Bulletin of the Museum of Comparative Zoology

AT HARVARD COLLEGE

Vol. 112, No. 2

DEEP WATER ELASMOBRANCHS AND CHIMAEROIDS FROM THE NORTHWESTERN ATLANTIC SLOPE

by

Henry B. Bigelow

and

William C. Schroeder

CAMBRIDGE, MASS., U.S.A.

PRINTED FOR THE MUSEUM

September, 1954

No. 2 — *Deep Water Elasmobranchs and Chimaeroids From the Northwestern Atlantic Slope*[1]

By Henry B. Bigelow and William C. Schroeder

CONTENTS

[1] Contribution No. 692 from the Woods Hole Oceanographic Institution.

INTRODUCTION

The slope of the bottom is so steep from the edge of the continent at the 150-200 fathom level down to the 800-900 fathom level off the northeastern United States and off Nova Scotia that the intervening zone is not wider than about 25 miles, anywhere between the offing of Chesapeake Bay and the Laurentian Channel, with a minimum breadth of only 7-10 miles. Nevertheless this zone, narrow though it be, is of great interest ecologically, because it is the site of the transition from the bottom-dwelling animals of the shallow waters of the continental shelf, to those of the Atlantic abyss.

The explorations by the "Blake," and especially those by the "Albatross" in the 1880's, yielded a wide variety of bottom-living fishes from the lower part of the slope at depths of 800 fathoms and more; they also sampled the bathypelagic communities of the overlying waters, many additional members of which have been brought to light subsequently. The fishes, too, of the northeastern American shelf have been studied intensively at many hands for many years, not only from the descriptive-taxonomic standpoint, but also from the standpoint of the commercial fisheries.

But the "Albatross" and "Fish Hawk" devoted less attention to the middle part of the slope. (They made only 63 trawl hauls at 250-500 fathoms, contrasted with 117 hauls deeper than 700 fathoms). And no subsequent attempt has been made to continue the scientific investigation of the bottom-living fishes in deep water in the northwestern Atlantic since 1887 when the "Albatross" was transferred to the Pacific, whether because of the expense that would have been involved, or because of a shift of interest to other subjects. And very little commercial fishing, either with hook and line or with the trawl, has ever been attempted deeper than about 250 fathoms along the slope with which we are concerned, partly because of the difficulty and expense of operating commercial gear in greater depths, and partly because it has not seemed likely that saleable food fishes would be found on bottom there in worthwhile quantities.

Consequently, while it seemed safe to forecast, from the fish faunae of shallow water and of deeper, what species of bottom fishes might be expected along the mid zone of the slope, the

belt in question was a *mare incognitum,* to all intents and purposes, as regards the quantities of any species to be found there.

In the hope of filling this gap in our knowledge, trawling campaigns were carried out by the Woods Hole Oceanographic Institution along the slope between the offings of southern New England and of La Have Bank, Nova Scotia, on the "Caryn" in June and September 1949; between the offings of Montauk, Long Island, New York, and of La Have Bank from the dragger "Cap'n Bill II" in June and July 1952; and between the offings of Virginia and of La Have Bank on "Cap'n Bill II" in June and July 1953. Otter trawls 35 feet wide were used in 1949, 35 and 50 ft. trawls in 1952, and 60 ft. trawls in 1953. One hundred and forty-three successful hauls were made in the three summers combined, dragging on bottom for 30-60 minutes, between 200 fathoms and 730 fathoms. And a total catch of about 25,000 bottom fishes in all the hauls combined seems good evidence that the nets worked with at least moderate efficiency.

The present report deals with the catches of elasmobranchs and of chimaeroids.

The following species of sharks and skates had been reported, through 1953, from depths greater than 200 fathoms on the American Atlantic slope north of Chesapeake Bay: *Apristurus profundorum* Goode and Bean 1895; *Centroscyllium fabricii* (Reinhardt) 1825; *Etmopterus princeps* Collett 1904; *Centroscymnus coelolepis* Bocage and Capello 1864; *Raja bathyphila* Holt and Byrne 1908; *Raja jenseni* Bigelow and Schroeder 1950; *R. mollis* Bigelow and Schroeder, 1950; *R. laevis* Mitchill 1817; *R. senta* Garman 1885; and *R. spinicauda* Jensen 1914. On the other hand, one species — *Scymnodon melas* — described by Bigelow, Schroeder and Springer (1953, p. 233) as new must now be relegated to synonymy (p. 51).

