

THE FISH FAMILY MORIDAE IN THE EASTERN NORTH PACIFIC WITH NOTES ON MORID OTOLITHS, CAUDAL SKELETONS, AND THE FOSSIL RECORD

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ABSTRACT

Four species of morids (*Antimora microlepis*, *Microlepidium verecundum*, *Physiculus nematopus*, and *P. rastrelliger*) are known to inhabit waters of the eastern North Pacific. These can be differentiated by numerous external and internal characters including fin-ray counts, dentition, head shape, gill-raker counts, vertebral counts, and otoliths. *Microlepidium grandiceps* and *Physiculus longipes* were found to be junior synonyms of *M. verecundum* and *P. nematopus*, respectively.

Only three characters appear to be infallible for recognizing members of family Moridae: large fontanelles in the exoccipitals through which elongate hornlike projections of the swimbladder extend and contact the auditory capsules; the otoliths; and the caudal skeleton. Otoliths and the caudal skeleton were used in evaluating the fossil record, and none of the 10 species that have been accepted as being morids, but which were known only from skeletal imprints, could be proven to be correctly identified. On the other hand, four species known only from fossil otoliths are unquestionably morids.

Morid otoliths are so distinctive and so characteristic that they appear to be reliable for distinguishing many species and most, if not all, genera. Based upon an examination of sagittal otoliths from 15 morid genera it was possible to distinguish four natural groups. These were designated the *Mora*-group containing *Mora*, *Halargyreus*, *Antimora*, and *Lepidion*; the *Physiculus*-group containing *Physiculus*, *Gadella*, *Tripterophycis*, *Brosmiculus*, *Laemonema*, and *Microlepidium*; the *Pseudophycis*-group containing *Pseudophycis*, *Auchenoceros*, *Lotella*, and *Salilota*; and the *Actuariolum*-group containing *Actuariolum*, a genus known at present from two species of extinct Miocene morids and one species living in the Antarctic.

The capture of a juvenile *Physiculus rastrelliger* off Eureka and the finding of their otoliths in a Pliocene deposit near the southern shore of Humboldt Bay aroused the curiosity of one of us (Barker) regarding the past and present distribution of this small morid. Every avenue we investigated led to frustration in the form of erroneous or unreliable information that had been perpetuated and compounded through the years. What appeared to be a 1- or 2-day project became a major undertaking just to satisfy a mild curiosity.

Unfortunately, before he was able to do much

more than lay the groundwork for this study, Lloyd Barker lost his life at sea while acting as an official observer for the California Department of Fish and Game on a sea lion catching boat that sank near Santa Rosa Island. Although many of the problems were discussed prior to Lloyd Barker's death, all errors, omissions, and oversights are the sole responsibility of the senior author.

Morids generally were unrecognized and unaccepted at the family level until Svetovidov (1948) pointed out for the third time the uniqueness of the swim bladder connection with the auditory capsule, a character that was infallible for distinguishing morids from other gadoids. In a subsequent study, Svetovidov (1967) distinguished additional morid genera and further

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established the validity of the "swim bladder and fontanelle" character, while other workers publicized equally stable characters in the morid caudal complex (Rosen and Patterson, 1969) and the sagittal otoliths (Schmidt, 1968; Karrer, 1971).

In spite of such common knowledge, the validity of characters used for distinguishing genera has not been demonstrated, and any estimate of speciation would be wild at best. Perusal of available literature indicates that perhaps 20 morid genera are recognized from among the 25 or so available names. Since about half of these genera are monospecific, it seems

highly probable that a critical study would result in a substantial reduction.

We limited our research to those morids inhabiting the eastern North Pacific for three reasons: (i) it is the faunal region of greatest immediate concern to West Coast fishery biologists and ichthyologists, (ii) study material was readily available, and (iii) the problems appeared to be solvable in the time we were able to budget for the study. Our work with morid otoliths and the fossil record stems from a long-seated interest in these two subjects, and knowledge of the otoliths and the caudal complex was needed in order to interpret the fossil record.

KEY TO GENERA AND SPECIES OF MORIDAE IN THE EASTERN NORTH PACIFIC

1. Snout projecting well beyond mouth as a flat, pointed rostrum; first ray of first dorsal filamentous, longer than head; 57 to 58 vertebrae; 36 to 38 caudal rays; a small oval patch of teeth on head of vomer *Antimora microlepis*

Mouth terminal, snout not flattened nor projecting; first ray of first dorsal not produced, equal to less than one-half head length; 43 or fewer vertebrae; 32 or fewer caudal rays; vomerine teeth absent or forming a single row, never in clumps or patches 2

2. Pelvic rays 2; vomerine teeth in a single row across head of vomer; 39 to 42 rays in second dorsal; 39 to 42 rays in anal; 44 to 46 vertebrae; no black fossa (luminous area) on belly between and behind pelvic fin bases *Microlepidium verecundum*

Pelvic rays 6 or 7; no teeth on vomer; 52 to 67 rays in second dorsal; 56 to 67 rays in anal; 52 to 55 vertebrae; a black fossa on midline of belly behind pelvic fin bases 3

3. Pelvic rays 6; gill rakers 16 to 19, 12 to 14 on lower limb; caudal rays 22 to 25; black fossa on belly round, width equal to length or nearly so; chin and throat densely scaled, rough to touch *Physiculus nematopus*

Pelvic rays 7; gill rakers 26 to 30, 18 to 22 on lower limb; caudal rays 27 to 32; black fossa on belly over twice as long as wide; chin and throat naked or with a few embedded scales, smooth to touch *Physiculus rastrelliger*

SPECIES ACCOUNTS

Antimora microlepis Bean, 1890

D. 4(4-5),^a 50(50-55)^a; A. 37(39-42)^a; C. 37; P. 20; P₂. 6(6-7)^a; Br. 7; rakers on first gill arch 5 + 15 = 20; posterior rakers on first gill arch 3 + 12 = 15; vertebrae including hypural 24-25 + 33 = 57-58.

^a Counts in parentheses are from Clemens and Wilby (1961).

There is a small round patch of teeth on the head of the vomer; those in the jaws are villiform and in several rows. The broad depressed snout forms a spadelike rostrum with sharp lateral margins. The mouth is inferior. The elongate barbel at the tip of the lower jaw is conspicuous. The filamentous first ray of the first dorsal fin is more than twice as long as the next longest ray. The second dorsal and anal fins are deeply indented posteriorly and terminate adjacent to the ninth from last vertebra, including the hypural. The caudal rays com-

mence adjacent to the sixth from last vertebra.

Schroeder (1940) reported that *A. viola*, *A. microlepis*, and *A. rhina* are synonyms of *A. rostrata* (Günther, 1878), and Clemens and Wilby (1961) and Fitch and Lavenberg (1968) followed this decision in reporting *Antimora* from the eastern North Pacific. Unfortunately, few of the characters used by Schroeder to support his action are of value for combining (or distinguishing) taxa at the species level. Type localities for *A. rostrata*, *A. viola*, *A. microlepis*, and *A. rhina* are the Indian Ocean, the western Atlantic, off Queen Charlotte Island, and off Panama, respectively. In view of the great distances separating these type localities, and until material from all four areas can be examined critically and compared in minute detail, we prefer to retain *microlepis* for the *Antimora* found in the eastern North Pacific.

A. microlepis has been reported as ranging from Central America (Fitch and Lavenberg, 1968) to Misaki, Japan (Svetovidov, 1948), but we have not seen material from south of Mazatlán, Mexico, or from west of the Bering Sea. Although we examined more than 50 individuals from the eastern North Pacific for key characters, we recorded meristic data on only one, a small specimen (LACM⁴ 30400-2) trawled near San Clemente Island, Calif.

Microlepidium verecundum (Jordan and Cramer, 1897)

D. 7-9, 39-42; A. 39-42; C. 29-32; P. 19-22; P₂. 2; Br. 7; rakers on first gill-arch 5-6 + 11-13 = 17-19; posterior rakers on first gill-arch 3 + 11-12 = 14-15; vertebrae including hypural 11-12 + 33-34 = 44-46.

About seven teeth in a single row form a gently curved bow on each side of the head of the vomer. The lower jaw contains a single row of conical, sharply pointed teeth; in the upper jaw, there are two rows of teeth near the center and three irregular rows along the sides; all jaw teeth are similar in size and shape. A barbel is present at the tip of the lower jaw, but this

TABLE 1.—Proportional measurements for three species of morids found in the eastern north Pacific.

