the main ocean currents and drifts and their related eddies, which fall into a different category than the local currents considered here. In really fast-flowing local tide channels, only large pinfish were found in good numbers, though they are not limited to the channels. The absence of small fish may be more a function of the depth of the channel, or of the inability of the fishes to maintain their position, than to a sensitivity to the current itself. Since the large fish occur in deep holes with no current as well as in the fast-flowing channels, their presence in the channels may be due simply to depth, rather than to a positive rheotropism. Reid (1956:313) has shown something of a negative relationship between pinfish occurrence and tidal current in Texas, but he notes that this relationship may be apparent, rather than real, and related to other factors as well.

While pinfish are not generally taken in the strong surf on the open sea beach (Gunter, 1945:63), postlarvae do sometimes appear on the open beaches, apparently arriving there during their initial inshore movement. Adults are also sometimes seen in the surf zone when there is a log or other semishelter for them. In general, however, a more sheltered habitat is sought than that afforded by the roil of an open beach surf zone. Shelter may be provided either by depth or actual material in the form of grass, rocks, pilings, etc., or the lee side of a land mass.

MISCELLANEOUS ABNORMAL ENVIRONMENTAL FACTORS.—The effects on pinfish of several factors not usually associated with a normal environment, and apparently not directly applicable to the discussions above, have been reported by various writers.

Ingle (1952) found pinfish in the vicinity of an active dredge in Mobile Bay, Alabama, and concluded that the action of the dredge and the concurrent silting did not affect this and other named species, at least not to an extent great enough to completely exclude them from the area of operation. It was not stated, if known, whether the pre-dredge-action population was harmed or benefitted by the dredging.

Daugherty (1951b) found experimentally that though pinfish were killed by polluting chemicals associated with oil well drilling, often large concentrations of these chemicals were needed to be toxic to this species. He thus suggested (Daugherty, 1951a) that since pinfish were so tolerant, so widespread geographically, and so common locally, that they might be used as a standard fish for testing industrial waste effluents.

Though *L. rhomboides* is seemingly very hardy in relation to most physical environmental factors, both natural and man-caused, it is, nevertheless, apparently susceptible to the catastropic effects coincidental to large phytoplankton blooms—known popularly today as the "Red Tide." Gunter, *et al.* (1948:313) note that large numbers of pinfish were found dead on the beaches at Captiva Island, Lee County, Florida, after a winter bloom of 1946–47. These writers further report that pinfish were said to have been among the first species of fish to wash up in many localities. Similar verbal reports were given me by on-the-spot observers at later red tide kills. However, in relation to percentage of the population, *L. rhomboides* may not be as strongly affected by the blooms as it first appears. The large numbers of pinfish killed by red tides may not be due to an actual peculiar toxic effect of the blooms on them, but rather to the overwhelmingly large numbers of this species found in the Gulf waters of Florida where red tides are so frequently reported.

GENERAL HABITAT PREFERENCE.—Although all of the factors cited above are operating to develop the ecology of the pinfish, they are also so variable that they must be considered as influencing rather than limiting distribution within a given local area. Apparently the character of the environment which most influences the local choice of habitat by the pinfish is the presence or absence of attached aquatic vegetation, at least in waters shallow enough to support such growth. Collections made during this study in many localities throughout Florida and in waters of other southeastern states have shown that where both vegetated and unvegetated situations occur, pinfish are found to be more abundant in the vegetated areas. Even the postlarvae caught at the open beach station at Cedar Key (see description of this station below) were taken in association with patches of floating weed or floating decaying vegetable debris, when available, and not in the clear water between these patches. A similar relationship between pinfish occurrence and vegetation has been shown by Reid (1954:44, 1955a:336, 1955b:442), Kilby (1955:222–23), and Hildebrand and Cable (1938:525) in marine situations, and by McLane (MS:317) in fresh water. Though the vegetation undoubtedly affords good protection, the frequent association of pinfish with it may be a function of food availability as well, since the vegetation supports abundant small invertebrate forms which seem to constitute the bulk of the food of this species.

In situations where vegetated bottom is not accessible, and as a secondary center of local abundance when it is present, pinfish seem to remain around rocks, pilings, docks, breakwaters, emerged stalks of vegetation such as mangroves, and the like. Perhaps this is because they too afford cover and usually support invertebrate growths. Such occurrence about cover not consisting of submerged aquatic plants was found in many geographical regions visited throughout the range of the pinfish during this study, and it has earlier been reported by Jordan and Gilbert (1879:378), LaMonte (1952:116), Schroeder (1924:26), Longley and Hildebrand (1941:133), and Hildebrand and Cable (1938:525).

Little is known of the habitat preferences of pinfish well offshore, where there is apparently no rooted vegetation of consequence. Since they are frequently taken in bottom-trawl hauls, it is assumed that they live primarily at or near the bottom, as they do inshore. They are also occasionally reported taken by hook and line from the bottom in deep water offshore (Adams and Kendall, 1891:292), though in conversations with numerous fishermen I find that pinfish are only rarely taken offshore in this manner. However, this may be due to the fact that usually only large hooks and baits are used—in fishing for large-mouthed snappers, groupers, and grunts—and the relatively small-mouthed pinfish may simply not take the hook, though they are actually present, and the great fishing depth involved may allow their typical nibbles at the bait to go unnoticed. Hook-and-line fishing in deep water is usually only carried on around rock patches and "snapper lumps," often only mud peaks rising above a deeper bottom. Thus, really large pinfish away from these situations might never be fished for, and being active and also able to bury in times of stress, they may be able to escape slow-moving trawls dragging over a smooth bottom. Thus, although large pinfish by inshore standards (175-200 mm. in length) are taken by trawlers, the really giant ones (over 200 mm.) are not yet taken regularly by any means. Such giants are known to exist in the Gulf from scattered specimens in collections—specimens with no precise locality data. Furthermore, it is possible that the very large pinfish living offshore undergo a complete change in habits and become pelagic. If such is the case, they would rarely, if ever, be taken—except perhaps by a trawl being drawn to the surface—since there is no midwater fishery far offshore for small-mouthed fishes. Thus, unless the really large pinfish presumed to be offshore are living at middepths, it seems likely that they occur near the bottom in areas where the topography is extremely rough—too rough for normal trawling operations—or around more well-defined rock patches or "snapper lumps," and, due to the factors noted above, they are not taken by fishing methods now employed in such situations.

## Seasonal Distribution and Abundance

It has already been shown in the section on spawning and in the discussions of depth and temperature as environmental factors that there is a general cold-weather offshore movement by pinfish into deep water. Thus, this species is relatively much more abundant inshore in the summer and late spring than in the fall and winter. The warm-weather increase in numbers is not only a function of large fish moving back inshore at that time, but it is also necessarily related to the increase in the size of the entire population as a result of spawning. As the young fish grow older, large numbers are lost, of course, through predation and other factors, and thus the size of the population, in numbers, is reduced. However, discounting this, there is still the definite seasonal inshore difference in the number of large fishes. A similar seasonal relationship of numbers inshore has been noted by Gunter (1945:63), Reid (1954:44, 80), and Joseph and Yerger (1956:135). Kilby (1955:238, 240) found pinfish in the marshes only in the winter and early summer. Since most of his fish were small and of the 0-year class, such a distribution would be expected, and represents the recently hatched fish moving in to the inshore shallows to begin their first year's growth. Toward the end of the summer they have grown large enough to leave the shallow water and have thus begun their movement out of the marshes to deeper water. Such a relationship between depth and size of individuals of this 0-year class will be discussed in detail below.

As mentioned above and in the section on spawning, and as shown by a compilation of pinfish catch records from the *Oregon*, there is a tendency for the frequency of capture of large pinfish in deep offshore water to increase in the winter months. Really large pinfish (200 mm. or over) are rarely taken inshore other than in certain deep channels and holes in banks in close proximity to deep, unprotected, offshore water. Even then, these large inshore-caught fish are usually taken only in the late spring and early summer, and in areas where they are taken in the colder months, there appears to be deep water particularly close inshore.

ECOLOGICAL HABITATS AT CEDAR KEY, FLORIDA.—Regular trips were made to Cedar Key from February 1953 through April 1954. Some 25 visits were made to five regular stations comprising different habitats described below, and several other stations were sampled sporadically. Collections were made at each regular station at least once each month, and whenever conditions permitted, each was visited twice. All stages of tide were included at some time during the study, though a midtide to high tide was usually selected in order to permit efficient operation of the boat. Comparisons between day and night collecting were made in the same 24-hour period, but no significant difference was found in the results obtained for the pinfish, though other species varied somewhat in relative abundance.

Though most of the habitats visited at Cedar Key have been described by Reid (1954), Moody (1950), Kilby (1955), and Caldwell (1955a), a brief description of them as they actually appeared during this study is given here. Stations regularly visited were:

*Inshore channel.*—Several channels cut through the shallow flats and banks of the semienclosed bay area at Cedar Key. The depth at the station visited ranged from 7 to 20 feet, though it averaged about 14 feet at mean low tide. The bottom was hard, of sand or sandy mud and rock, with considerable shell detritus. Except for occasional bits of algae, permanent vegetation was practically nonexistent, though on several trips large amounts of uprooted spermatophytes were floating there. During the study the water temperature, when the station was visited, ranged from 14.1° to 30.6°C. and the salinity from 24.4 to 31.0 parts per thousand. Turbidity was usually fairly high.