The trawling operations of "Cap'n Bill II" add *R. fyllae* Lütken 1887 to this list. And it is likely that *R. hyperborea* Collett 1878 will be found off Labrador or off Newfoundland sooner or later. But the number of trawl-hauls that have been made along the 300-550 fathom zone between the Hudson Canyon and the offing of La Have Bank, Nova Scotia, is now so large that the list of elasmobranchs to be found on the bottom there is not likely to be increased much in the future.

SHARKS

Family SCYLIORHINIDAE
Cat Sharks

Apristurus profundorum (Goode and Bean) 1895

This deep-water shark had been known from two specimens only, both of them from the offing of Delaware Bay, until the summer of 1952 when "Cap'n Bill II" trawled it at 7 stations (8 specimens) scattered along the slope from the offing of New York (Lat. 39°46′N, Long. 71°35′W) to the offing of southern Nova Scotia (Lat. 42°39′N, Long. 63°54′W). And with 8 more, taken in 1953 at 6 stations, the records for it are numerous enough now and distributed widely enough to show that it is to be found generally, though sparsely, along the slope from the offing of Nova Scotia to that of Virginia (most southerly station, Lat. 37°39′N, Long. 74°06′W; most northerly, Lat. 42°40′N, Long. 63°52′W). The depths of capture range between 360-420 fathoms and 640-720 fathoms for the two years combined. The temperature on bottom, at the stations where it was taken, was 3.7° to 4.5°C in 1953, and presumably was about the same in 1952, though no bottom readings were taken that year at the particular localities in question.

Points of taxonomic interest are discussed in our earlier paper (Bigelow, Schroeder and Springer, 1953, p. 214).

Family SQUALIDAE
Spiny Dogfishes

Centroscyllium fabricii (Reinhardt) 1825
Black Dogfish

Earlier captures of the black dogfish on the slopes of the Nova Scotian Banks, and of Georges Bank, had not been numerous enough to suggest the existence of more than a sparse population there, though a widespread one as had been known for many years. In fact, only two specimens had come into our hands, in the Museum of Comparative Zoology, at the time when our earlier discussion of its occurrence in the western Atlantic was written (Bigelow and Schroeder, 1948a, p. 486). But catches of 69 black dogfishes by "Caryn" in 1949, and of 715 and 371 of them by "Cap'n

Bill II'' in 1952 and 1953 respectively, show that our previous estimate of its numbers off Nova Scotia and off Georges Bank must be revised upward. This seems, indeed, to be the most plentiful shark there at depths greater than those frequented by the common spiny dogfish (*Squalus acanthias*).

No doubt the reason for the quantitative discrepancy between the older records for the species in Nova Scotia slope waters, and the catches of it made there in 1949, 1952 and 1953 is that all of the former were based on fish taken with hook and line by the halibut fleet which did not fish much below 200 fathoms, i.e. not deep enough to sample more than the uppermost fringe of the population of this deep-water shark.

The number of specimens at hand is now large enough to throw some light on the quantitative occurrence of the species, both geographic and bathymetric. The average catches, per successful haul,[1] within the depth range where *fabricii* was taken at all, were about 24 specimens to the eastward of longitude 66°W for the years 1949, 1952 and 1953 combined (49 hauls); between 4 and 5 specimens from longitude 66° to longitude 69°59′W (26 hauls); 2 specimens from longitude 70° to longitude 71°59′ (10 hauls); and about 1 specimen westward and southward thence to the offing of Virginia (12 hauls). Similarly, the largest catches made in any one haul were 92 and 95 specimens east of longitude 66°; 29 between longitudes 66° and 69°59′W; 8 between longitudes 70° and 71°59′W; and 3 farther to the west and south. The regularity, too, with which *fabricii* was taken shows a corresponding gradient from northeast to southwest, for while 97 per cent of the hauls made in 1952 and 1953, within its preferred depth zone, yielded it to the eastward of longitude 66°, only 65 per cent did so along the slope off Georges Bank (longitudes 66° to 69°59′); 60 per cent in the offing of southern New England (longitudes 70° to 71°59′); and 50 per cent farther westward and southward.