Measurement ¹	<i>Microlepidium verecundum</i>	<i>Physiculus nematopus</i>	<i>Physiculus rastrelliger</i>
Standard length	51-101	93-158	79-207
Total length	1105-1126	1080-1120	1079-1124
Head length	267-283	245-285	242-290
Snout length	049-058	057-073	062-076
Maxillary length	116-125	114-136	117-136
Diameter of fleshy orbit	082-093	062-079	067-081
Longest gillraker length	025-034	018-027	018-028
Snout to first dorsal fin insertion	274-300	253-288	262-298
Snout to anal fin insertion	390-426	317-351	316-359
Snout to pectoral fin insertion	268-287	249-288	253-292
Snout to pelvic fin insertion	191-247	213-246	200-255
Pectoral fin length	208-238	161-179	143-185
Pelvic fin length	244-292	272-298	122-169
Longest ray in first dorsal fin	085-108	102-123	098-127
Longest ray in second dorsal fin	094-115	092-112	078-107
Longest ray in anal fin	099-116	092-112	077-107
Caudal peduncle depth	016-019	020-025	018-022
Peduncle length (dorsal)	108-117	048-061	069-095
Peduncle length (ventral)	108-117	048-061	069-095
Number of specimens	10	10	20

¹ Standard lengths are in millimeters; all other measurements expressed as thousandths of standard length.

is so tiny and inconspicuous it often can be located only with the aid of a microscope. The dorsal and anal fins terminate adjacent to the eighth from last vertebra, including the hypural; the caudal rays commence adjacent to the fifth from last vertebra.

Morphometric data are presented in Table 1.

The unique holotype, described as *Lepidion verecundum*, was trawled at Albatross station 2993 (lat 18°17'15"N, long 114°44'30"W) near Clarion Island in 665 m (364 fm); it was reported as being a "young specimen, 2¼ inches long." Subsequently, Garman (1899) noted that in a specimen "only three and one-half inches in length, its ovaries are filled with eggs that appear to be about mature." We examined a female 83.5 mm SL that was running ripe in January and have seen females as small as 67 mm SL with developing eggs in their ovaries. The largest specimen we have seen was 101 mm SL (112 mm TL).

M. verecundum has been captured throughout the oceanic area from just south of Cape San Lucas, Baja California (lat 22°45'N), to about 322 km SW of Pta. San Telmo (lat 15°57'N) and offshore to Clarion Island (lat 114°44'30"W). Within this area they have been taken with mid-water trawls fished well beneath the surface, and

⁴ Institutions containing specimens studied are listed with standard abbreviations in Acknowledgments.

their remains have been found in the stomachs of deep-feeding predators.

In describing *Lepidion verecundum*, Jordan and Cramer (1897) reported "dorsal VIII-40; anal 37; ventral apparently 1 (some rays broken on each side)." A radiograph of the 51-mm-SL holotype (USNM 47748) revealed that these counts should be D. 8, 39; A. 40; P₂. 2; in addition there are 19 pectoral rays, 30 caudal rays, 7 branchiostegals, and 45 vertebrae of which 12 are precaudals.

In describing the genus *Microlepidium*, Garman (1899) made several erroneous observations on the specimens he examined. He reported a "V-shaped single series of teeth on the vomer" (the single series is slightly bowed or crescent-shaped), ventral fins comprised of four rays (there are only two), and no barbel (a barbel is present, though microscopic). He noted that his *M. grandiceps* could be "distinguished from *M. verecundum* Gilb. [sic] by the larger number of rays and the shallower notch in the anal fin, the greater length of ventrals, pectorals and maxillary, and the larger number of scales in a longitudinal series." His report of "A. 4" for *M. grandiceps* is obviously a typographical error, and since the radiograph of the holotype of *Lepidion* [= *Microlepidium*] *verecundum* showed 40 anal rays, this character is negated for distinguishing the two. The other characters Garman used for separating *M. grandiceps* from *M. verecundum* are equally without basis in fact, and since we were unable to find even slight variance between the two, we relegate *M. grandiceps* to the synonymy of *M. verecundum*.

We have examined material of *M. verecundum* from the following localities, all off Mexico; lat 22°51'30"N, long 108°14'W, 12 Nov. 1967, *Velero* 11750, 1 spec.; lat 22°45.2'N, long 110°00.7'W, 16 Jan. 1969, *Alaska* 69A1-11, 2 specs.; lat 21°13.8'N, long 107°08'W, 18 June 1952, SIO66-411, 1 spec.; lat 20°56.2'N, long 108°44'W, 16 May 1960, SIO63-979, 1 spec.; lat 20°21'N, long 106°10'W, 19 Jan. 1970, *Velero* 13759, 3 specs.; lat 20°16'N, long 111°32.2'W, 19 Apr. 1954, SIO54-88, 7 specs.; lat 19°54.1'N, long 108°38.9'W, 18 May 1960, SIO63-981, 3 specs.; lat 19°52'N, long 113°20.5'W, 21 Apr. 1954, SIO54-92, 13 specs.; lat 18°41'N, long 111°00'W, 20-21 Apr. 1954,

SIO54-91, 26 specs.; lat 18°41'N, long 110°51'W, 18 Feb. 1971, *Searcher* 57, LACM 31751-3, 1 spec.; lat 18°17'15"N, long 114°44'30"W, 6 Mar. 1889, *Albatross* 2993 (x-ray of holotype examined); lat 15°57'N, long 105°56'W, May 1968, remains of 16 fish including otoliths in stomachs of *Dosidicus gigas*.

Physiculus nematopus Gilbert, 1890

D. 9-11, 57-67; A. 62-67; C. 22-25; P. 23-25; P₂. 6; Br. 7; rakers on first gill-arch 4-6 + 12-14 = 16-19; posterior rakers on first gill-arch 3-5 + 10-13 = 14-17; vertebrae including hypural 13-14 + 38-40 = 52-53.

There are no teeth on the vomer and palatines; those in the jaws are villiform and in bands. A round block fossa, reportedly a luminous organ, lies on the midline of the belly about opposite the posteriormost base of the pelvic fins. The chin and throat region are densely scaled and rough to the touch. The dorsal and anal fins terminate adjacent to the sixth from last vertebra, including the hypural; the caudal rays commence adjacent to the fourth from last vertebra.

Morphometric data are presented in Table 1.

Jordan and Evermann (1898) designated specimens labeled USNM 46486 and 46555 as lectotypes from among the material collected in the Gulf of California by the *Albatross*. *P. nematopus* ranges from the northern Gulf of California (lat 30°26.3'N) to the Gulf of Panama (lat 07°06'15"N) and has been captured at depths ranging from 76 to 1,271 m. Specimens from depths greater than about 366 m probably are captured well off the bottom; juveniles particularly are often taken in or near the scattering layer. The largest individual we have seen was 170 mm SL (189 mm TL).

Although *P. nematopus* was described from material dredged in the Gulf of California north of La Paz (*Albatross* stations 2997, 3011, 3015, and 3016), Goode and Bean (1895) in recording the species noted that it was found "off the southern coast of California." This erroneous statement has been perpetuated in the literature ever since (Jordan and Evermann, 1898; Jordan, Evermann, and Clark, 1930).

Garman (1899) described *P. longipes* from Panama and noted that it can be "distinguished from *Phyciculus* [*sic*] *nematopus* Gilb., by a greater number of rays in the dorsal and a smaller number in the ventrals," but the dorsal and ventral ray counts that he gave for *P. longipes* (D.10 + 55-63; V.6) are identical to counts we made on *P. nematopus*. We examined a radiograph of one of Garman's types of *P. longipes* (USNM 57876) and were unable to find any character to distinguish it from *P. nematopus*. We therefore relegate *P. longipes* into the synonymy of *P. nematopus*.

We examined material from the following localities: **Gulf of California:** 18.5 km SE of San Felipe, Feb. 1949, UCLA W49-91, 1 spec.; lat 30°26.3'N, long 114°12.1'W, 19 Jan. 1968, 76-86 m, SIO68-92, 20 specs.; lat 30°20'N, long 114°10'W, 19 Jan. 1968, 148-225 m, SIO68-93, 106 specs.; lat 29°54'N, long 113°03.2'W, 30 Mar. 1960, 110 m, SIO60-119, 6 specs.; lat 29°19.9'N, long 113°10.4'W, 19 Jan. 1968, 265-283 m, SIO68-94, 90 specs.; lat 23°51'N, long 107°33'W, 137 m, SIO59-264, 1 spec.; lat 23°50.5'N, long 107°18.2'W, 77-88 m, SIO59-263, 2 specs. **Costa Rica:** off Punta Quepos, Puntarenas, 16 July 1969, LACM 30721-3, 1 spec.; ±9 km off Cape Velas, 7 May 1963, UCLA W63-142, 3 specs.; near Puntarenas, UCR 490, 3 specs.; 18.5 km SW of Isla Canos, 143 m, 15 July 1969, UCR 328-6, 6 specs. **Panama:** USNM 57876, 1 spec., paratype of *P. longipes*.