*Edge of channel.*—The vegetation at this station near Seahorse Key (see Reid, 1954:4, for map of the Cedar Key area) consisted primarily of various forms of algae, predominantly brown. This type of vegetation persisted during the entire year, with a slight reduction in its abundance during the early spring. Some manatee grass (*Cymodocea*) and turtle grass (*Thalassia*) were present during the late spring and in all summer months, though at no time did their bulk outrank the algal covering. No slimy coating appeared on this vegetation as it did on that of the protected and unprotected shallow flat stations. The bottom consisted primarily of muddy sand with some shell detritus. The depth normally varied from 3½ to 9 feet, with an average of about 4½ feet at mean low tide. The water temperature at the station, when it was visited, varied from 14.1° to 30.3°C. and the salinity from 24.0 to 31.1 parts per thousand. This habitat is similar to the deep flat to be described below, except that it receives the stronger tidal sweep associated with the channels, and as a consequence, turbidity at this station was usually quite noticeable. This was particularly true in winter, when turbidity was generally higher than in the summer months. This seasonal variation was possibly due to the general degeneration of the rooted bottom vegetation in winter, which thus tended to bare the bottom and permit a more thorough disturbance of it by wave action and currents.

*Deep flat.*—This station, located off the west side of North Key (Reid, 1954:4) varied in depth from 3 to 12 feet, with a depth of approximately 4½ feet at mean low tide. As Reid (1954:5) notes, this habitat type is never exposed, even at the lowest tides. The bottom at the station consisted of muddy sand and considerable shell debris. The vegetation there was a lush growth of manatee grass and some turtle grass in the late spring and summer, but was nearly replaced in the fall and winter by heavy growths of brown algae. At no time was a slimy coating found on this vegetation. The water temperature varied from 15.6° to 31.4°C. and the salinity from 25.4 to 31.0 parts per thousand. As at the station on the edge of the channel, the turbidity increased in winter, but it was even less noticeable in the summer than on the channel edge.

*Unprotected shallow flat.*—This station, located off the northwest end of Seahorse Key (Reid, 1954:4) showed a depth at mean low water of 2 to 3 feet. Occasionally, at the lowest winter low tides, this habitat may be partially exposed, though maximum depths of 8 feet were recorded during some high-tide collections. In the summer, the muddy-sand and shell bottom supported thick growths of turtle, manatee, and shoal (*Halodule*) grasses, with some patches of brown algae. In the cold months, the spermatophyte covering was nearly lost and was replaced by heavy patches of brown algae covered with a slimy coating—apparently filamentous algae—which persisted into the spring. This coating was absent from all the vegetation of the flat during the summer. Turbidity varied from none to pronounced, depending on the action of the wind and waves on the shallow waters there. Water temperatures ranged from 14.4° to 32.5°C. and salinity from 22.7 to 31.1 parts per thousand during the visits to this station.

*Protected shallow flat.*—The station visited during this study was located off the end of the airstrip, on Way Key, near Reid's (1954:4) Shallow Flat Number One. Except that the station was well protected by land and close to oyster bars, which the pinfish seemed to avoid in general, this protected flat was nearly identical in vegetation and bottom to the unprotected shallow flat described above. Even the winter and spring slimy coating was present on the vegetation. Depth ranged from 2 to 6 feet and was approximately 2½ feet at mean low tide. Like the unprotected shallow flat, this station was partly emerged at times during the winter. The range of water temperatures during the visits was 17.4° to 36.9°C. and the salinity 18.4 to 30.2 parts per thousand.

Habitats visited only late in the study were:

*Offshore channel.*—Located approximately 1½ miles south of Seahorse Key (Reid, 1954:4), outside the protection of the islands, this station was visited only from November 1953 to April 1954. The bottom was sand and shell, and the depth varied from 12 to 16 feet, with an average of about 14 feet at mean low water. No spermatophytes were found there, and only sparse patches of brown algae. Turbidity was highest in winter, though some was present during the entire sampling period. Water temperature during these visits ranged from 14.5° to 25.9°C., and salinity varied between 25.8 and 31.8 parts per thousand.

*Open beach.*—Several winter and early spring collections were made at the edge of the water on the sandy beach exposed to the open Gulf on the south side of Seahorse Key. The bottom at the station was of mud or mud overlain by sand, and in the latter case was fairly hard. There was no rooted vegetation, although some patches of uprooted spermatophytes and algae, or decaying plant debris, were usually present near the edge of the water. The depth was only a few inches. Water temperature ranged from 17.2° to 30.2°C. and salinities from 26.0 to 29.9 parts per thousand. Except in December, when turbidity was high, the collections were made in rather clear water.

*Protected beach.*—Several late winter and early spring collections were made at the edge of the water near a dock in the well-protected cove on the north side of Seahorse Key, near the present Seahorse Key Marine Laboratory. The locality had been dredged and the collections were made along the edge of the dredged, muddy sand beach. Black mangroves (*Avicennia*) were nearby, but there was no other water-associated vegetation in the immediate vicinity. There were only occasionally sparse bits of floating weed. The depth ranged from a few inches to 2 feet. The water temperatures varied from 16.8° to 27.6°C. and the salinity from 25.5 to 29.5 parts per thousand. No turbidity was encountered when the collections were made.

Habitats similar to some of the above were visited at Cedar Key (in addition to the regular stations); at other Florida localities; near Beaufort, North Carolina; at Brunswick, Georgia; Pascagoula, Mississippi; and Port Aransas, Texas. Though these collections were sporadic, whenever habitats similar to the regular Cedar Key stations were compared for the same month in the year, similar results were obtained. Thus it is assumed that the ecological requirements of pinfish of the same size are similar throughout its range, where conditions permit.

DISTRIBUTION OF THE 0-YEAR CLASS AT CEDAR KEY.—No fish smaller than 11 mm. was taken at Cedar Key. Only one specimen this size was taken, the smallest regularly captured were 12 mm. in length. Furthermore, the length-frequency curves of this year class are abruptly cut off at this length, giving the impression that only a part of the expected normal curve is present (fig. 14). This is further evidence for the occurrence of the small fish somewhere other than inshore, and so, obviously, offshore (see section on spawning). These 12 mm. pinfish were found regularly only on the open and protected beaches and on the protected and unprotected shallow flats. They first appeared on the unprotected shallow flat and on the open beach in December, but were not taken on the protected shallow flat until January. Collections were not begun at the protected beach stations until February, but the young fish were there then. As Hildebrand and Cable (1938:525) noted for those at Beaufort, North Carolina, the postlarvae appear to settle more or less near the bottom on arriving inshore, thus forsaking their assumed planktonic existence offshore. Specimens as small as 16 mm. continued to appear on both shallow flats until May, though by that time some of the early-hatched fish had reached a length of approximately 65 mm. No pinfish of any size were taken at the beach stations after April, though ones as small as 11 mm. were taken in that month on the open beach. Two specimens, 15 and 19 mm. long, were captured on the deep flat in April, but none under 43 mm. were taken there at any other time. No specimens smaller than 54 mm. were taken at either channel station at any time, though Hildebrand and Cable (1938:525) found young 12 to 16 mm. long in the channels at Beaufort in winter. As found at Beaufort, the young pinfish taken at the unvegetated beach stations at Cedar Key were unpigmented and shallow bodied, while those taken on the grassy flats were nearly all pigmented and the body showed a definite tendency toward deepening.

Once appearing on the grassy shallow flats, members of this year class continued to be taken there the rest of the year. However, as they grew larger, many, or most of them, moved onto the deeper channel edge and deep flat. They first appeared in numbers in these two habitats in May, when the smallest on the deep flat were 43 mm. and those on the channel edge were 29 mm. The maximum size in this year class in that month was almost the same at the two stations. Assuming that the movement by the large fish from shallow to deep water is a gradual one, the presence of smaller fish on the channel edge in the same month might be expected. This habitat is on a slope, and in collecting, specimens from varying depths would be taken in the same haul, while at the deep flat station the depth remained essentially constant during a haul. Further evidence for a movement into deeper water as growth progressed lies in the fact that the numbers of small fish at the various stations remained relatively constant during the summer taking predation into consideration. Thus, the new recruits to the population—those spawned later—apparently maintained the population of small individuals on the shallow flats while the older and larger individuals moved onto the deeper flat and channel edge, there forming a population of large fish. This population did not appear until much later in the season, and must, therefore, necessarily have consisted of the early-spawned fish found on the shallow flats earlier in the season. Furthermore, by the end of the summer the population on the deep flat and channel edge had increased in relative numbers, while that on the protected shallow flat had diminished greatly. On the more offshore unprotected shallow flat, the population size remained relatively constant, though the mean size of the fish increased since there was no further recruitment from spawning. At this later season, although the fish from the populations on the deep flat and channel edge had a slightly longer mean length, those of the shallow flat were much more similar in size to them than they had been earlier in the summer. It is assumed that the old fish had moved by then into even deeper water, and that the wide gap in mean size between the two populations, as seen earlier in the season, was now being closed. The remaining fish were those spawned late in the season and thus were more nearly the same age in both localities. Fish of this age group were not taken in the inshore channel until November, when specimens no smaller than 72 mm. were collected. Smaller individuals (54 mm.) were taken there in January, and it is assumed that their presence in the deep channel was brought about by the cold winter weather. Large (63 mm.) specimens of this year class were present in the offshore channel when it was first visited in November. Though a few remained, the populations of this year class were almost obliterated in the winter on the shallow flats, and they were greatly reduced on the deep flat and channel edge. This is probably the result of growth with its associated movement into deeper water, and the general offshore movement of all age classes during the cold months of the year.