Evidently, then, the center of abundance for *fabricii,* in American waters, lies at least as far to the eastward and northward as the offing of western Nova Scotia, perhaps farther still in that direction. Even here, however, the black dogfish — like other fishes — vary widely in numbers from place to place within

[1] We take no account of such of the hauls as obviously were unsuccessful for one reason or another.

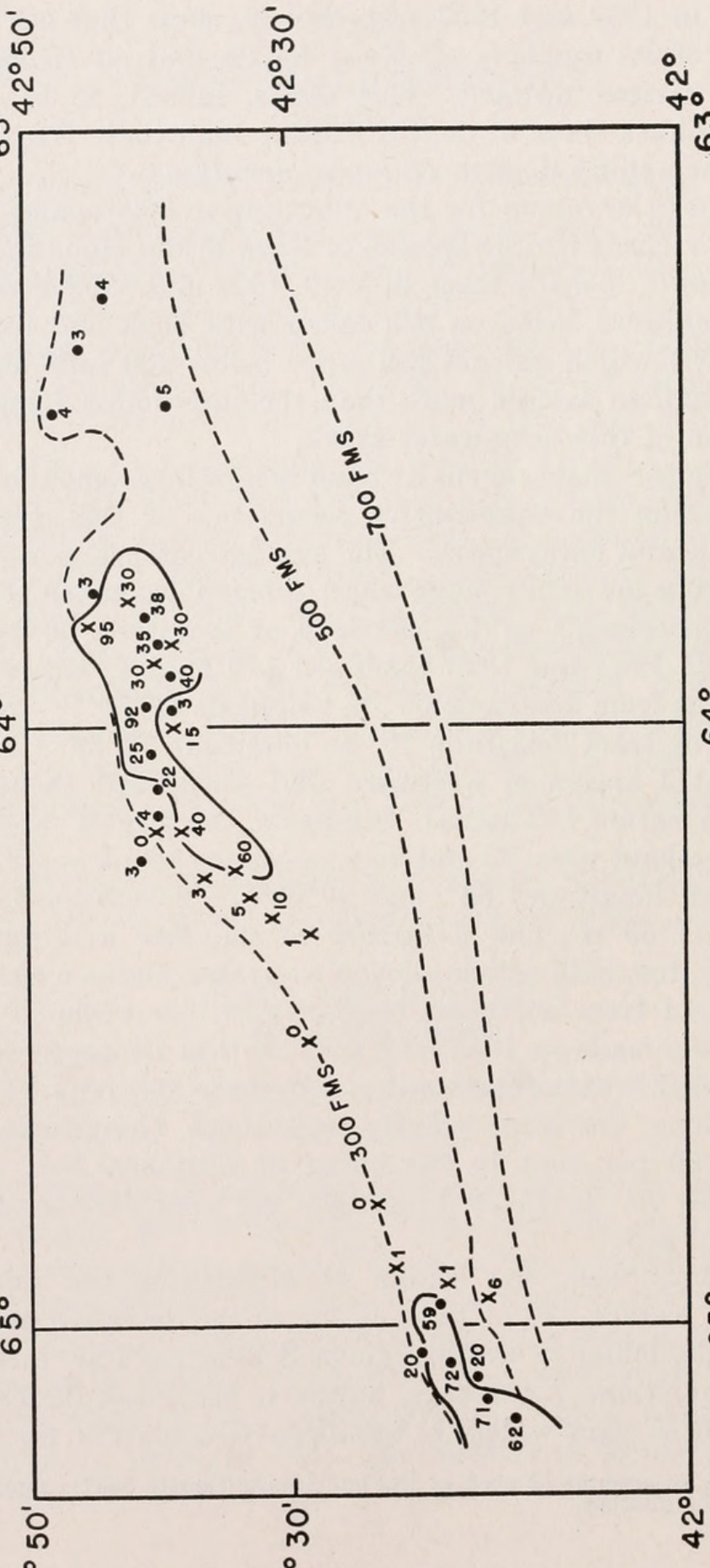

Fig. 1. *Centroscyllium fabricii.* Numbers per haul taken east of longitude 66°W in 1952 (•) and in 1953 (x). The solid curves enclose the areas where the catches per haul were consistently greater than 25.