Phyciculus rastrelliger Gilbert, 1890

D. 8-11, 52-62; A. 56-63; C. 27-32; P. 24-28; P₂. 7; Br. 7; rakers on first gill-arch 7-9 + 18-22 = 26-30; posterior rakers on first gill-arch 4-6 + 14-20 = 18-24; vertebrae including hypural 12-14 + 40-42 = 52-55.

There are no teeth on the vomer and palatines; those in the jaws are villiform and in bands. An elongate black fossa, reportedly a luminous organ, lies on the midline of the belly about opposite the posteriormost base of the pelvic fins; it is two or three times as long as wide. The chin and throat region are naked, or at most a few scattered embedded scales are present. The dor-

sal and anal fins terminate adjacent to the eighth from last vertebra, including the hypural; the caudal rays commence adjacent to the fifth from last vertebra.

Morphometric data are presented in Table 1.

Jordan and Evermann (1898) designated the specimen labeled USNM 48266 as the lectotype, but did not give a locality of capture. Daniel M. Cohen (personal communication) informs us that USNM 48266 is a lot of seven specimens from *Albatross* station 3045 and that these and a single specimen (USNM 44281) from the same station are both labeled as types. *Albatross* station 3045 was at lat 26°24'N, long 113°49'W in 336.5 m (Townsend, 1901). Thus, the type locality is approximately southwest of Bahía de Ballenas, Baja California. *P. rastrelliger* ranges from 20.7 km WSW of the Mad River, Calif., (lat 40°55'N, long 124°22.5'W) to the Gulf of Panama (lat 07°12'20"N, long 80°55'W). It seldom has been captured shallower than 183 m or deeper than 366 m, but verified depths range from 128 to 523 m. The largest individual we have seen was 207 mm SL (225 mm TL).

P. rastrelliger was originally described from material dredged at *Albatross* stations 2987 and 3045, both off central Baja California. For some unknown reason, but probably an error of omission (e.g., Baja), Goode and Bean (1895), in recording this species, noted both of these stations as "off the southern coast of California." That erroneous statement very likely caused Jordan and Evermann (1898) to ascribe this species to southern California. Not until 1923 however, was *P. rastrelliger* reported from California based upon material actually taken there (Fowler, 1923). Reports subsequent to Fowler's (Ulrey, 1929; Jordan, Evermann, and Clark, 1930; Barnhart, 1936) could have been based upon any of the previous three, but probably did not involve additional Californian captures. The listing of *P. rastrelliger* by Fitch and Lavenberg (1968) was based upon numerous Californian captures of the species, not specified in detail.

We have examined material from the following localities: **California:** lat 40°55'N, long 124°22.5'W, 12 Nov. 1970, 143-146 m, *N. B. Scofield* 70S8-21, 1 spec; off Gaviota, Santa Barbara Co., 6 Aug. 1967, 263 m, SBMNH 00229, 1 spec.;

13.9 km NW of Cavern Point, Santa Cruz Isl., 23 Jan. 1961, 229 m, UCLA W61-48, 3 specs.; lat 33°58'N, long 118°43'W, 5 Aug. 1969, 320-323 m, *N. B. Scofield* 69S5-16, 2 specs.; lat 33°57'N, long 118°39'W, 5 Aug. 1969, 283 m, *N. B. Scofield* 69S5-18, 1 spec.; lat 33°35.5'N, long 118°05.3'W, 18 Aug. 1970, 128-146 m, Oxy 70 8-18, 12 specs.; lat 33°34.2'N, long 118°04.8'W, 19 Sept. 1970, 274 m, Oxy 70 9-19, 7 specs.; lat 33°32.2'N, long 118°08'W, 27 Jan., 9 Apr., 29 Apr., and 27 Oct. 1971, 274 m, Oxy 71, 16 specs.; 6.8 km WSW of Del Mar, 12 Oct. 1950, 274 m, SIO50-249A, 6 specs.; La Jolla area, 16 and 18 Aug. 1916, Barnhart coll. D42 and D49, SIO67-138 and SIO64-287, probably the two specimens reported by Fowler (1923); 14.8 km W. of Point Loma, 21 Jan. 1965, 347.5 m, SIO65-9, 1 spec.

Baja California: off Bahía San Quentin, 1 Apr. 1962, 183 m, SIO62-522, 3 specs.; lat 28°18.1'N, long 115°24.1'W, 247-265 m, SIO71-122; 3 specs.; lat 27°59'58"N, long 116°32'W, 20 Aug. 1967, midwater trawl, surface to 1,372 m, *Velero* 11634, LACM 30019-12, 1 spec.; lat 27°12.9'N, long 114°30.5'W, 21-22 June 1971, prawn trap 183-210 m, *Alaska* 71A5-10, 8 specs.; lat 26°04.5'N, long 113°40'W, 2 Dec. 1960, 229-293 m, SIO60-466, 39 specs.

Gulf of California: lat 28°19.3'N, long 112°08'W, 293-307 m, SIO68-103, 15 specs.; lat 23°07.8'N, long 109°21.3'W, 10-11 Jan. 1968, 252 m, SIO68-56, 1 spec.

Costa Rica: vicinity of Cabo Blanco, 17-21 May 1970, 219 m, UCR 427-7, 2 specs.; off Puntarenas, UCR490, 2 specs.

Panama: lat 07°12'20"N, long 80°55'W, 23 Feb. 1891, 333 m, *Albatross* 3355, USNM 57877, 1 spec. x-ray.

MORID OTOLITHS

Although morid otoliths were illustrated and described by Vaillant in 1888 and have been reported both in paleontological and ichthyological literature during the 20th century, Schmidt (1968) appears to have been the first to record in print their uniqueness at the family level. He illustrated sagittae from five Atlantic genera of morids and noted that "although the form of the otolith within this family is by no means uni-

form, it is so characteristic that one can speak of a morid type."

The characteristic which makes the morid sagitta so distinct is the deeply channeled bifurcate cauda (posterior portion of the sulcus, or groove, on the inner face of an otolith). Frost (1924) noted this character with the statement "In no other species that has passed through my hands is a double cauda to be seen," but he apparently had not seen sufficient comparative material to recognize it as being diagnostic of the family.

Karrer (1971), in an excellent treatise on morid otoliths, pointed out that the thin bladelike ridge (crista) which divides the deeply channeled cauda longitudinally is actually the posterior colliculum. She reported that the diversity of characteristics found on the morid otolith are sufficiently reliable as to permit identification of the various genera. Based upon an examination of otoliths from 13 genera (20 species), she established three natural groups of living morids: the *Mora*-group comprising *Mora*, *Halar-gyreus*, *Antimora*, and *Lepidion*; the *Physiculus*-group comprising *Physiculus*, *Gadella*, *Triptero-phycis*, *Brosmiculus*, *Laemonema*, and *Salilota*; and the *Pseudophysicis*-group comprising *Pseudo-phycis* and *Auchenoceros*. She hesitantly places *Lotella* with the *Physiculus*-group.

Our investigations involved otoliths from 12 genera (Figures 1 and 5), and even though we had no prior knowledge of Karrer's research, we had decided that morid otoliths fitted into the identical three groups that she described, but we added a fourth to include an Antarctic species and two New Zealand fossils. To illustrate these we had drawings prepared of *Mora pacifica*, *Physiculus rastrelliger*, and *Pseudophysicis bachus* (Figures 2, 3, and 4), and photographed the Antarctic species and one of the fossils (Figure 5). We believe that *Lotella*, based upon the proportion of ostium length into cauda length in *L. callarias*, is more closely allied with *Pseudophysicis* than with *Physiculus*. *Salilota* also appears to belong with the *Pseudophysicis*-group.

Since morid otoliths are likely to be encountered in food habit studies, fossil deposits, and bottom sediments, and could be useful in a taxonomic revision of the family, we have construct-

ed a key for identifying to genus the sagittae we have seen. Although obviously incomplete, this key can be expanded when otoliths of the dozen

or so other genera come to hand. A species-by-species discussion of these otoliths is also presented.