It must be remembered that despite these general population trends, some fish seem to remain in the shallow inshore water during their entire first year of life or longer, or they migrate back into it after an initial offshore movement. Kilby (1955:223) found such a situation in and near the marshes at Cedar Key and at Bayport, and such older fish were also found there during this study.

Distribution of Older Year Classes at Cedar Key.—As was mentioned in the section on spawning and in the general remarks on seasonal distribution made earlier in this section on ecology, the larger fish tend to occur in deeper water. However, as is shown in figure 14, some members of the 0-year class seem to remain inshore at least into their second year and to continue growth after the winter slowdown (see section on growth rate), or as noted above, move back inshore. If this latter is the case, a constant shuttling of the larger 0-year class fish back inshore as the developing ones leave for the first time could give the impression in graphs, such as figure 14, that the population of older 0-year class fish consisted of the same individuals. Such a question might be answered by a tagging study coupled with collections made farther offshore than equipment available during this study at Cedar Key permitted. How long these older fish remain inshore, if they actually do so, is unknown, though a definite third age group is shown for the month of June in figure 14. A few of these older fish—probably at least in their second year—were found on the shallow flats in summer. More were taken on the deep flat and channel edge, and the majority were taken in the channels. In winter, a few remained on the shallow and deep flats and channel edge, though most members of the generally reduced winter population appeared in the channels.

The general graphic appearance of the populations of pinfish on the shallow flats, deep flat, and channel edge is essentially the same as that shown when all the Cedar Key length-frequency data are combined, even to the presence of a few large, and thus older, fish in the shallow waters after their first year, figure 14. Such variation as does occur from the trends shown in figure 14 lies in the differences in sizes of the fish and times the first members of the 0-year class appear, as discussed above. The charts for the channel stations are not as complicated, and are amply represented by the older year classes shown in figure 14.

These findings for the distribution of the various size groups, while somewhat more detailed, are comparable to those of Kilby (1955:223) and Reid (1954:44) in Florida, Gunter (1945:63) in Texas, and Hildebrand and Cable (1938:524) in North Carolina.

## Growth Rate

Growth rate curves (fig. 15) for the 0-year class at Cedar Key were prepared by using the means of the monthly samples of this age group. The size limits of the classes each month were determined from the length-frequency curves presented in figure 14.

On a mean basis, a length of approximately 70 to 75 mm. was attained by the end of the first summer, though it is apparent from an examination of figure 14 that a length of 90 to 95 mm. could be attained—supposedly by the older individuals—while some—presumably the younger individuals—reached a length of only 50 mm. by winter. By the end of the first full year, the older ones reached a length of 100 to 110 mm. while the younger ones attained lengths of 65 to 70 mm. These findings are comparable to those of Kilby (1955:223) in Florida, though Hildebrand and Cable (1938:519) indicate a slightly faster average growth rate for pinfish in North Carolina, though their ranges of variation are rather similar to those at Cedar Key.

It can be seen in figure 14 that there is a general cessation of mean growth in winter by the members of the 0-year class which are presumed to remain (see discussion of ecological distribution at Cedar Key) in the shallow inshore waters. Growth is apparently resumed, however, with the onset of warm weather.

After the first year the growth rate seems to decrease. It is apparent from an examination of the June sample, shown in figure 14, that by the second year a mean increase of only about 50 mm. over the first year has taken place, and that by the third year one of only about 45 mm. over the second year has occurred. Unfortunately, large samples of the large-sized fish were not available for comparable study, but assuming an increase in length of approximately 45 mm. per year is made by pinfish after their first year, the largest specimen now known (328 mm.) would, at a minimum, be approximately in its seventh year. However, since animals usually exhibit a sigmoid type of growth curve, with the older members of the species growing slower than the middle age group, this large, 328 mm. pinfish may actually have been even older than indicated here.

## Length-Weight Relationship

Though only a few specimens were so examined, a large enough series in several size groups was studied to present a useful formula

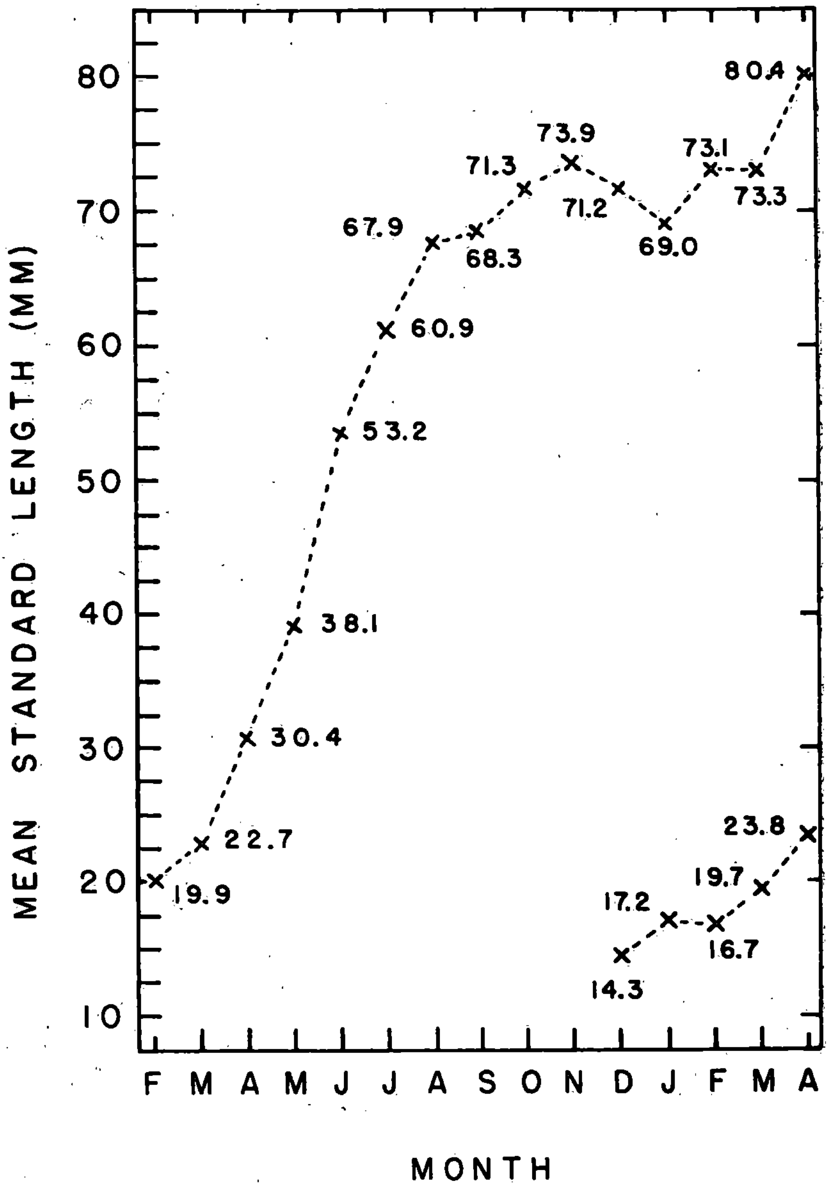



Figure 15.—Growth rate of the 0-year class of *Lagodon rhomboides* (L.) at Cedar Key, Florida, during 1953 and 1954. The mean standard length for each month is indicated at each point on the curve.

for the comparison of standard length and weight in pinfish after preservation in formaldehyde. This in turn is a valid approximation of the relationship between standard length and live weight. This relationship may be expressed by the formula

$$\log W = -4.3734 + 2.9136 \log L$$

where $L$ equals standard length and $W$ equals weight after preservation.

Hildebrand and Schroeder (1928:266) list a few lengths and weights of fresh pinfish from Chesapeake Bay. The lengths are presumed to be total lengths and are given in inches; the weights are in grams. When these lengths and weights are converted to standard length in millimeters and weight in grams, similar results are found in comparison with the preserved length-weight relationship noted above.

## Body Weight–Body Surface Area Relationship

Gray (1953:286) found, at least in pinfish from 49 to 58 grams in weight, that there is an average value for $K$ of 7.5 (varying from 7.0 to 8.0), and that this value could be substituted into the formula

$$S = Kw^{2/3}$$

where $S$ equals the area of the body surface and $w$ is body weight, thus permitting the calculation of body weight or body surface area when one or the other is known.

## Food Habits

The pinfish is apparently completely catholic in its food habits. So many food items, both animal and plant, have been recorded in the literature for it, that it is evident that almost anything that is edible is included in the diet of this species. The bulk of the food, however, apparently consists of small animals, particularly crustaceans, which seem to be associated with the usually grassy habitat of the pinfish, and the plant materials present in stomach contents may be, at least in part, incidentally ingested during the capture of the animal food.

The contents of a number of stomachs from various localities were examined, although no systematic food study for pinfish was made during this study. No major types of food previously unreported by the following authors were added to the list, however. The only variation in food between localities would be in the specific forms of copepods, mollusks, fishes, etc., found in different geographical regions.