short distances, independent of the precise depth, as is illustrated by catches ranging from 3 to 92 per haul within a distance of about 5 miles along the 340 to 520 fathom zone between longitudes 63°58′ and 64°06′ in 1952; from 15 to 95 per haul within about 10 miles in that same general region in 310 to 625 fathoms between 63°50′ an 64°00′ in 1953; and from 5 to 40 within a few miles to the southwestward (longitudes 64°10′ to 64°17′; 280 to 475 fathoms) that same summer. But a plot of the catches made per haul (Fig. 1) shows that these were not haphazard, for in each year there was a definite center of abundance, concentrating at about longitudes 63°50′ to 64°10′, extending for something like 30 miles along the slope between 310 and 545 fathoms, with the bottom less productive both to the northeastward and to the southwestward. And a similar concentration was encountered some 35-40 miles to the southwestward (longitude 65° to 65°10′) in 1952 at about that same depth (310-490 fathoms). This precise locality was not revisited in 1953. The discovery of these rather definite centers of population is of general interest as evidence that the relative productivity of the bottom, in fishes, may vary as widely from place to place, far down the slope, as every fisherman knows that it does on the great fishing banks on the continental shelf.

It may be worth adding that an average catch of 21 specimens per haul, with the trawls used, would work out at about 4 specimens per acre, the richest catches (92 and 95 per haul) at about 18 per acre — if the trawls caught all the specimens lying in their path, which they certainly did not; how much to add for failure in this respect would be sheer guesswork.

If the catches can be taken at face value, *fabricii* is only about ⅕-⅙ as numerous along the slope of Georges Bank and off southern New England as it is off Nova Scotia, and still less numerous farther to the west and south.

Nevertheless, captures of five specimens off Delaware Bay in 3 hauls (Lat. 38°41′N-38°47′N), of one off the coast of Maryland (Lat. 38°05′N), and of one off the coast of Virginia (Lat. 37°39′N) show that *fabricii* ranges farther to the southward, along the American Atlantic slope, than had been known previously.

Off Nova Scotia, the shoalest capture of *fabricii* was in a haul at

185-220 fathoms (3 specimens) ; the largest catches (92 and 95 specimens) were made between 310 and 360 fathoms; and the species seems to have been distributed rather uniformly down to about 600 fathoms, to judge from average catches of about 28 per haul at 301-400 fathoms, of 22 at 401-500 fathoms, and of 33 at 501-600 fathoms. But catches of only 15 in a haul at 610-625 fathoms, and 6 in one made at 660-705 fathoms[1] suggest that *fabricii* is less plentiful deeper than 550 fathoms than shoaler. But average numbers of specimens taken per haul at different depths may be deceptive, if taken by themselves, for they conceal the fact that the numbers caught, in individual hauls, varied about as widely within representative depth zones as they did geographically (Fig. 1), no doubt for the same reason.

Maximum and minimum numbers caught per haul, east of longitude 66°W, in 1949, 1952 and 1953 combined, at depths greater than 300 fathoms, are as follows:

Depth in fathoms	Number of hauls	*Fabricii* caught per haul
301 - 350	12	3 - 95
351 - 400	6	4 - 71
401 - 450	7	0 - 59
451 - 500	6	1 - 40
501 - 550	4	3 - 62
551 - 600	1	5
601 - 650	1	15
651 - 700	1	6

Farther to the west and south *fabricii* is not only less numerous, but the upper boundary to its vertical range lies deeper down the slope, progressively. Thus the shoalest hauls in which it was taken were at 355-400 fathoms (1 specimen) and 360-420 fathoms (2 specimens) along the slope of Georges Bank, at 390-460 fathoms (3 specimens in 3 hauls) in the offing of southern Massachusetts, and 485-520 fathoms, southward from the offing of New York.

[1] These were the only hauls to the eastward of longitude 66° that worked as deep as 600 fathoms, either in 1952 or in 1953.

The deepest catches were made at 660-705 fathoms off Nova Scotia (6 specimens in one haul); at 600-670 fathoms off Georges Bank (5 specimens in 1 haul); at 710-730 fathoms off southern Massachusetts (5 specimens in 1 haul); at 630-675 fathoms (3 specimens in 1 haul) and at 640-720 fathoms (2 specimens in 1 haul) farther to the westward and southward. As these were the deepest successful hauls, with one exception, that were made in the respective sectors of the slope, it is a question for the future how much deeper the range of *fabricii* may extend.