KEY TO OTOLITHS OF 12 MORID GENERA

1. Lower rim of cauda bowed out posteriorly creating an expanded chamber ventral to the posterior colliculum (*Mora*-group) .. 2
 Lower rim of cauda straight or turned downward at tip, but never forming an expanded area posteriorly 5
2. Anterior end of sagitta greatly expanded dorsally 3
 Anterior end of sagitta not expanded dorsally; height of otolith at anterior end about the same as height at center 4
3. Ratio of otolith height into length 1:1.6 or 1:1.7 *Mora*
 Ratio of otolith height into length 1:2.0 or 1:2.1 *Halargyreus*
4. Ventral portion of otolith projecting beyond dorsal portion anteriorly; ventral canal of cauda only slightly expanded posteriorly *Antimora*
 Dorsal portion of otolith equal in length to ventral portion anteriorly, or projecting somewhat beyond; ventral canal of cauda greatly expanded posteriorly *Lepidion*
5. Ostium (anterior part of sulcus) comprising approximately one-half of otolith length (*Pseudophyscis*-group) 6
 Ostium comprising approximately one-third or less of otolith length 8
6. Anterior end of otolith greatly expanded dorsally *Auchenoceros*
 Anterior end of otolith pointed 7
7. Dorsal rim of cauda longer than ventral rim; otolith knobby and greatly expanded in middle one-third *Pseudophyscis*
 Dorsal rim of cauda shorter than ventral rim; otolith relatively smooth middorsally, never expanded in central portion *Lotella*
8. Dorsal rim of cauda about equal in length to ostium; about half as long as ventral rim (*Physiculus*-group) .. 9
 Dorsal rim of cauda about twice as long as ostium; more than eight-tenths as long as ventral rim (*Actuariolum*-group) .. *Actuariolum*
9. Otolith with a thin shelflike blade projecting ventrally from posterior portion of inner face *Microlepidium*
 No ventral projection on inner face of otolith 9
10. Otolith broadly rounded anteriorly; greatest height in anterior one-third of length *Laemonema*
 Otolith somewhat pointed anteriorly; greatest height in middle one-third *Physiculus*
Tripterophyscis

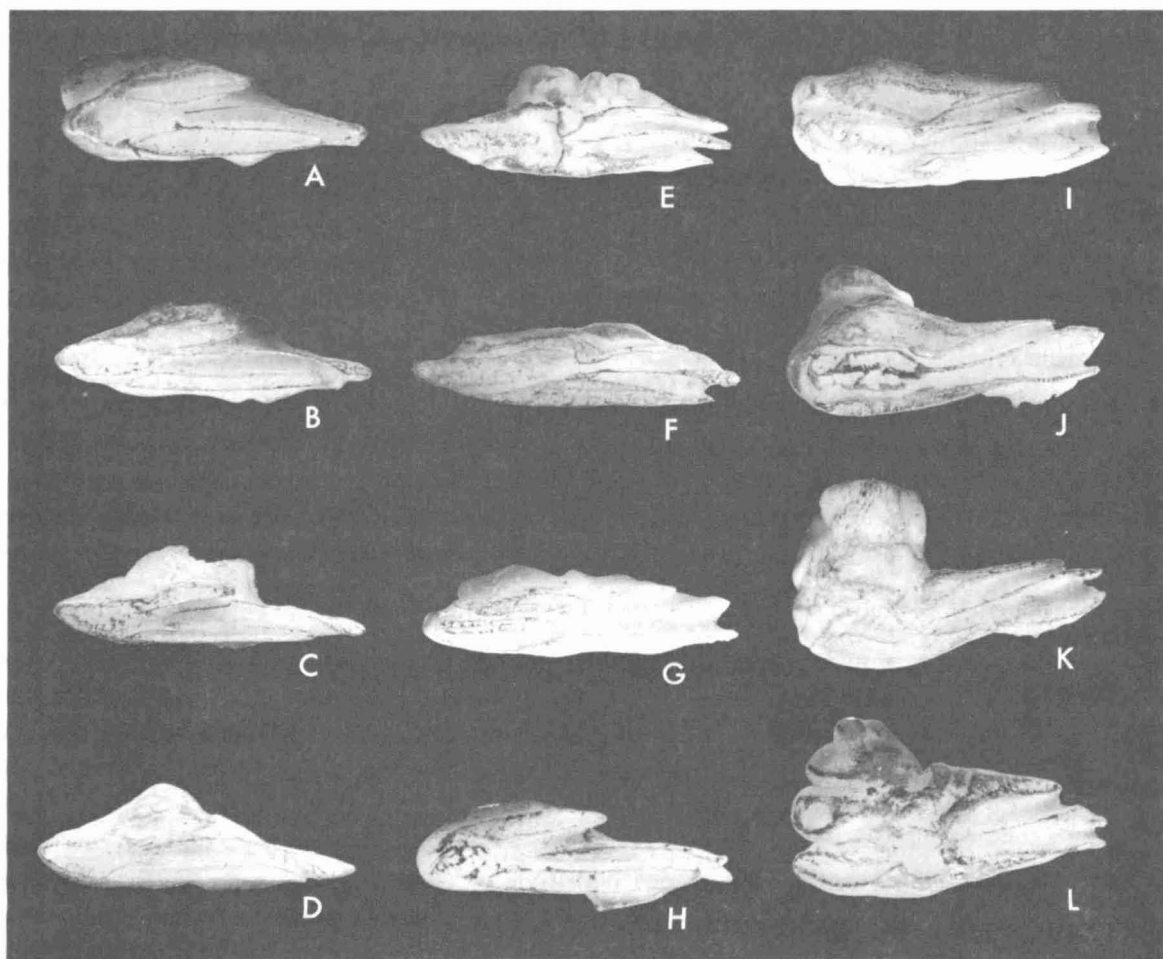


FIGURE 1.—Inner faces of right sagittae of 11 genera (12 species) of living morids: A. *Laemonema barbatulum*, B. *Tripteroptychys gilchristi*, C. *Physiculus nematopus*, D. *Physiculus rastrelliger*, E. *Pseudophycis bachus*, F. *Lo-tella callarias*, G. *Antimora microlepis*, H. *Microlepidium verecundum*, I. *Lepidion eques*, J. *Halargyreus johnsonii*, K. *Mora pacifica*, L. *Auchenoceros punctatus*.

OTOLITH SPECIES ACCOUNTS

Mora-group (Figure 2)

Otoliths in this group are characterized by a bowing-out of the crista inferior (the ventral rim of the cauda or groove on the inner face of the sagitta), at about its midpoint, so that an expanded chamber is formed in the posterior portion of the lowermost canal. The crista superior (uppermost rim of the cauda) is more than

three-fourths as long as the bladelike posterior colliculum (thin ridge which bisects the cauda horizontally). The anterior end of the sagitta may or may not be expanded dorsally. Sagittae of this group that have been illustrated are *Mora mora* (Vaillant, 1888, as *M. mediterranea*; Schmidt, 1968; Karrer, 1971); *Halargyreus johnsonii* (Fitch and Brownell, 1968, as morid #3; Schmidt, 1968, as *H. affinis*; Karrer, 1971), *Lepidion eques* (Schmidt, 1968; Karrer, 1971); and *Antimora rostrata* (Karrer, 1971).

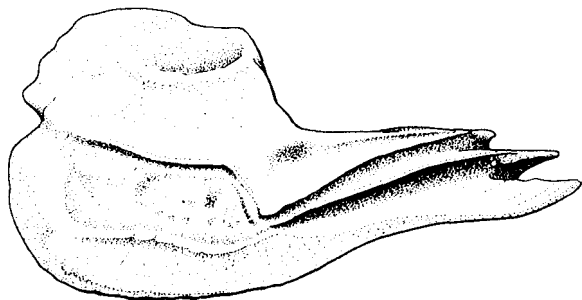


FIGURE 2.—Drawing of right sagitta from *Mora pacifica* illustrating features of *Mora*-group otoliths.

Mora pacifica Waite, 1914 (Figure 1K).—In the illustrated specimen (9.5 mm long) the ostium measures 3.8 mm and the cauda, 5.7 mm. The posteriormost 3.0 mm of the ventral canal is expanded. The sagitta of *M. pacifica* (11 pairs examined) differs consistently from that of *M. mora* (5 pairs examined) in the configuration, including angles, of the expanded anterior end. In all *Mora* otoliths examined, the ratio of height into length was 1:1.6 to 1:1.7.

Halargyreus johnsonii Günther, 1862 (Figure 1J).—In the illustrated specimen (11.6 mm long) the ostium measures 4.5 mm and the cauda, 6.6 mm. The posteriormost 3.2 mm of the ventral canal is expanded. In the *Halargyreus* sagittae examined (5 pairs), the ratio of height into length was 1:1.20 to 1:1.21. This ratio is sufficient to distinguish *Halargyreus* otoliths from those of *Mora*, *Antimora*, and *Lepidion*.