Gunter (1945:64) reports razor clam shells, algae, and grass as being eaten by pinfish in Texas. Reid (1954:46) found that amphipods, copepods, shrimp, and crabs were the major food items for 15 to 128 mm. pinfish at Cedar Key, though he also found pelecypod and gastropod mollusks, fishes, and plant detritus in the stomach contents of pinfish examined which were over 50 mm. in length. He also found some stomachs containing organic detritus and mud, which was probably ingested accidentally by the fish as it pursued some burrowing animal. Goode (1884:394) reported that in the Indian River region of Florida, pinfish feed on "minnows, small crabs, and shrimps." McLane (MS:317–18) found isopods, amphipods, copepods, decapods, marine polychaete worms, chironomid larvae, and algae and other plant material in the stomachs of *L. rhomboides* he examined from the fresh or nearly fresh waters of the St. Johns River. Holbrook (1860:62) noted that pinfish in South Carolina fed upon "various crustaceous animals, and on smaller fish." In North Carolina, Smith (1907:300) reported *L. rhomboides* eating "small fish, worms, crustaceans, mollusks, and seaweed," while in pinfish stomachs from Beaufort in particular, Linton (1905:380) found gorgonia spicules, bryozoa, sea urchin spines, bivalve mollusks, gastropods, annelids, amphipods, copepods, crabs, shrimp, fish, vegetable material, faeces (from stomachs of fish taken at the laboratory wharf), and sand (some with associated foraminifera). In Chesapeake Bay, Hildebrand and Schroeder (1928:265) found that pinfish stomachs contained vegetable debris, crustaceans, mollusks, and annelids, in that order of abundance. Louis Mowbray wrote me in 1954, that pinfish at Bermuda feed on "small mollusks and worms, etc." Writing of pinfish in general, LaMonte (1945:72; 1952:116) and Gabrielson and LaMonte (1950:58) report its food as consisting of small fishes, crustaceans (crabs, shrimps, barnacles), mollusks (clams and others), and worms.

## Feeding Habits

As Gunter (1945:64) suggested, *L. rhomboides* is a grazer. This is evidenced by the wide range of food items, the form of the teeth, and by actual underwater observations of their feeding behavior.

When the food item is small enough, it is taken whole, and since many such small items appear complete in pinfish stomachs, they must also be swallowed whole. However, larger food items are nibbled —a process aided considerably by the sharp incisor teeth—and thus much of the food found in the stomachs is fragmentary, and obviously not made so through normal processes of digestion. I have observed pinfish nibbling at organisms growing on rocks, and the notoriety of this species as a bait stealer is widespread. In captivity they also nibble at the fins of other fishes confined with them (see economic section), and Hildebrand and Cable (1938:519) have pointed out that pinfish were a particular nuisance to an investigator working at Beaufort in that they continually mutilated caged crabs being used in experiments. They did this by biting off the legs and other appendages of these crustaceans which projected through the cages, and these writers note that the fish went so far as to swim completely upside down in order to get at the crabs, from underneath the suspended cages.

Pinfish seem to be voracious feeders; in the wild and in captivity I have observed tremendous numbers of them converge suddenly on a single small bit of food thrown into the water above them. I have observed, while fishing for them with hook and line, that an individual from quite deep down will often follow a retrieved bait almost to the surface before returning to the bottom from which it came. John D. Kilby tells me that at Beaufort, North Carolina, he observed a large aggregation of pinfish feeding in a channel near the surface on small red oligochaete worms which were being swept along by the tide. He noted that the fish were "popping" at the surface while catching the worms, much as do fresh-water bream.

On several occasions, while handlining for pinfish, I noted that they were biting well until the sun began to set. When this happened the fishing suddenly slacked off, and by dusk no pinfish would bite, though other species continued to do so. Pinfish, both in aquaria and under natural conditions, when observed with a light after dark, were quite inactive. Furthermore, their pattern of stripes and bars was much more pronounced during this period of assumed vulnerability than it had been during the day, and perhaps as a camouflage is related to their usual habitat of vegetation. Longley and Hildebrand (1941:133), observing pinfish in aquaria at Tortugas, noted this intensification of bars at night and remarked upon the physical means by which it is accomplished.

## PREDATORS

Only a few predators on pinfish have been listed, though there is little doubt that the extreme abundance of this species throughout most of its range must make it a common food item in the yet unrecorded diets of the many piscivorous fishes and the large piscivorous birds.

Some fishes which are known to have consumed pinfish under presumably natural conditions are: sailfish, *Istiophorus americanus* (Cuvier), reported by Voss (1953:229); spotted sea trout, *Cynoscion nebulosus* (Cuvier), listed by Moody (1950:167); Gulf hake, *Urophycis floridanus* (Bean and Dresel), by Reid (1954:23); toadfish, *Opsanus beta* Goode and Bean, reported by Reid (1954:64); and the Gulf flounder, *Paralichthys albigutta* Jordan and Gilbert, by Reid (1954:66). In that the pinfish is the preferred bait in many places for grouper, snook, and tarpon, as well as the above mentioned trout, it must form an important part of the natural diet of these fishes, where their ranges coincide with that of *L. rhomboides*.

Scattergood (1950:507) reported pinfish from the stomachs of the double-crested cormorant, *Phalacrocorax a. auritus* (Lesson), and I have identified as *L. rhomboides*, fish which Charles Wharton of the University of Florida tells me were dropped by nesting cormorants at Cedar Key. Howell (1932:87) listed pinfish as being preyed upon by the eastern brown pelican, *Pelecanus occidentalis carolinensis* Gmelin, (based on a record by Pearson, 1919). Howell (1932:95) also includes the man-o-war bird, *Fregata magnificens rothschildi* Mathews, as a pinfish predator, and Longley and Hildebrand (1941:133) noted one of these birds attempting to pick up a floating pinfish.

It is interesting to note that Gunter (1942b:274) did not list *L. rhomboides* among fishes from the stomachs of 29 Atlantic bottlenose dolphins, *Tursiops truncatus* (Montague), from Texas, despite the abundance of pinfish in the coastal waters of that state in habitats visited by porpoises while presumably feeding. These findings can thus be correlated with remarks made by the late Arthur McBride, then curator of Marine Studios, Marineland, Florida, who once told Stewart Springer that the captive *T. truncatus* there would not eat pinfish, neither those alive in the tank nor the fish when offered to them dead. A similar situation has been found by the staff of the Florida's Gulfarium, at Fort Walton Beach, where the captive porpoises of this same species do not seem to bother the numerous live pinfish in the same tank. These mammals do catch and eat other species of fish in the tank. The porpoises there, however, have eaten dead pinfish on occasion, when the fish were offered by the porpoise trainer. Perhaps these quite intelligent mammals have found by experience that the sharp spines of the pinfish are so disagreeable when the fish are being caught or swallowed that they avoid this species on later encounters. This behavior is contrary to that reported for the spotted dolphin, *Stenella plagiodon* (Cope), which was observed apparently feeding on individuals from surface-swimming aggregations of pinfish, offshore in the Gulf of Mexico (Siebenaler and Caldwell, 1956:127; Springer, 1957:170).

Reid (1954:84) points out that man also must be considered as a fish predator of importance. Since pinfish are commonly taken and eaten by fishermen, widely used for fishing bait, and are accidentally killed in great numbers during certain commercial fishing operations, man must therefore be included as a predator on this species.

## Associated Fish Species

Since the pinfish has such a wide range of ecological tolerances, and thus variety in the habitats in which it is taken, it is necessarily found in association with an extremely wide variety of fish species.

Several species were taken quite frequently in the same collections with pinfish at Cedar Key—and in other areas sampled where their ranges overlap—though usually not in as large numbers as *Lagodon*. These associated species were: pigfish, *Orthopristes chrysopterus* (L.); silver perch or yellowtail, *Bairdiella chrysura* (Lacépède); common filefish, *Stephanolepis hispidus* (L.); Florida pipefish, *Syngnathus floridae* (Jordan and Gilbert); Scovell's pipefish, *S. scovelli* (Evermann and Kendall); and the common mojarra, *Eucinostomus gula* (Quoy and Gaimard). At the Cedar Key open beach station, large numbers of the postlarval spot, *Leiostomus xanthurus* Lacépède, were taken with the postlarval pinfish.

Whether these associations were beneficial or harmful to the pinfish could not be determined, and actually, the associated species probably simply share the characteristic habitat types associated with pinfish occurrence.

## Parasites

An effort was made to collect any parasites seen, although a detailed study of such organisms on pinfish was not attempted. Though internal parasites were not taken, some have been reported from pinfish by various authors. The external parasites which I collected were very kindly identified by David Causey of the University of Arkansas. His identifications are included in table 7, a list of internal and external parasites obtained from the literature, and undoubtedly incomplete.