In 1953, when the temperature was taken on bottom with maximum-minimum thermometers at almost all the stations where trawl hauls were made, all the captures of *fabricii* occurred where bottom temperatures ranged between about 4.5°C, and about 3.3°C, the great majority between 4.5° and 3.9°. And even if the range of *fabricii* reaches down as deep, say, as 1200 fathoms — of which there is no evidence — its lower thermal boundary along the American slope would not be colder than about 2.5°C. At the other extreme, specimens that work their way up the Nova Scotian slope to 200 fathoms or so, such as were brought in by the halibut fleet years ago, are likely to meet water at least as warm as 6-7°C. Thus, the range of temperature within which it occurs in greatest numbers in American waters is only about 2°C, the extreme range there perhaps 4-5°C for the entire population.

Consequent on the steepness of the slope, the maximum breadth of the zone where *fabricii* occurs the most regularly is only something like 25-30 miles off the Grand Banks and off Nova Scotia, even if it ranges down to 1000 fathoms there; 10-12 miles along Georges Bank and off southern New England; and perhaps 15 miles in the offing of Maryland and of Virginia.

The catches of *fabricii* made east of longitude 66°W averaged considerably larger in 1952 than in 1953 as tabulated below. But with the catches in individual hauls ranging from 1 to upwards of 90 in each of the two years, the discrepancy may not be wider than can be credited to what we may call "fisherman's luck," for want of a better name.

Catches east of longitude 66°W, at depths greater than 300 fathoms

	Successful hauls	Hauls with *fabricii*	Percentage of hauls with *fabricii*	Total catches	Average per haul	Maximum catch
1952	19	19	100%	610	32	92
1953	15	14	93%	333	22	95

Among 25 specimens that were opened in 1953, 10 were empty; the others contained remains of fishes, decapod crustaceans, (shrimps), schizopod or euphausiid, squids, and octopus.[1]

Etmopterus princeps Collett 1904

We have already reported (with description) the capture of 47 specimens of this deep-water shark along the slope between the offings of southern New England and western Nova Scotia (Bigelow, Schroeder and Springer, 1953, p. 47). Earlier records for *princeps* had been from the Faroes-Hebrides region (Collett, 1904, p. 3; 1905, p. 28) and from the offing of the Straits of Gibraltar (Koefoed, 1927, p. 21). The trawlings of 1953 yielded 7 more, all of them from the offing of western Nova Scotia. The largest numbers taken were 9 (once), 8 (once) and 7 (once) while 1 was the number taken the most often (fourteen times).

The hauls that took *princeps*, in the three seasons, were at depths ranging from 310-320 fathoms down to 490-540 fathoms, with the largest catches (7, 8 and 9) at 480-520 fathoms, 420-480 fathoms, and 390-440 fathoms respectively, which suggests that *princeps* is about equally plentiful, downward, across the depth zone along which it occurs off our coasts. And it is to be expected considerably deeper there as well, for it has been taken at 1134 fathoms off the Straits of Gibraltar.

The 18 hauls that yielded it in 1949 and 1952 were scattered all along from the offing of La Have Bank (longitude 63°38′W) to the offing of Cape Cod (longitude 70°05′W), with the largest catches (3, 7, 8 and 9 individuals) off Nova Scotia. Similarly, 5 of the 7 specimens taken in 1953 were from the general offing of La Have Bank, only 2 off the eastern part of Georges Bank, although many successful hauls were made there and to the

[1] Stomach contents identified by Dr. Benjamin Laevitt.

westward along the 300-550 fathom zone that summer. It is a question for the future whether this difference is evidence of a corresponding fluctuation in the western boundary of *princeps*, in numbers large enough for the trawl to pick it up, or whether we are dealing with a matter of pure chance. In either case, there is nothing to suggest that this shark ranges westward beyond the offing of Cape Cod, a limitation we cannot explain as due to temperature, for readings taken by "Cap'n Bill II" in 1953 on bottom along the 300-550 fathom zone were very nearly the same to the westward of longitude 70°W (3.5°-4.8°) as to the eastward (3.3°-4.5°).