Antimora microlepis Bean, 1890 (Figure 1G).—In the illustrated otolith (10.4 mm long) the ostium is 3.9 mm long and the cauda, 5.9 mm. The posteriormost 3.5 mm of the ventral canal is expanded. The anterior ends of *Antimora* otoliths bulge very slightly dorsally, a characteristic which was grossly exaggerated in Karrer's (1971) illustration by inadvertently rotating the otolith out of lateral alignment. *Antimora* sagittae differ from those of *Lepidion* in that the anteroventral portion is somewhat pointed and extends well beyond the anterodorsal profile. They differ from those of *Mora* and *Halargyreus* in lacking the greatly expanded

anterior end. More than 30 pairs of sagittae from *A. microlepis* were examined.

Lepidion eques (Günther, 1887) (Figure 11).—In the illustrated otolith (8.0 mm long), the ostium is 3.3 mm long and the cauda, 4.2 mm. The posteriormost 2.2 mm of the ventral canal is expanded. The anterior ends of *Lepidion* sagittae (4 pairs) are somewhat squared-off dorsally and project well beyond the anteroventral angle, a characteristic which distinguishes *Lepidion* otoliths from those of *Antimora*. The generally straight dorsal profile distinguishes this otolith from those of *Mora* and *Halargyreus*.

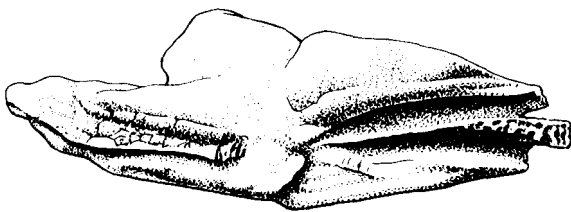


FIGURE 3.—Drawing of right sagitta from *Pseudophyscis bachus* illustrating features of *Pseudophyscis*-group otoliths.

Pseudophyscis-group (Figure 3)

Otoliths in this group are characterized by having the ostium approximately equal in length to the cauda. The crista superior is more than three-fourths as long as the crista inferior. Greatest otolith height typically is at about mid-length, but in some (*Auchenoceros*) the anterior end is expanded (highest). Sagittae of this group that have been illustrated are *Pseudophyscis bachus* (Frost, 1926, as *Physiculus bacchus*; Karrer, 1971, as *P. bacchus*), *P. barbatus* (Karrer, 1971), *P. brevisculus* (Karrer, 1971), *Lotella rhacina* (Karrer, 1971, as a member of the *Physiculus*-group), *Auchenoceros punctatus* (Karrer, 1971); and *Salilota australis* (Karrer, 1971).

Pseudophyscis bachus (Bloch and Schneider, 1801) (Figure 1E).—In the illustrated otolith

(12.7 mm long), the ostium is 6.3 mm long and the cauda, 6.3 mm. In this genus, the crista superior is as long as or longer than the crista inferior, which distinguishes *Pseudophysicus sagittae* from those of other genera in this group. An additional distinguishing character is the greatly expanded, knobby middorsal portion. Three pairs of *P. bachus* sagittae were available for examination.

Auchenoceros punctatus (Hutton, 1873) (Figure 1L).—In the illustrated otolith (4.7 mm long) the ostium is 2.3 mm long and the cauda, 2.4 mm. The greatly expanded anterior end easily distinguishes *Auchenoceros* sagittae from those of the other genera known to belong in this group. Two pairs of *Auchenoceros* otoliths were examined.

Lotella callarias Günther, 1863 (Figure 1F).—In the illustrated otolith (11.3 mm long), the ostium is 5.7 mm long and the cauda, 5.5 mm. The combination of a pointed anterior end, a relatively smooth, unexpanded middorsal portion, and a crista superior that is shorter than the crista inferior distinguishes *Lotella* otoliths from those of other genera assigned to this group. Eight pairs of sagittae from *L. callarias* were examined.

Physiculus-group (Figure 4)

Otoliths in this group are characterized by having a relatively short ostium (comprising one-third or less of total otolith length) and a crista inferior that is almost twice as long as the crista superior. The anterior end of the sagitta usually is bluntly pointed but may be broadly rounded, it is never expanded. Sagittae of this group that have been illustrated are *Physiculus dalwigki* (Vaillant, 1888), *Physiculus peregrinus* (Kotthaus, 1970), *Physiculus capensis* (Karrer, 1971), *Physiculus* spp.? (Hatai, 1965, as *Odontobutis*; Fitch and Brownell, 1968, as morid #1 and morid #2), *Gadella maraldi* (Schmidt, 1968, as *Uraleptus maraldi*; Karrer, 1971), *Laemonema robustum* (Vaillant, 1888), *L. laureysi* (Schmidt, 1968; Karrer, 1971), *L.*

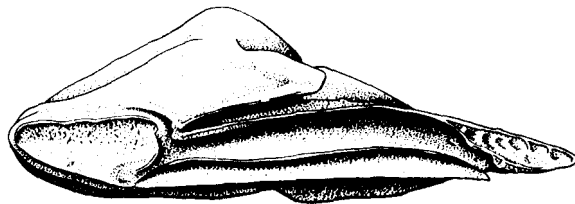


FIGURE 4.—Drawing of right sagitta from *Physiculus rastrelliger* illustrating features of *Physiculus*-group otoliths.

barbatulum (Karrer, 1971), *Tripterophysicus gilchristi* (Karrer, 1971), and *Brosmiculus imberbis* (Karrer, 1971).

Microlepidium verecundum (Jordan and Cramer, 1897) (Figure 1H).—In the illustrated otolith (3.5 mm long), the ostium is 0.8 mm long and the cauda, 2.7 mm. The crista superior (1.2 mm) comprises 33% of total otolith length and is slightly less than one-half the length of the crista inferior (2.3 mm). This otolith is characterized by having a thin ventrally directed “blade” projecting from the posteriormost 40% of the inner face. Ten pairs of sagittae from *M. verecundum* were examined.

Laemonema barbatulum Goode and Bean, 1895 (Figure 1A).—In the illustrated otolith (7.3 mm long), the ostium is 2.4 mm long and the cauda, 4.6 mm. The crista superior (2.1 mm long) is slightly less than one-third the total otolith length, but more than one-half as long as the crista inferior (3.5 mm). Sagittae of *Laemonema* are broadly rounded anteriorly, and by this character can be distinguished from otoliths from other genera placed in the *Physiculus*-group. Eleven pairs of sagittae from *L. barbatulum* were examined.

Physiculus rastrelliger Gilbert, 1890 (Figure 1D).—In the illustrated otolith (9.6 mm long), the ostium is 2.7 mm long and the cauda, 6.7 mm. The crista superior (2.7 mm long) comprises about 28% of total length and is slightly more than half as long as the crista inferior (4.8 mm). The otolith of *P. rastrelliger* can be distinguished from that of *P. nematopus* by the width of the

flattened area immediately above the crista superior. At any given otolith length, this area is only about half as wide on *P. nematopus* sagittae as on those of *P. rastrelliger*. We were unable to find any reliable character or set of characters for distinguishing *Tripterophycis* sagittae from those of *Physiculus*, but for any given species a careful comparison on a size-for-size basis appears to have merit. More than 30 pairs of sagittae from *P. rastrelliger* were examined.

Physiculus nematopus Gilbert, 1890 (Figure 1C).—In the illustrated otolith (7.5 mm long), the ostium is 2.2 mm long and the cauda, 5.3 mm. The crista superior (2.2 mm long) comprises approximately 29% of total otolith length and is slightly more than half as long as the crista inferior. As in other species of *Physiculus*, the anterior end is almost conical in lateral outline. The lumpiness of the outer face is highly variable and is of no value for distinguishing species. Such lumps are always more pronounced on otoliths of juveniles than adults. Ten pairs of sagittae from *P. nematopus* were examined.

Tripterophycis gilchristi Boulenger, 1902 (Figure 1B).—In the illustrated otolith (8.0 mm long), the ostium is 2.4 mm long and the cauda, 5.5 mm. The crista superior (2.2 mm long) comprises about 28% of total otolith length and very slightly exceeds half the length of the crista in-

ferior (4.3 mm). Sagittae of *Tripterophycis* are very difficult to distinguish from those of other genera placed in the *Physiculus*-group that have conical anterior ends. Fifteen pairs of sagittae from *T. gilchristi* were examined.

Actuariolum-group (Figure 5)

Otoliths in this group are characterized by having a relatively short ostium (comprising one-third or less of total otolith length), a crista superior that is about three-fourths as long as the crista inferior, and an expanded anterior end. Sagittae which have been illustrated from this group are *A. bicaudatum* (Frost, 1924, as *Physiculus bicaudatus*; Karrer, 1971) and *A. terakohensis* (Frost, 1933, as *Physiculus terakohensis*; Karrer, 1971). Both of these species are extinct Miocene fossils from New Zealand.