It may be significant to note that only a few externally parasitized pinfish—and then only small individuals—were found during this study despite a cursory examination of thousands of specimens. Chandler (1935:125) found that all of the pinfish which he examined for parasites from Galveston Bay, Texas, were free of them, and *L. rhomboides* as a host has been noticeably absent from lists of parasitized marine fishes from various regions throughout its range, and

TABLE 7

PARASITES KNOWN FROM THE PINFISH, *Lagodon rhomboides*.

| SPECIES | LOCATION ON FISH | LOCALITY | AUTHORITY AND CITATION |
|---|---|---|---|
| Phylum Protozoa | | | |
| Class Sporozoa | | | |
| Order Myxosporidia | external | CK | Causey, this paper |
| Phylum Platyhelminthes | | | |
| Class Trematoda | | | |
| Order Monogenea | | | |
| *Pseudohaliotrema carbunculus* Hargis | gills | AH | Hargis, 1955:189 |
| Order Digenea | | | |
| *Lepocreadium ovalis* | intestine | B | Manter, 1931 |
| *Lepidauchen hysterospine* | intestine | B | Manter, 1931 |
| *Distomum monticellii* Linton | intestine | B | Linton, 1905:381 |
| *D. appendiculatum* Rudolphi | ? | B | Linton, 1905:382 |
| *D. vitellosum* Linton | intestine | B | Linton, 1905:382 |
| *D. pyriforme* Linton | ? | B | Linton, 1905:382 |
| *D. corpulentum* Linton | ? | B | Linton, 1905:382 |
| *Distomum* sp. | ? | B | Linton, 1905:382 |
| *Cymbephallus vitellosus* (Linton) | ? | WH | Linton, 1940:76 |
| Class Cestoidea | | | |
| *Scloex polymorphus* Rudolphi | intestine | B | Linton, 1905:381 |
| *Rhynchobothrium* sp. | visceral cysts | B | Linton, 1905:381 |
| *Otobothrium crenacolle* Linton | cysts | B | Linton, 1905:381 |
| *Tetrarhynchus bisulcatus* Linton | cysts | B | Linton, 1905:381 |

in those papers in which it is mentioned as a host, it is noted as being only rarely so.

## BEHAVIOR

Though no systematic studies of pinfish behavior were made, the following notes concerning this subject were accumulated.

### Territoriality

Although it was not always exhibited, and only a few individuals in an often large aggregation showed the tendency when it was seen, a defense of a definite territory was observed for pinfish under both

TABLE 7 (Continued)

PARASITES KNOWN FROM THE PINFISH, *Lagodon rhomboides*.

| SPECIES | LOCATION ON FISH | LOCALITY | AUTHORITY AND CITATION |
|---|---|---|---|
| Phylum Nematoda | | | |
| *Ascaris* sp. | body cavity on viscera | B | Linton, 1905:381 |
| Phylum Acanthocephala | | | |
| *Echinorhynchus pristis* Rudolphi | intestine | B | Linton, 1905:380 |
| *E. sagittifer* Linton | on viscera | B | Linton, 1905:381 |
| Phylum Arthropoda | | | |
| Class Eucrustacea | | | |
| Subclass Copepoda | | | |
| *Caligus praetextus* Bere | external | CK | Causey, this paper |
| *Caligus praetextus* Bere | ? | E | Bere, 1936:583 |
| *Hatschekia linearis* Wilson | gills | AH | Pearse, 1953:219 |
| *Lernanthropus amplitergum* Pearse | gills | AH | Pearse, 1953:213 |
| *Lernaeenicus polyceraus* Wilson | external | CK | Causey, this paper |
| *Argulus funduli* Kryer | ? | E | Bere, 1936:577 |
| *A. varians* Bere | ? | E | Bere, 1936:579 |
| Subclass Malacostraca | | | |
| *Agathoa medialis* Richardson | gills | AH | Pearse, 1953:233 |

CK refers to Cedar Key, Florida; E, to Englewood, Florida; AH to Alligator Harbor, Florida; B, to Beaufort, North Carolina; and WH, to Woods Hole, Massachusetts.

wild and captive conditions. It was shown by large and small individuals, though it seemed to be the larger members of any aggregation—whether made up of a single age group or of mixed ages—which defended a territory (Allee and Dickinson, 1954). The territory defended was usually small, only a few lengths of the defender in all directions, but it was zealously guarded. The defender chased the intruders well away and returned rapidly to his original position. Often, especially when large numbers of fish were present, the defender was kept continually busy chasing invaders, while his neighbors, which were apparently not defending territories, freely intermingled and held more or less their approximate position, either while feeding or resting. Though the water for some distance over them was also defended, the examples of territoriality observed consisted of the defense of a small patch of bottom vegetation, an area around a rock or other piece of detritus, or even a patch of clear bottom. Never was a section of open midwater seen defended. Furthermore, the tendency seemed to be to chase other pinfish, but not other fish species, and in no case was an attack seen made on an intruding invertebrate or member of another class of vertebrate. In one instance, in the large main tank at the Florida's Gulfarium, a large pinfish successfully defended the top of a rock for as long as observed (sporadically for a number of hours) against all other pinfish—a few slightly larger, but most smaller. No attack was made on pigfish, *Orthopristes chrysopterus* (L.), many smaller than the defender, or on larger spadefish, *Chaetodipterus faber* (Broussonet), and sheephead, *Archosargus probatocephalus* (Walbaum), which violated the territory. In other smaller and more confining tanks, wandering crabs, mollusks, and baby sea turtles were apparently ignored by pinfish defending a territory. In another instance a large number of small pinfish (approximately 30 to 40 mm. in length) were being kept temporarily in two 5-gallon carboys. One fish in each container exhibited tendencies of holding a small territory consisting of an open patch of bottom—there was no cover of any kind in the jars. All fish—only pinfish were present—that came near the defender were chased vigorously, though the defender did not stray far from his territory in order to chase the intruders. Several prolonged defender-intruder contacts were noted in which the two individuals swam in tight counterclockwise circles, head to tail, with their bodies parallel. In all such encounters the intruder finally departed. As noted above, the defender was one of the larger specimens in the tank.

Observations on territoriality, similar to the above but under natural situations, were made using diving gear.

## Flashing

Pinfish are often seen to "flash," particularly on bright days. This phenomenon is the result of their turning on their sides so that the sun glints on their silvery flanks, and it is most obvious to the observer when the fished are viewed from above. When watching these fish, while in the water with them or through the portholes of large oceanariums, it was apparent to me that most fish while flashing were either avoiding a territory defender or were rising rapidly to feed on some midwater food item. Such behavior was exhibited by single individuals and by various-sized groups acting on a single stimulus.

## Burying and Hiding

While cleaning the bottom of a small aquarium containing four pinfish, I accidentally hit one with a suction tube. The fish immediately buried itself in the deep sand on the bottom of the tank. The burial, which was complete, was accomplished by quick movements of the tail—almost faster than the eye could follow—which drove the fish headfirst into the sand, on its side. The fish was entirely hidden, with no sand mound to mark its location, and it remained completely buried for ten minutes before I prodded it to try to get it to uncover. With repeated proddings, the fish moved enough to expose the edge of the opercle, the edge moving in a normal manner—an inward and outward motion—which disturbed the sand and made the presence of the body part more obvious. Next the mouth appeared, with sand grains, possibly eventually expelled through the gill cover, flowing into it, and then the eye. The fish remained completely motionless until it was entirely uncovered. As long as any part of it was hidden it remained quiet. On being completely uncovered it swam away in a normal manner. The process of burying was reinstigated several times simply by hitting the fish with a rod. John D. Kilby told me that he has seen pinfish bury in this manner in nature and also that he has seen them curl up in empty mollusk shells when disturbed. Thus, an effective protective mechanism—probably not employed except under extreme stress—has been developed by a species of fish usually free-swimming and not generally considered secretive in habit.

## Schooling

Pinfish often form quite large aggregations which might be termed schools, though these groups do not seem to operate under the common stimulus which seems to so instantaneously direct the large schools formed by some fishes (Morrow, 1948:27). Large aggregations made up of an estimated several thousand adult-sized pinfish were reported on one occasion swimming at the surface well offshore in the Gulf of Mexico (Springer, 1957:170). Springer notes, however, that ten fishermen aboard the vessel observed the aggregations and that none of them guessed the species forming them. Not until some of the fish were caught was it found that they were *L. rhomboides*. That such groups of pinfish were not expected at the surface was evidenced by the fact that there was over 100 years of fishing experience among the observers. However, the fact that the fish were on the surface rather than deeper down may have been an abnormal condition prompted by schools of porpoises apparently feeding on them (Springer, 1957:170; Siebenaler and Caldwell, 1956:127).

In another instance the *Oregon* encountered a bottom-dwelling aggregation of fish so large that it made a definite trace on a fathometer recording tape (fig. 16). The group was identified as consisting of pinfish since the trawl being dragged at the time was landed soon after seeing the trace, and large numbers of very active individuals of this species were taken, to the exclusion of practically all other species. The aggregation extended some three fathoms from its top to the sea bottom. Actually, the fish in the aggregation may have been taking advantage of some particularly suitable localized ecological situation, such as a rock pile or patch of debris, rather than forming a compact school over an open bottom.

Inshore, where suitable habitat is found, pinfish seem to occur so homogeneously and in such large numbers that definite schools or aggregations are indistinguishable. Compact groups such as those noted above have not been reported for this species in such inshore waters.

## Fossil Record

There have been two discoveries of fossil fish teeth referable to the genus *Lagodon* which indicate that it has existed relatively unchanged, at least in tooth form, in North America at least since the middle Miocene. The finds are referred to:

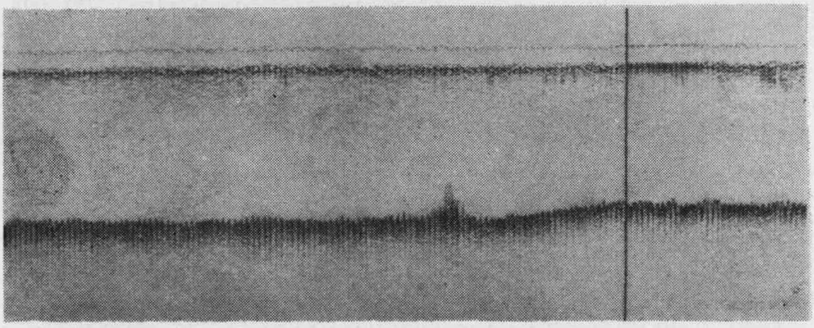


Figure 16.—Fathometer trace showing a bottom-dwelling aggregation of *Lagodon rhomboides* (L.). Made from the U.S. Fish and Wildlife Service M/V *Oregon* on 11 March 1954, at latitude 28° 19′ N., longitude 83° 30′ W., in 14 fathoms, at station 928 in the Gulf of Mexico.