Centroscymnus coelolepis Bocage and Capello 1864
Portuguese shark

The trawlings of 1953 yielded three specimens of this species: two juvenile males, 565 mm. and 690 mm. long, and an adult female of 1035 mm. which gave premature birth on deck to 15 embryos 266-282 mm. long, 5 of them males and 10 females. The number of embryos is in line with Vaillant's (1888, p. 66) record of 13 to 15 for this species. Moreau (1891, p. 9), it is true, has reported only 5 for a Mediterranean female, identified as *coelolepis*, but her small size (599 mm.) suggests that she belonged to some other species in reality.

It has been a tacit assumption, until recently, among students of sharks, that the denticles which develop on any given part of the body at different stages of growth are similar in shape; hence, that the shape of the denticles is a more or less reliable specific character — or even a generic one. But Radcliffe (1916, p. 267) has pointed out that the denticles to be seen on specimens of different ages differ somewhat in shape in some species of the genus *Carcharhinus*. Tortonese, too, (1952, p. 386, fig. 1; p. 387) has recently found that the denticles on the sides of a juvenile male, 270 mm. long, seemingly referable to *Centroscymnus coelolepis* by other characters, were strongly tridentate, whereas those on the adult *coelolepis* have evenly rounded edges, as has been known for many years. And the "Cap'n Bill II" series of that species enables us to corroborate his very interesting finding. Thus those on the body of our adult female 1035 mm. long are

evenly ovoid in outline, with concave crowns, and regularly overlapping (Fig. 2*D*) ; they have been pictured and described similarly for this species by Bocage and Capello (1866, pl. 3, fig. 3), by Vaillant (1888, pp. 64-65), by Garman (1913, pl. 14, fig. 8), and by us (1948a, p. 495, fig. 94A). But the denticles on the embryos to which she gave birth[1] are tridentate, weakly so on the top of the head, where they are moderately widely spaced, but much more strongly tridentate on the sides of the body where they are more widely spaced as well (Fig. 2*A*).