Actuariolum sp. (Figures 5A and 5B).—Karrer (1971) erected the genus *Actuariolum* (type species *A. bicaudatum*) for Frost's (1924, 1933) two fossils, and in corresponding with one of us (Fitch) she thought that "one day a recent species will be found which will belong to this genus or show a very close relationship." Subsequently, in examining a number of unidentified morid otoliths from cruises of the *Eltanin*, we turned

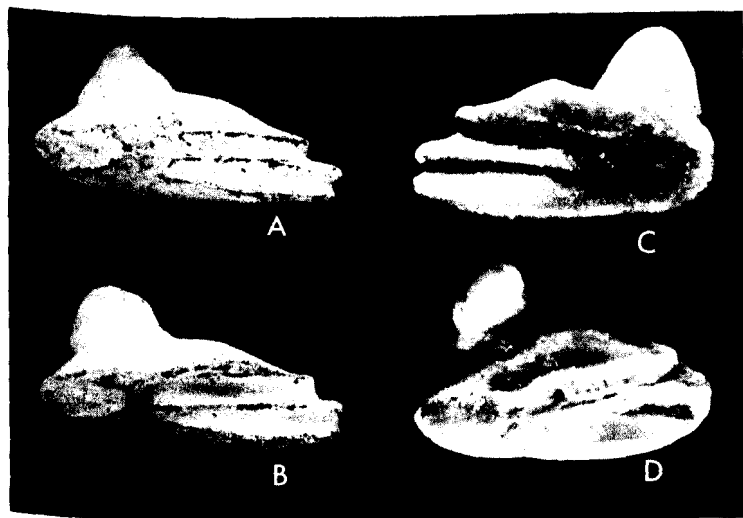


FIGURE 5.—Otoliths from *Actuariolum*: A and B, right sagittae, 5.2 and 4.2 mm long, respectively from an undescribed species collected at *Eltanin* station 1851, lat 49°40'S, long 178°53'E, 476-540 m, 3 Jan. 1967; C. and D., left and right sagittae from *A. terakohensis* collected in Lower Miocene deposits (Paratoetoe Fm.), Parengarenga Harbor, North Island, New Zealand, 2.9 and 3.0 mm long, respectively.

up several sagittae which match all salient characters of the fossil *Actuariolum*. In the illustrated specimens (from *Eltanin* station 1851, lat 49°40'S, long 178°53'E, 476-540 m) which are 5.2 and 4.2 mm long (Figures 5A and 5B) the ostium measures 1.7 and 1.2 mm; the crista superior, 2.9 and 2.6 mm; and the crista inferior, 3.3 and 2.9 mm, respectively.

For comparison, measurements of the illustrated fossil sagittae (*A. terakohensis* from the Paratoetoe Formation, Lower Miocene, Paren-garenga Harbour, Figures 5C and 5D) are: total length, 2.9 and 3.0 mm; ostium, 0.9 and 1.0 mm; crista superior, 1.4 and 1.6 mm; and crista inferior, 1.9 and 1.9 mm, respectively.

Additional specimens of the undescribed species were trawled at *Eltanin* station 1411 at lat 51°00'S, long 162°01'E in 333 to 371 m. All morids from these two stations are in the U.S. National Museum fish collections (Hugh H. DeWitt, personal communication); those from station 1851 appear to represent an undescribed species.

THE MORID CAUDAL SKELETON

The morid caudal skeleton (Figure 6) not only is unique among gadoids, it is unique among teleosts. The two lowermost hypurals (1 and 2 of Rosen and Patterson, 1969) are fused at their base, which lies adjacent to the penultimate ural vertebra, but are otherwise autogenous. Above these, hypurals 3, 4, and 5 diverge posteriorly as separate entities from the ultimate ural vertebra. Among other gadoids, hypurals 1 and 2 are

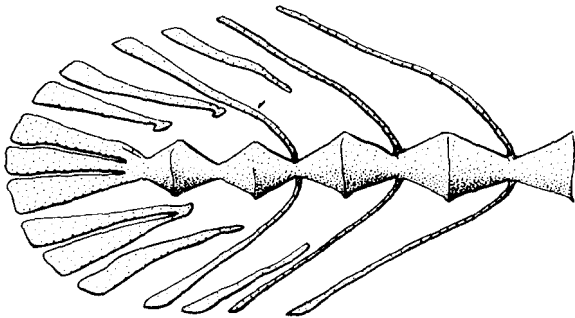


FIGURE 6.—Caudal skeleton of *Antimora microlepis*.

fused into a single plate, as are hypurals 3, 4, and 5.

The remaining caudal skeleton, although typical for all morids examined, is not unique to family Moridae. Anterior to the dorsalmost hypural, there are successively: two autogenous epurals with bases adjacent to the penultimate ural vertebra, a neural spine arising from the first preural centrum, a free-floating splinter bone (dorsal accessory bone of Rosen and Patterson, 1969), and then neural spines on successive centra. Preceding the lowermost (first) hypural is an autogenous parhypural with its base adjacent to the penultimate ural centrum, a haemal spine affixed to the first preural vertebra, a free-floating ventral accessory bone, and then haemal spines on successive centra. The two epurals and the parhypural are present in most other gadoids, but the autogenous splinter bones (dorsal and ventral accessory bones) may or may not be present depending upon which gadoid genus is being examined.

Thus in any fossil skeletal imprint, if one could locate either the autogenous lowermost hypurals (1 and 2) with their fused base, or the diverging uppermost hypurals (3, 4, and 5) which project posteriorly from the ultimate ural centrum, the imprint unquestionably would be that of a morid.

FOSSIL MORIDS

The fossil record for family Moridae is based upon an abundance of skeletal imprints and otoliths, primarily from the Northern Hemisphere. Most of these were described prior to 1940, and most were placed in family Gadidae, which at that time included the morids. Danil'chenko (1953) was the first to assign fossil gadoids to family Moridae, but included *Melanonus* which Marshall (1965) subsequently removed to its own family. In 1960, Danil'chenko suggested that *Eclipes* from the Californian Miocene was a morid, and at the same time he removed to family Brotulidae one of the species he considered a morid in 1953.

In our search for diagnostic characters which we could use to evaluate the fossil record, we found that only three features were infallible for distinguishing members of family Moridae:

the otoliths (Karrer, 1971), the caudal complex (Rosen and Patterson, 1969), and the large fontanelles in the exoccipitals through which elongate hornlike projections of the swim bladder extend and contact the auditory capsules (Svetovidov, 1948, 1967). Unfortunately, the diagnostic fontanelles cannot be distinguished in two-dimensional fossil imprints because of crushing, and three-dimensional skeletal remains are extremely rare, so one must rely upon either otoliths or the caudal complex to distinguish fossil morids.

Otoliths are abundant in most shelly marine deposits, but seldom are accompanied by other skeletal remains. On the other hand, in deposits where skeletal imprints abound, aragonitic substances, including otoliths, seldom remain. We know of only one deposit where otoliths have been found in situ in morid skeletal imprints. This is a Miocene diatomite deposit east of Los Angeles, Calif., and the morid is an undescribed species. Apparently several species examined by Danil'chenko (1960) from the Maikop deposits also have retained their otoliths, but he did not mention finding them in morids.

The tiny diagnostic hypurals of a morid caudal complex are difficult to observe unless the fossilized skeleton is preserved in lateral aspect, and such perfectly preserved specimens are extremely rare. In many of the gadoid skeletal imprints that we have seen, the caudal is either missing or so badly fragmented as to be virtually useless for determining relationships.

In commenting on the material reported upon by Danil'chenko (1953, 1960) we have relied heavily upon information obtained from Daniel M. Cohen, who examined much of it. During a trip to New Zealand, one of us (Fitch) examined fossil otoliths in the University of Auckland collections and noted sagittae from four species of Miocene morids, including both species reported upon by Frost (1924, 1933). In addition to two unreported species in the New Zealand Miocene, we have seen morid otoliths in the Miocene of California (two species), Jamaica (one species), and Poland (one species) which have not been reported in the literature. One of the two species from California probably represents an extinct genus, but additional comparative material

will need to be examined before this can be determined for certain.

STRINSIA ALATA STEINDACHNER, 1859

Danil'chenko (1953) placed this species from the Upper Miocene of Europe in family Moridae, based upon its presumed resemblance to the recent *Strinsia tinca* Rafinesque, 1810, and to one of his fossils, *Strinsia sobievi*. Subsequently, he decided that his *Strinsia sobievi* was a brotulid (Danil'chenko, 1960), and Cohen and Torchio (1964) showed that Rafinesque's *Strinsia tinca* (the type species) was a macrourid. A search for Steindachner's *S. alata* in Vienna during April 1971 was unsuccessful (Daniel M. Cohen, personal communication). On the basis of published information it is not possible to associate *S. alata*, described from a poorly preserved partial skeletal imprint, with family Moridae.