## Lagodon *sp.*

The first of the two discoveries, and the oldest geologically, has been reported by Berry (1932) in a paper describing four teeth from the middle Miocene St. Mary formation (Chesapeake group) of Maryland. Though his excellent photographs of one of these teeth do indicate a form almost certainly referable to the genus *Lagodon,* Berry notes that it is unlikely that the only existing species of that genus, *rhomboides,* goes back unchanged to that time. However, he admirably does not elect to assign a specific name to this form merely on the basis of the few teeth. Though the teeth of a given specimen of *L. rhomboides* vary in width, it is interesting to note that the measurements given by Berry indicate that the Miocene tooth belonged to a fish within the size range of *L. rhomboides.* A tooth from a 239 mm. pinfish measured 1.4 mm. in greatest width, and one from a fish 206 mm. in length measured 1.5 mm. The Miocene tooth was 1.2 mm., which indicates that it belonged to a fish approximately 175 mm. in length, assuming the fish was similar in proportions to the pinfish.

## Lagodon *cf.* L. rhomboides

Two teeth (UF 2232), so similar to those of *L. rhomboides* that they must tentatively be ascribed to this species, were collected by Walter Auffenberg, of the University of Florida, at a locality near the village of Haile, Alachua County, Florida. The locality, Pit VI, A, located in SW ¼, Sect. 24, R. 17 E., T. 9 S., is in the Alachua formation and of Pliocene age. Goin and Auffenberg (1955:500, 503), in describing this deposit, note that it is of freshwater origin, and Auffenberg (1955:135) more particularly notes that it "apparently represents a fluviatile or sink-hole deposit." In view of the presence of the presumably essentially marine *Lagodon* cf. *L. rhomboides*, it would appear that the deposit, while still reasonably referable to fresh water, was originally a spring or freshwater stream relatively close to salt water and with a direct connection to the sea. *L. rhomboides* is known to penetrate such waters (Herald and Strickland, 1950:106; Gunter, 1942a:315; McLane, MS:316; and section on ecology in this paper). Cooke (1945:112) indicates that the Pliocene marine shoreline of eastern Florida was much nearer this locality than that shoreline is today. Although their condition is similar to that of the freshwater fossils and does not indicate long-term waterwear, the possibility cannot be overlooked that the marine teeth may be in the essentially freshwater deposit as the result of fresh water reworking a marine deposit just previously laid down, or to a short-term marine inundation of the locality just after the deposition of the freshwater forms. In either case the slight wear on all the fossils is similar, though they may be of different ages and from different ecological conditions.

Most authors (for example, Eigenmann and Hughes, 1888:66) note that all of the incisor teeth of *L. rhomboides* are deeply notched. An examination of numbers of specimens of this species shows that this is not necessarily the case, and teeth from very small individuals may be trinotched rather than singly so (see section on morphology). While the teeth nearest the midline seem always to be distinctly notched to some degree—not necessarily deeply—the more posterior ones may be unnotched, though, in anterior aspect they are triangular above the base like the notched front teeth (fig. 19). In the few large pinfish examined, it is apparent that in those teeth which are clearly notched, the notching becomes progressively more noticeable as the fish becomes larger, as does a definite dorsoventral furrow in the midline of the tooth (fig. 17). A similar furrow is shown on the Miocene tooth illustrated by Berry (1932:304) and on the two deeply notched Pliocene teeth (fig. 18). All of the fossil teeth and those from modern *L. rhomboides* show a cutting edge which slants upward to one corner. In the modern teeth, and presumably so with the fossil ones, the highest side is toward the anterior part of the mouth (fig. 19). Both Pliocene teeth measure 1.7 mm. in greatest width; and assuming the fish to which they belonged had proportions similar to *L. rhomboides,* and taking into consideration the variation in tooth size within a single specimen, they represent a fish approximately 200 to 250 mm. in length, well within the size range of *L. rhomboides.*

According to family descriptions given by Jordan and Evermann (1896b, 1898, 1900), there are only a few families of fishes with members which have incisor teeth and which occur in the waters of North and middle America. A number of these occur in Florida—the Pomacentridae, Acanthuridae, Ostraciidae, Balistidae, Aluteridae, and the Kyphosidae. All are marine groups, however, and are presently unrecorded from fresh water in North and middle America (Gunter, 1956). Two other marine families with representatives in North

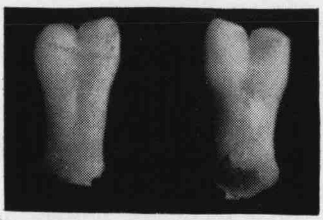


Figure 17.

Figure 18.

Figure 17.—Anterior incisor tooth from a 206 mm. specimen of *Lagodon rhomboides* (L.) from Vero Beach, Florida. Left, anterior aspect. Right, posterior aspect.

Figure 18.—Two teeth of *Lagodon* cf. *L. rhomboides* from a Pliocene fossil locality at Haile, Alachua County, Florida. Left, anterior aspects. Right, posterior aspects.

and middle America have incisor-toothed members. One of these, the Embiotocidae, is presently restricted to the Pacific. The other, the Pleuronectidae, though having members in Florida, has its incisor-toothed representatives restricted to the Pacific, according to Jordan and Evermann (1898:2602). Two other families, the Characidae and Cichlidae, are of primarily freshwater fish, but penetrate North America only to southern Texas (Knapp, 1953). Members of the family Cyprinodontidae which have incisor teeth enter Florida fresh waters. I have examined specimens of incisor-toothed representatives of all of the above named families, with the exception of the Embiotocidae and Characidae, and find that their teeth are quite unlike the fossil ones in form and usually also in size. An examination of figures of characin incisors in Eigenmann (1917, 1918, 1921, and 1927) and in Eigenmann and Myers (1929) shows that these teeth are also unlike the fossils. The description of the teeth of an incisor-toothed embiotocid (Jordan and Gilbert, 1881) indicates that they too are unlike those of *Lagodon*. While some clingfishes, family Gobiesocidae, have incisor teeth, John C. Briggs, who recently did a worldwide revision of the entire group (Briggs, 1955), tells me that these teeth too are not at all like the Florida fossils.

Only the incisor teeth of members of the family Sparidae resemble the Florida specimens, and only four genera of western North Atlantic sparids possess this type of tooth. Of these, one is *Lagodon*. In the second, *Stenotomus*, in the material examined, the incisors of the two species, *S. chrysops* (L.) and *S. caprinus* Bean—both North American and restricted to salt water—are lanceolate, long and narrow, and are not broadly expanded toward their distal ends. A few teeth of large specimens of *S. chrysops* have a shallow rounded notch and a dorsoventral groove, though the narrow tooth could not be confused with the broadly expanded, triangular, sharply notched tooth of *Lagodon*. Since the remaining genera, *Archosargus* and *Diplodus*, are closely related to *Lagodon*, and since their teeth are similar in many respects, specimens of all species occurring on the Atlantic North American coasts, and the one species occurring in the Pacific, were examined in detail to see if there was any morphological overlap between their teeth and those of *Lagodon*. None was found in the material examined. Except for *D. argenteus* (Valenciennes) and *A. pourtalesii* (Steindachner) which were examined grossly, jaws of all of them were cleaned, and photographs made with teeth in place. As a result of this examination, the fossil teeth are clearly shown to belong to a species closely related to or identical with *L. rhomboides*.

In the case of *Diplodus holbrooki* (Bean), which has been recorded from a nearly freshwater spring in Florida (Caldwell, 1955a:76), and *D. argenteus*, which is unrecorded from fresh water in North and middle America (Gunter, 1956), the incisor teeth are not notched (fig. 20). Furthermore, they have incisors which, in anterior aspect, are more rectangular above the narrowed base than in *Lagodon*. Also, the upper part is proportionately longer in relation ot the base than in pinfish, and in lateral profile is rather strongly incurved toward the cutting edge—much more so than that of pinfish. Finally, there is a posterior buttress on the inner base of the tooth, which is absent in *Lagodon*.

The incisor teeth (fig. 21) of *Archosargus probatocephalus*, a sparid also recorded from fresh water in Florida (Gunter, 1942a:315), are similar to those of *Diplodus*. However, the rectangular upper parts are less strongly incurved in profile, the narrow base is longer in proportion to the upper part, and a slight notch may appear in teeth of large fish although the furrow and the precise notch shown in *Lagodon* teeth are not observed in *A. probatocephalus*.

The incisor teeth of *A. rhomboidalis* (fig. 22), a species not recorded from fresh water, have a buttressed base like the incisors of *Diplodus* and *A. probatocephalus* and rectangular or even square upper parts, which, more like those of *Diplodus*, are noticeably incurved near the cutting edge. However, the cutting edges of the lower teeth are lunate, rather than distinctly notched or entire, while the upper teeth tend to be lunately notched, slightly serrated, or entire. Teeth examined grossly in specimens of *A. pourtalesii*, a closely related species from the Galopagos Islands, show a similar condition.