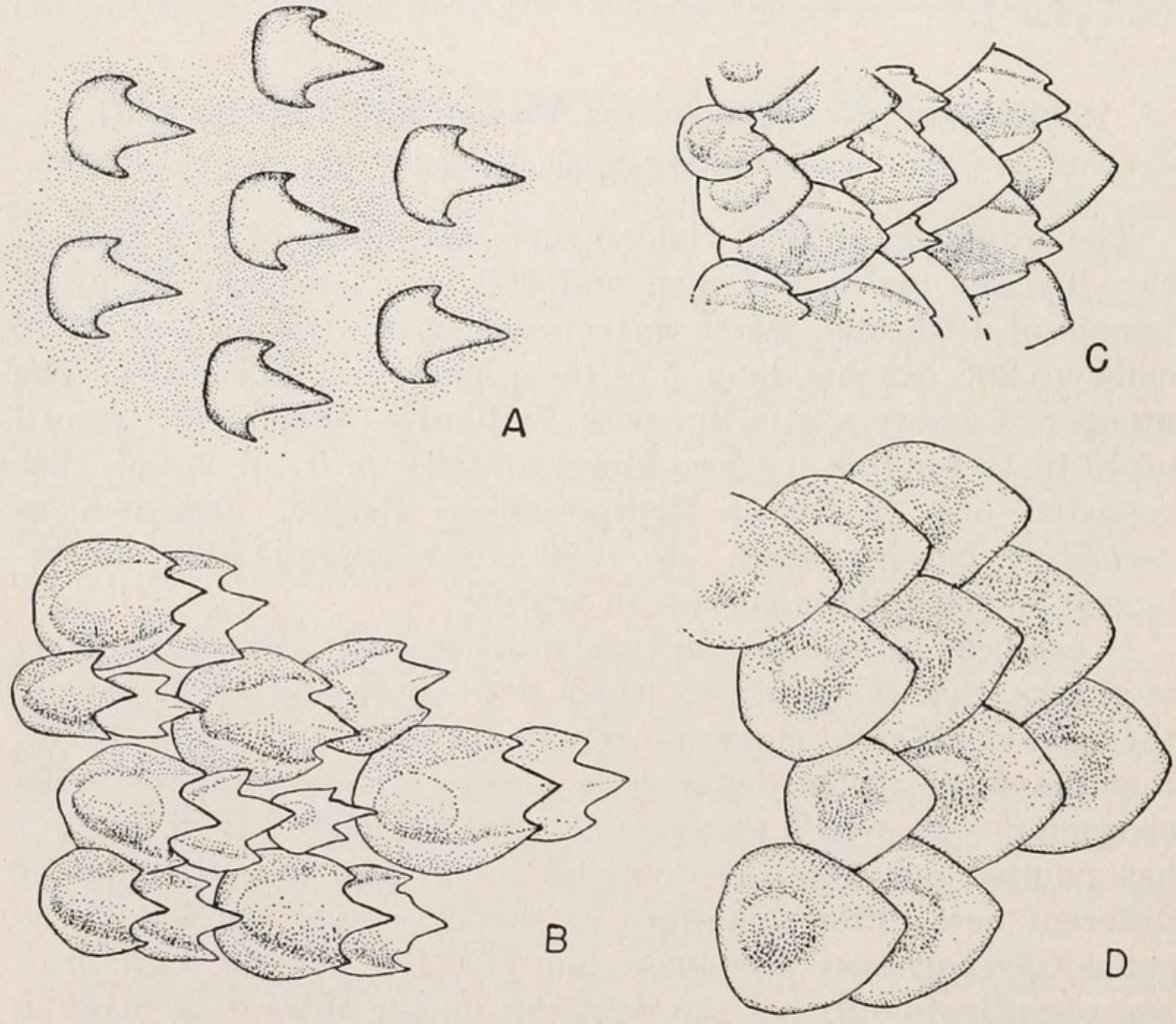

Fig. 2. *Centroscymnus coelolepis.* Dermal denticles from side of trunk below first dorsal fin. *A,* Embryo male, 282 mm. long, from adult female of 1035 mm., about 13 x. *B,* Juvenile male, 565 mm. long, about 8 x. *C,* Juvenile male, 690 mm. long, about 6 x. *D,* Adult female 1035 mm. long (mother of embryo shown in *A*), about 5 x.

[1] Embryos well formed, but with only the tips of the teeth exposed, while the denticles had not yet erupted through the skin.

It is evident, too, from partly grown specimens of different sizes that the margins of the denticles that are developed successively, during growth, are less and less dentate. The smaller of the denticles, for example, on the flanks and belly of a juvenile male 565 mm. long are strongly tridentate still, but the larger (i.e. younger) ones only weakly so, and with one overlapping the next more or less widely in most cases (Fig. 2*B*). At this stage the denticles on the sides below the first dorsal fin range from about 1.2 mm. to about 2 mm. in length.

At a slightly more advanced stage, as represented by a male of 690 mm., the smallest (i.e. the oldest) of the denticles on the trunk are tridentate (Fig. 2*C*), but many of the larger (i.e. younger) ones now have entire margins, though with pointed tips still, while denticles of intermediate sizes show various intermediate stages and the denticles on the body now overlap so regularly that they hide the skin.

Up to this stage the denticles vary considerably in size from one to the next, with those on the sides below the first dorsal fin ranging from about 1 mm. to about 2.4 mm. in length. But those on the adult female of 1035 mm. (Fig. 2*D*) are all about equal in size over any given region of the body. And they no longer include any tridentate forms except near the tips of the pectoral fins.

This seems an appropriate place to remind the reader that on adult *coelolepis* (females, at least; adult males have not been seen) the denticles are largest (about 3-3.5 mm. long) on the mid sector of the trunk, belly as well as sides and back, and are progressively smaller not only forward, but rearward as well, with those on the caudal peduncle on the average only about 70 per cent as long as those on the sides below the first dorsal fin.

The discovery that the denticles are of one shape on young specimens of this particular species of shark, but of a strikingly different shape on adults, opens vistas that are interesting from the standpoint of elasmobranch morphology in general, as well as from that of taxonomy.