ONOBROSMIUS ELONGATUS (KRAMBERGER, 1883)

Onobrosmius (type species *Brosmius elongatus* Kramberger, from the Upper Miocene of Croatia) was proposed by Bogachev (1938) for fossil cods with a single dorsal fin, which is separated from the caudal fin by a small interval. The absence of teeth on the vomer and palatines was weighted heavily by Danil'chenko (1960) in assigning *Onobrosmius* to family Moridae, but none of the characters he reported for this fossil genus or any of the species assigned to it is diagnostic for the family. It very likely is a gadoid, but its acceptance as a morid must await examination of material on which any of several diagnostic characters are clearly evident.

PHYSICULUS RASTRELLIGER GILBERT, 1890

Fitch (1969) reported finding otoliths from *P. rastrelliger* in Pliocene deposits at Los Angeles, San Pedro, and Newport Beach, Calif. In two of the three deposits that yielded *Physiculus* sagittae, they were the most abundant otoliths

present, representing 27 and 10% of the total otolith yield. Subsequently, Zinsmeister (1971) reported otoliths of *P. rastrelliger* from one of these same two deposits (LACM Invert. Paleo. Loc. 471) but did not give data on numerical abundance. One of us (Fitch) has found otoliths of *P. rastrelliger* in other southern Californian Pliocene and Pleistocene deposits at San Diego (LACM Invert. Paleo. Loc. 305), Newport Beach (Jamboree Blvd.), and near Rincon Point, Santa Barbara County (Bates Road), and a Centerville Beach locality (south Humboldt Bay) investigated by Barker also has yielded fair numbers. The Centerville Beach deposit appears to be of Pliocene age and represents the farthest north the species has been found.

ECLIPES VETERNUS JORDAN AND GILBERT, 1919

The type specimen of *E. veternus*, now in the California Academy of Sciences collection, is an incomplete (tail missing), poorly preserved skeletal imprint with the head rotated into a different alignment than the body. Jordan and Gilbert (1919) placed this small fish in family Apogonidae, but did not feel strongly regarding this assignment. Subsequently, Jordan (1921) moved it into family Gadidae, where it was retained by David (1943). Danil'chenko (1960), although he did not examine the type, felt that the genus *Eclipes* was much more closely related to family Moridae than Gadidae. However, the characters he used to support this opinion are not unique to the morids, either by themselves or in combination.

A careful examination of the type specimen revealed that not only is the type description wholly unreliable, there is no character or combination of characters that will permit assigning this small fish to any gadoid family. Only because of its small size, flattened anterior neural spines, and the shape, placement, and extent of its dorsal and anal fins can it be associated with other fossil gadoids in the Miocene diatomites and shales of California. Since *E. veternus* is the type species of *Eclipes*, but is not a morid, the name *Eclipes* is not available for use in family Moridae.

MERRIAMINA ECTENES JORDAN AND GILBERT, 1919

The identity of this little fish presents an enigma. In describing *M. ectenes*, Jordan and Gilbert (1919) placed it in family Brotulidae and designated specimen number XIII as the type. Their caption for Figure 1, Plate XXVII (Jordan and Gilbert, 1919) reads "*Merriamina ectenes* Jordan & Gilbert; type XIII (El Modena)," but the illustrated slab (Figure 1) clearly is labeled "XII."

In checking Jordan's fossils in the California Academy of Sciences collection we found their specimen XIV (Figure 3, Plate XXVII), which now bears in Lore David's handwriting the inscription "*Merriamina ectenis* [sic] type El Modena = *Eclipes veternus*," but we were unable to locate the type (XIII), the illustrated "type" (XII), or specimen CVII from which Jordan and Gilbert obtained their vertebral count. In the text (p. 56-57), they mentioned examining seven different specimens of *M. ectenes* and gave numbers for each of these, but "XII," the specimen illustrated as the type, is not listed, which leads us to believe that the use of "XIII" in the text and figure caption might have been a typographical error. In any event, the photograph of specimen XII (Figure 1, Plate XXVII) shows a poorly preserved gadoid-like fish with what is obviously a regenerated caudal fin. Thus, if specimen XII is in fact the type, *Merriamina ectenes* cannot be assigned to a family with any certainty, even though Jordan (1921) subsequently declared *M. ectenes* a synonym of *Eclipes veternus* and placed it in family Gadidae.

Jordan and Gilbert's other illustrated specimen (XIV), part of the type series, has hypural elements 3, 4, and 5 fused into a single plate, so it cannot be a morid (E. H. Ahlstrom, personal communication).

ECLIPES MANNI JORDAN, 1921

An examination of the caudal complex on Jordan's type specimen (No. 543), now in the California Academy of Sciences collection, revealed that hypurals 3, 4, and 5 are fused into

a single plate. For this reason, *E. manni* can not be assigned to family Moridae.

Although Jordan (1921) reported that the beautifully preserved type is "17½ inches long," and David (1943) lists it as being "355 + 35 = 390 mm [15½ inches] in length," we found that it measures only 339 mm SL (13⅜ inches), or 378 mm TL (14⅞ inches). David's measurement can be duplicated by including the lower jaw and by failing to note where the caudal rays actually terminate. Unfortunately, the lower jaw became disarticulated and moved forward during fossilization, so it cannot be used as a point of reference in measuring total length. On the other hand, the caudal appears to terminate 31 mm behind the hypural, but upon careful scrutiny it can be seen that one or more of the uppermost rays extend for 38 mm behind the hypural.

David's (1943) description of *E. manni* was based on a composite of several specimens representing at least two species and should be regarded as generally unreliable for characterizing the species.

ECLIPES EXTENSUS JORDAN, 1921

The type specimen of *E. extensus* (Jordan's No. 716) is the "tail only of a long and slender fish." The hypural elements are in such a poor state of preservation that we were unable to determine what direction was dorsal, an opinion shared by E. H. Ahlstrom (personal communication). It appears to be a gadoid, but there are no characters which will permit assignment to a particular gadoid family. The long slender vertebrae and strong neural and haemal spines differ strikingly from those found in the other three species ascribed to genus *Eclipes*.

ACTUARIOLUM BICAUDATUM (FROST, 1924)

In describing this otolith from New Zealand, Frost (1924) noted that it "resembles in a remarkable way the otolith of the living New Zealand species *Physiculus* [= *Pseudophyscis*] *bacchus* [sic]." The broadly triangular, flared anterior end of this fossil resembles superficially

the configuration of *Auchenoceros sagittae*, but the very short ostium precludes its being congeneric. Karrer (1971) proposed the name *Actuariolum* for this fossil and placed it in her *Pseudophyscis*-group, but we believe the very short ostium of the fossil sagitta negates affiliation with *Pseudophyscis*. In fact *A. bicaudatum* has sufficient anomalous characters to warrant establishing a separate group for it and *A. terakohensis* (Frost, 1933). The type series (three otoliths) is from a Pukeuri road cut, north Otago, in the Rifle Butts Formation, Awamoan Stage, Pareora Series and is Lower Miocene in age (J. A. Grant-Mackie, personal communication).

ACTUARIOLUM TERAKOHENSIS (FROST, 1933)

This otolith described (as *Physiculus terakohensis*) from "the unique holotype" is the basis for dating family Moridae from the Oligocene (Berg, 1940). Karrer (1971) recognized its erroneous placement with *Physiculus* and assigned it to her new genus *Actuariolum*. The holotype is from the Golden Bay Cement Company's marl pit at Tarakohe, Nelson, in the Tarakohe Mudstone, Altonian Stage, Southland Series which is Lower Miocene in age, not Upper Oligocene as originally reported by Frost (J. A. Grant-Mackie, personal communication).

While in New Zealand, one of us (Fitch) examined more than a dozen otoliths of *A. terakohensis* in the University of Auckland collections. All of these were from the Paratoetoe Formation (Lower Miocene) at Parengarenga Harbor on the North Island; otoliths associated with them included myctophids, berycids, bregmaceroids, macrourids, gonostomatids, congrid, and other deepwater forms as well as a few shallow-water species.