## Economic Importance

### Economic Relationships

The pinfish is usually included in fishery statistical reports as a commercial species. Such reports come primarily from North Carolina and Florida, where, for example, in 1952 (Anderson and Power, 1955), the combined landings from these two states—the only ones reporting "pinfish"—were 978,800 pounds valued at $32,812. These same authors (Anderson and Power, 1956a and 1956b) do not list this species from North Carolina in 1953 and 1954, but do list 85,400 pounds with a value of $4,156 from both coasts of Florida combined for 1953, and 281,600 pounds valued at $22,688 for 1954. The Florida portion of the 1952 total was 450,800 pounds valued at $28,851. Unfortunately, these figures probably do not give a true picture of the poundage landed and the value of this species as a commercial fish. Pinfish are frequently lumped in reports as "trash," "scrap," or "unclassified," and these classifications undoubtedly explain the absence of pinfish in reports from such states as South Carolina, Georgia, Alabama, Mississippi, and Texas, where the species is abundant, and is frequently used for certain commercial purposes (see below). It was included from Alabama and Mississippi, as well as from Florida, in

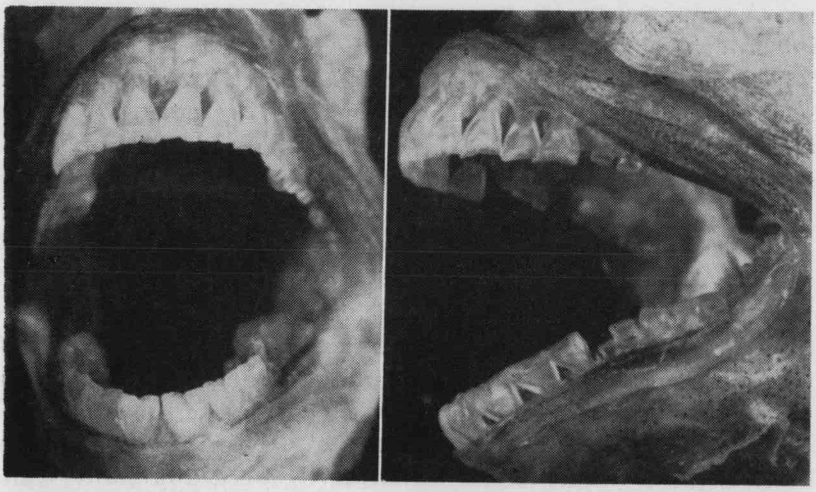


Figure 19.—Mouth of *Lagodon rhomboides* (L.) showing the form and arrangement of teeth. Left, anterior view. Right, left profile.

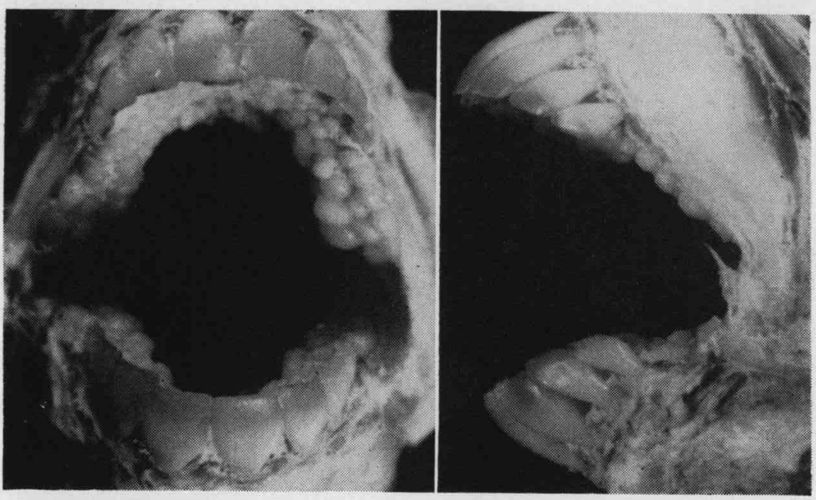


Figure 20.—Mouth of *Diplodus holbrooki* (Bean) showing the form and arrangement of teeth. Left, anterior view. Right, left profile.

1890 (Collins and Smith, 1893). I have also found from personal experience that species other than *L. rhomboides* are often included by fish houses in their reports as "pinfish," or *L. rhomboides* is reported under a name other than "pinfish." Taking these factors into consideration, it is my opinion that the figures presented by Anderson and Power are an underestimate of the true dollar value

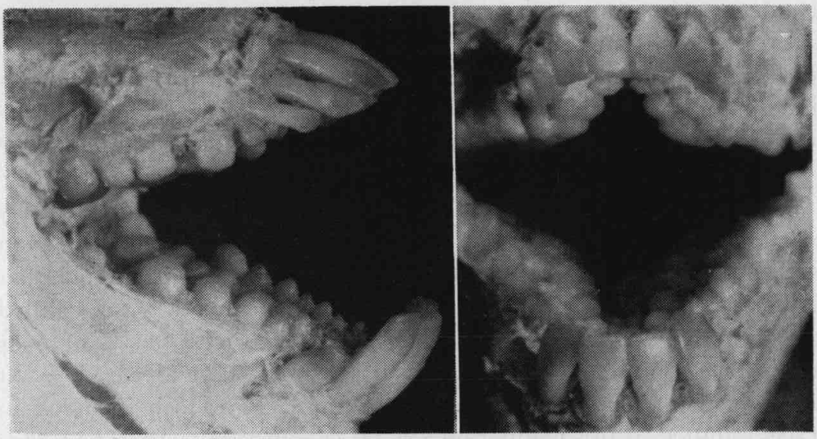


Figure 21.—Mouth of *Archosargus probatocephalus* (Walbaum) showing the form and arrangement of teeth. Left, anterior view. Right, left profile.

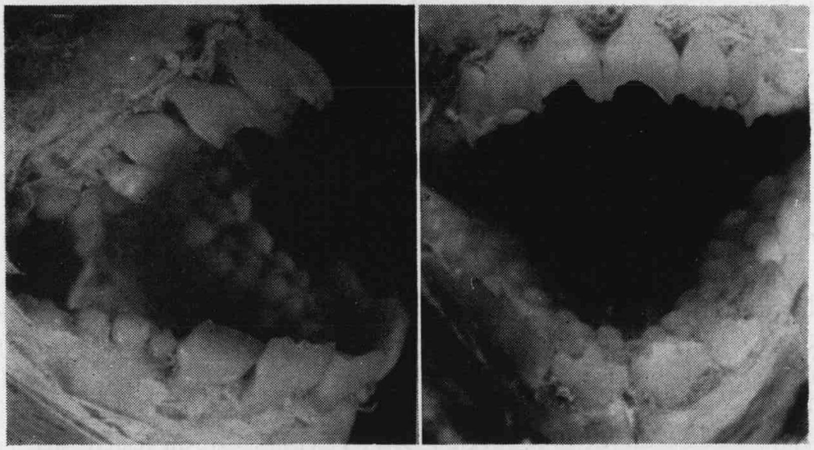


Figure 22.—Mouth of *Archosargus rhomboidalis* (L.) showing the form and arrangement of teeth. Left, anterior view. Right, left profile.

and commercially utilized poundage of pinfish. The misidentification of pinfish as other species, or other species as pinfish, is probably of minor and self-equalizing importance.

Pinfish are of relatively small importance as a commercial food fish. Though delicious, they are too small, on the average, to be utilized for anything but a low-priced panfish, and are usually sold for this purpose only in small neighborhood fish markets, where, I am told, they are often called "Canadian Bream." Gregg and

Gardner (1902:114, 153) have commented on the eatability of this species, and my own experience and that of friends has pointed up the desirability of the pinfish for food. I have found no direct fisheries for them for food; they are included in "mixed panfish" whenever they happen to be taken. The species apparently had more commercial value in the 19th century than it does today, for Goode (1884:394) notes that it is ". . . highly prized for food, occasionally salted . . . sometimes sent in ice to Savannah and Charleston [from the Indian River region of Florida]." Jordan (1884:78) noted that it was often brought to market alive in the Florida Keys and killed after purchase, a practice frequently followed in those days of poor refrigeration, and one still occasionally seen in that area today. At Key West, for instance, I have seen a few large pinfish included in fishes handled in this manner on a small commercial scale. Thousands of pounds are undoubtedly used for food today by sport fishermen, who frequently catch them from docks, piers, bridges, while bottom-fishing over fairly shallow waters from boats, etc. This poundage utilized as food, is never included, of course, in the statistical reports, which are almost all gathered from commercial fish houses or from a few particularly active sportfishing centers. The sportfishery is in itself of economic value, though probably unmeasurable. Not only does it have a recreational value to many, particularly children, but it aids those people unable to buy fish usually considered more desirable as food.

Though, as noted above, there are apparently no direct fisheries for pinfish for food, this animal is particularly sought for bait (see below). In addition, at least three recent authors have suggested that commercial fisheries be established which would include pinfish. Baughman (1950a:122) noted that they might be included in an inshore fishery on littoral species. Buller (1951:10) suggested that a limited commercial trawl fishery in depths of less than 100 fathoms be established for pinfish and other bottom species off North Carolina. Siebenaler (1952) indicated that a trawl fishery might be established in Florida which would utilize pinfish and similar species for a fish meal and oil industry. Actually, such scrap species are now being commercially utilized in certain areas. Examples of this utilization which I have personally observed may be found in Pascagoula, Mississippi, where a large plant is operated which utilizes mixed fish in the manufacture of canned cat food. These scrap fish are the object of a direct trawl fishery and any species normally considered commercial, such as shrimp and flounders, are sold as the byproduct of the scrap fishery. In Brunswick, Georgia, the trash fish from shrimp trawling operations are generally saved and sold for bait for the commercial blue crab fishers of the area. Such utilization of scrap species is undoubtedly carried on elsewhere, and in areas where pinfish are abundant, this species must play an important role as a component of the scrap. Hildebrand and Cable (1938:518) reported, for instance, that sometimes, when large catches were made, pinfish were processed by the Beaufort, North Carolina, menhaden reduction plants into fish meal or fish scrap and oil, the latter said to be of a very high grade.