LOTELLA ANDRUSSOVI (BOGACHEV, 1933)

This species was assigned to genus *Brosmius* by Bogachev (1933) on the assumption that it had but a single, elongate undifferentiated dorsal fin. Danil'chenko (1953) determined that it did in fact have two dorsal fins, and because of the

two dorsal fins, a lack of teeth on the vomer and palatine bones, and other similarities with his fossil *L. smirnovi*, he placed it in genus *Lotella*. The type specimen (from middle Miocene) is in the form of a well-preserved double impression about 90 mm long, but lacking the anterior part of the head (Danil'chenko, 1960). Two other specimens, from the Tarkhan Beds of the Kerch Peninsula, were available to Danil'chenko (1960), but his description fails to mention the dentition. Positive assignment to family Moridae will necessitate finding a skeletal imprint with otoliths in situ or with a discernible morid caudal complex. Even then it cannot be assigned to *Lotella* unless the dentition that is characteristic of this genus can be observed.

ECLIPES SANTAMONICAE DAVID, 1943

The type specimen of *E. santamonicae* (David's No. 10223), now in the collection of the Natural History Museum of Los Angeles County, is a badly fragmented, poorly preserved gadoid, on which indelible brown ink has been used to draw in missing parts and to highlight others. Not only has the type slab been retouched, the photograph of the altered type (Figure 4, Plate 5: David, 1943) has been further retouched.

A careful comparison of the types of *E. santamonicae* and *E. manni* leads us to believe that they are conspecific; thus, *E. santamonicae* is relegated to the synonymy of *E. manni*. It is not a morid.

ONOBROSMIUS OLIGOCAENICUS BOGACHEV, 1938

Danil'chenko (1960) noted a marked similarity between some species of *Onobrosmius* and the fossil species referred to *Lotella*, and reported that among the few but conspicuous differences between *Onobrosmius* and *Lotella* are a slightly bipartite dorsal fin, wider pectorals, and particularly a greater number of pelvic fin rays in *Lotella*. Interestingly, he ascribed eight pelvic fin rays for both *L. smirnovi* and *L. andrussovi*, whereas he noted "V 7-8" for *Onobrosmius oligocaenicus*.

As with the description of *O. elongatus*, no character reported for *O. oligocaenicus* is diagnostic for family Moridae. *O. oligocaenicus* occurs in the Zuramakent Horizon, Upper Maikop, and according to Danil'chenko (1960) the fauna of this horizon cannot be compared with the fossil fauna of any other region, so the problem of its absolute geologic age remains obscure. Although the Zuramakent Horizon has been variously placed in Lower Miocene and Upper Oligocene, we believe from available evidence that it could be no older than Lower Miocene at most.

LOTELLA SMIRNOVI DANIL'CHENKO, 1953

In assigning this species to *Lotella*, Danil'chenko overlooked the very characteristic dentition of the genus: an outer row of widely spaced large teeth and an inner band of small teeth. According to Daniel M. Cohen (personal communication) the dentition of *L. smirnovi* is readily visible and is not as described above. Although there is nothing in the type description that would rule out assigning *L. smirnovi* to family Moridae, Daniel M. Cohen (personal communication) said that "the tail appears to have been regenerated, so I cannot be absolutely certain that it is a gadoid." In light of these anomalies it will be necessary to reevaluate *L. smirnovi* using irrefutable familial and generic characters, if such can be found on the available imprints.

L. smirnovi occurs in the same horizon as *Onobrosmius oligocaenicus*, and, as noted above, there is no substantial evidence that this horizon is older than Lower Miocene.

STRINSIA SOBIEVI DANIL'CHENKO, 1953

In his original description, Danil'chenko placed this fossil in family Moridae and stated that the holotype, a double impression 40 mm long, is similar to the Upper Miocene *S. alata* Steindachner which is known only from fragments of the head and forward part of the body. Subsequently, with additional material at hand, he designated *S. sobievi* as the type species for a new genus, *Protobrotula*, and moved it into family Brotulidae (Danil'chenko, 1960). Daniel M. Cohen examined Danil'chenko's material of this species and informed one of us (Fitch) that

"*Strinsia sobievi* is based on very faint impressions [and] . . . I cannot say what it is." In view of the fact that the type of the genus *Strinsia* is a macrourid, that Steindachner's *S. alata* cannot be located, that Danil'chenko has moved his *S. sobievi* from family Moridae into family Brotulidae, and that diagnostic features cannot be found on the available material representing this species, it seems unlikely that this fish is a morid.

LEPIDION MIOCENICA SATO, 1962

Although this Miocene fossil from Japan probably is a gadoid and may be a morid, characters which could validate its assignment to family Moridae are either lacking or cannot be seen in the unique holotype. The vertebrae behind the second dorsal fin base are missing, otoliths are not mentioned and apparently were dissolved during fossilization, and if fontanelles ever were present in the exoccipitals they were rendered unrecognizable when this fish was crushed into a two-dimensional imprint.

In making his generic assignment, Sato (1962) states that "the present species is apparently referable to the genus *Lepidion* . . . in having [the] following important features: tail elongate and tapering posteriorly; two dorsals well developed together with the anal, and they are all composed of soft rays; anal fin is inserted far behind a perpendicular through origin of second dorsal fin base; snout is short and rather bluntly pointed in lateral view." Unfortunately, none of these characters is diagnostic of *Lepidion*, either by itself or in combination with the others. It would have been helpful to know if there were teeth on the vomer and the length of the anterior ray of the first dorsal fin (Norman, 1957).⁵ Although Sato (1962) reported that the vomer was present, he failed to indicate whether it was toothed or naked. The anterior ray of the first dorsal fin is neither prolonged nor filamentous in the photograph of the type, but in his reconstruction Sato has made it filamentous.

⁵ Norman, J. R. 1957. A draft synopsis of the orders, families and genera of recent fishes and fish-like vertebrates. British Museum (Natural History), London, 649 p. (Unpubl. manuscr.)

ODONTOBUTIS CF. OBSCURA HATAI, 1965

Apparently because of incorrectly identified comparative material Hatai (1965) assigned a "worn [morid] otolith measuring about 5 mm in length" from the Pliocene of Japan (Hamada sea cliff, Tanabu-machi, Shimo-Kita-gun, Aomori Prefecture) to family Eleotridae under the name *Odontobutis cf. obscura*. We do not know what species of morid he had for comparison [listed as *Odontobutis obscura obscura* (Temminck and Schlegel), and *O. o. yuriagensis* new subspecies], but the otoliths he illustrates appear to be identical to one reported by Fitch and Brownell (1968) from the stomach of a pygmy sperm whale harpooned off Japan. His fossil otolith has a bluntly rounded anterior end and differs in other features from those he affiliated it with, so it could not be identical. Based upon morid sagittae we have seen, Hatai's fossil otolith is most closely related to *Physiculus*, but correct generic placement must necessarily await comparison with morid species inhabiting the waters of Japan today. Karrer (1971) assigns this fossil to genus *Physiculus* (i.e., "ohne Zweifel der Gattung *Physiculus* angehören").

DISCUSSION

Based upon skeletal imprints, 12 fossil species have been assigned to family Moridae at various times in the past. Subsequently, one of these (*Merriamina ectenes*) was deemed conspecific with another (*Eclipes veterinus*), and a second (*Strinsia sobievi*) was made the type of a new genus and moved into family Brotulidae. Our studies revealed that of the ten remaining species, one (*Eclipes santamonicae*) is conspecific with *E. manni* and three others (*E. veterinus*, *E. manni*, and *E. extensus*) definitely are not morids. In addition we were informed that the type and only known specimen of *Strinsia alata* cannot be found, but since the tail portion of this imprint was never present and the remaining skeletal parts are not diagnostic, it could not be assigned to family Moridae even if the type were located. For the same reason (missing caudal complex), neither *Lotella smirnovi* nor *Lepidion*

miocenica can be retained in family Moridae with any certainty. Finally, the descriptions of the remaining three (*Onobrosmius elongatus*, *Lotella andrussovi*, and *Onobrosmius elongatus*) are all lacking in characteristics which are diagnostic of any gadoid family, and until or unless such features can be observed on the type specimens, the only reason for retaining them in family Moridae would be mere intuition.

Morids have also been reported in the fossil record from otoliths found in New Zealand, California, and Japan. One of these, reported as *Odontobutis* cf. *obscura* (an eleotrid) from the Pliocene of Japan, appears to represent an extant species of *Physiculus*, but no specific assignment can be made until comparative material from Japanese waters has been examined. All of the species known from otoliths are unquestionably morids.

On paleontological evidence, Danil'chenko (1960) reported that the Moridae constitute probably the oldest family of the order Gadiformes. He based this opinion on the belief that *Melanonus*, abundant in Oligocene rocks, was a morid, but Marshall (1965) removed *Melanonus* to its own family, and our investigations have revealed that none of the fossil morids, or presumed morids, is more ancient than Lower Miocene. Rosen and Patterson (1969) pointed out additional reasons for questioning morid antiquity and the logic of relating their ancestry to other gadoids.

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