Probably one of the major economic values of the pinfish, and one for which there is often a direct fishery, is its use as a bait species. It is widely used today for this purpose, both live and as cut-bait, by both sport and commercial fishermen. It is particularly popular as bait for the redfish, *Sciaenops ocellata* (L.), the spotted sea trout, *Cynoscion nebulosus* (Cuvier), and grouper, Serranidae, on the coast of the Gulf of Mexico; for the tarpon, *Megalops atlanticus* (Valenciennes) on the lower Gulf coast of Florida; and for the snook, *Centropomus,* in the waters of southern Florida on both the Atlantic and Gulf coasts. The use of pinfish as a bait species for particular species of fish has been remarked upon by Moody (MS:11), Ackerman (1951: 58), and Knapp (1953:139). I have seen small pinfish (3 to 4 inches long) being sold for live bait for as much as ten cents each, and since they are seasonal in abundance, one bait dealer near Steinhatchee, Florida, (northern peninsular Gulf coast) stated that he hoped to maintain stocks in tanks for sale at even higher prices during the "off season" when they could not readily be taken. I am told by various persons connected with the operation of the *Oregon* that pinfish have been used successfully as bait in the exploratory long-line fishing operations for yellowfin tuna, *Thunnus albacares subulatus* (Poey) offshore in the Gulf of Mexico.

Not only are pinfish sold alive or fresh as bait, but small specimens (1 to 3 inches long) are occasionally seen being offered, along with seahorses, cowfish, porcupine fish, pipefish, and other percomorph fishes, as dried specimens for curios. In this respect, I have seen them sell for about five cents each. Their sheer abundance also causes them to be frequently exhibited in commercial aquaria, where they make colorful individual specimens for small tanks, and effective large-aggregation "fillers" in large tanks. Their beauty and hardiness for this purpose was suggested many years ago (Bean, 1892:90), though the advent of today's large marine exhibitions has brought them to the fore in this respect.

Up to this point I have presented some of the direct economic uses of pinfish, showing that they may be purposeful or secondary objects of commercial and sport fisheries, and that they may be used as tools for the pursuance of other commercial projects. They are, however, probably just as important, or perhaps more so, as an indirect economic factor. From this aspect, they are undoubtedly of great importance in areas where they are abundant as forage fish for more valuable carnivorous commercial and sport fishes. Moody (1950:167) has shown, for example, that at Cedar Key, pinfish form a major portion of the diet of adult spotted sea trout, one of the most important commercial fishes of the Gulf coast of Florida. This value as a forage species will undoubtedly become more evident as more studies are carried out dealing with carnivorous marine fishes, particularly those feeding in the shallow waters of those areas where pinfish abound. The overwhelming numbers of this species in such areas make it almost impossible not to be encountered frequently by predators. Such an area of high abundance, and hence great indirect economic importance, lies along the west coast of Florida, where the pinfish is one of the most abundant forage species. Another suggested indirect economic use for the pinfish is that proposed by Daugherty (1951a). He notes that since it occurs generally throughout the Atlantic coast of the United States, and since it has average tolerances to harmful conditions and is easily obtained, *L. rhomboides* might be used as a standard fish in testing industrial pollutants.

Some other indirect economic values of pinfish are less obvious than the above and are actually negative. For instance, hundreds of man-hours are lost yearly by commercial gill-net fishermen in ridding their nets of pinfish. This species often becomes entangled in great numbers, particularly when the net is set over grassy flats, and their dorsal and anal spines, and especially the procumbent part of the first dorsal spine, are so efficient in holding them into the net that they often must be tediously untangled one by one by hand, rather than shaken out quickly or easily pushed completely through the net meshes as are the desired mullet. This process almost invariably is accompanied by numerous painful skin pricks on the hands as a result of the needle-sharp spines. Aside from this problem, their small mouths, which make them difficult to catch on a large hook, and their nibbling feeding habits, make them notorious bait stealers, and they thus cause considerable anguish and loss of valuable bait to hook-and-line fishermen (Baughman, 1950b:250). They, with other scrap species, also present extra labor to shrimp fishermen in having to be sorted from the desired shrimp. Although already shown to be of economic value as an aquarium fish, they also have a negative value in that respect in that they are "nippers" and frequently mutilate or even kill rare and more valuable fish in the tanks with them. It is often a question of which is more important from the public's viewpoint, lots of easily obtained pinfish, or a few rare specimens. To the collectors' and biologists' chagrin, the pinfish usually win out. The average paying customer-observer desires only to see great numbers of fish, not necessarily rare ones.

## Seasonal Variation in Economic Importance

As has been shown earlier in this paper, pinfish show a definite variation in seasonal abundance, being most common in inshore waters in the late spring, summer, and early fall. Since most of its economic value lies inshore, the species is therefore most important economically during this period. This is particularly true regarding its value as a bait fish, for the proper-sized individuals are practically nonexistent inshore during the winter, and hence it is usually not economically feasible to fish for them then. They also decrease in value as a forage fish during this period, but their absence also lessens their nuisance effect. Thus, the seasonal lessening of their negative effect—except of course where they are confined in aquaria—must then become a positive value in inshore situations, while the former positive values inshore tend toward negative ones when the fish leave in their offshore winter movement. Conversely, their value as a scrap species increases in winter as large numbers move offshore and into the range of the trawlers—with this their negative value as a nuisance to shrimp fishermen must necessarily increase.

## Methods of Capture

Pinfish are regularly captured by almost any standard type of fishing gear. However, commercially, most are taken for live bait in small baited or unbaited traps, by hook and line using a very small baited hook, and with cast nets and push nets. Those utilized as scrap for crab bait or cat food are taken primarily with large bottom trawls. Other methods of capture frequently used are haul seines, gill nets, and trammel nets. Sportsmen encounter them almost exclusively when bottom-fishing with hook and line, unless they are seeking them for bait, when the above methods may be employed. They are generally too small to be of interest to spear fishermen.

## Summary

A complete synonymy of the sparid fish, *Lagodon rhomboides* (Linnaeus), the pinfish, is presented, with a list of the common names applied to it. The genus *Lagodon* is found to be monotypic, and two recently described forms, *Lagodon mercatoris* Delsman and *Salema atkinsoni* Fowler, are relegated to the synonymy of *Lagodon rhomboides*. The Linnaean specific name *"rhomboidalis"* is shown to apply to the form presently recognized by most authors as *Archosargus unimaculatus* (Bloch) rather than to the pinfish, as has sometimes been suggested.

Despite records in the literature to the contrary, the results of this study indicate that the present geographical range of the pinfish is limited to continental waters of the Atlantic from Cape Cod, Massachusetts, to the northeastern tip of Yucatan, Mexico, and in Bermuda.

Regular collections were made for over a year at a variety of habitats at Cedar Key, Florida, where pinfish are particularly abundant, and the ecological results there obtained were considered as being representative for the species, since they essentially agreed with sporadic collections made over a period of several years at widely distant localities within its marine coastwise range. The data from a number of offshore collections were also considered, along with notes gained from collections made in nearly fresh waters. The results of these collections, coupled with information obtained through a search of the literature, have shown that the pinfish is primarily a marine littoral carnivore usually found associated with vegetated bottoms, but that it occurs well offshore in continental waters, as well as regularly penetrating fresh water. Furthermore, it was found to have wide tolerances in relation to many physical factors of the environment. There was an offshore movement in late fall and winter, and in general the large pinfish were found in deep water. This phenomenon was exhibited throughout life after the young, which were spawned offshore during the early fall and winter, reached the shallows to undergo their first year of rapid growth. Spawning was apparently undertaken initially by large fish in their third year.

Many morphological features, both internal and external, meristic, proportional, and descriptive, were examined. It was found that while there is considerable variation within the species, and some with ontogeny, this variation is relatively consistent throughout its

geographical range despite the great latitudinal distances involved. No evidence, not assumed attributable to varying physical factors of the environments, was found which indicated that the pinfish is not taxonomically homogeneous throughout its entire range, and this was related to various factors dealing with the spawning and early life history of the fish.

Some pinfish were seen to defend territories, and others showed a defensive mechanism of burying or hiding during times of extreme stress. Several compact aggregations made up of individuals of this essentially nonschooling species are reported.

Fossil teeth, apparently ascribable to *L. rhomboides*, or to a form very closely related to it, are reported from the Pliocene of Florida.

The economic relationships of pinfish were examined, and it was found that while it is not necessarily particularly valuable as the object of a direct fishery, *L. rhomboides* has some secondary commercial value and is probably extremely important as a forage species for more directly valuable commercial species, in both cases on a seasonal basis.

In addition to the above major categories of investigation, some information was derived dealing with the following aspects of the biology of the pinfish: length-weight relationship, body weight–body surface relationship, associated fish species, predators, and parasites.

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