To begin with, it poses the question, how long is the normal life span of a dermal denticle in relation to the life of the individual? So far as we can learn, no special attention has been paid to this point, nor is it safe to reach any conclusion *a priori*

here, for while the teeth of sharks, which correspond in all essentials with the placoid scales or dermal denticles, are replaced periodically, the dorsal fin spines — equally homologous with the denticles — are retained throughout life in such sharks as have them. Among bony fishes, the general rule is that a scale, once formed, persists throughout the life of the fish, growing in size meantime, at a rate that keeps pace (more or less) with the rate of growth of the fish. In fact, the determination of the ages of fishes by the markings on their scales, a familiar procedure in fisheries biology nowadays, is based on belief in the validity of this rule. But Hertwig's (1874, p. 358) observation that new dermal denticles are formed between pre-existing ones in some sharks,[1] not only during embryonic development but during later life as well, shows that the situation is not so simple for elasmobranchs.

Counts of about twice as many denticles within a given percentage of the total length of a specimen, below the first dorsal fin, of *C. coelolepis* 565 mm., 690 mm., and 1035 mm. long as on an embryo of 277 mm. (for details, see p. 49) show that the final number is developed, in this particular species, by the time a given specimen is about half grown — how much earlier is not known. It also seems evident, from the shapes and relative sizes of the denticles, and from their irregular arrangement, that several generations of them are represented on small examples as illustrated by our specimens of 565 and 690 mm. (Fig. 2, *B*, *C*). But the uniformity in size and shape of the denticles on adults, and the regularity with which they are arranged, suggest that the ovoid ones that first develop on specimens a little more than half grown represent the final generation, which persists throughout the later life of the individual concerned. We can go no farther than this from information available up until this time.

We think it probable, too, that a similar succession in the shapes of the denticles takes place between young specimens and adults, in the case of *Centroscymnus owstoni* Garman 1906, from Japan, a near relative of the North Atlantic *C. coelolepis*. When adult, its denticles resemble those of adult *coelolepis* very closely in shape. But they are tridentate over the trunk as a whole on two

[1] It is not clear, from the context, whether Hertwig made these particular observations on *Mustelus*, on *Acanthias*, on *Dalatias* or on *Heptranchias*.

Japanese squalids, 260 mm. and 287 mm. long, in the Museum of Comparative Zoology, which agree very closely in all other respects (including very minute denticles, very oblique lower teeth, and no median tooth in the lower jaw) with two adult males of *owstoni*, 785 mm. and 805 mm. long, in the Museum. Incidentally, the two small specimens just mentioned came from Japan labelled *Scymnodon squamulosus*. But they differ sharply from *squamulosus* as pictured by its describer (Günther, 1878, pl. 2, fig. B) both in their very oblique lower teeth, and in pectorals reaching back as far as the level of the origin of the first dorsal fin, for the lower teeth of *squamulosus* are shown as nearly erect, and the tips of its pectorals as falling short of the level of the origin of the first dorsal by a distance about as great as the length of the snout in front of the mouth.

On the other hand, the successional history of the denticles of *Centroscymnus coelolepis* strengthens the specific validity of *C. cryptacanthus* Regan 1906, from Madeira, the denticles on the type specimen of which (about 700 mm. long) were tridentate with 3 parallel keels on the trunk anterior to the first dorsal, but "the others smooth, with rounded edges and with a rounded depression on the free surface of each" (Regan, 1906, p. 437).

Present realization that it is not safe to define species of sharks by the shape of their denticles — unless the ages of the specimens in question be taken into account — forces us, next, to conclude that the juvenile squalids, 330-462 mm. long on which Bigelow, Schroeder and Springer (1953, p. 233) based the new species *Scymnodon melas* actually represent nothing more than an early stage in the growth of *Centroscymnus coelolepis*. Thus their denticles correspond very closely to the smallest and most tridentate of those of our 565 mm. *coelolepis* (p. 49, Fig. 2*B*), though they contrast so strongly with the rounded denticles of the adult that we would never have guessed that they belonged to the same genus, much less to the same species, had it not been proven that the denticles of the young of *coelolepis* are similarly tridentate, to be replaced by ovoid ones later. The somewhat wider spacing of the denticles on the supposed *melas* than on partly grown *coelolepis* points merely to an earlier stage in the growth of the individuals. Neither can we find any better excuse for retaining the species, whether in proportional dimensions, in the fins, or

in the shapes and number of teeth. And while we had thought its black color distinctive, as contrasted with the chocolate hue of the adult *coelolepis*, embryos of the latter, of proven parentage, are a very deep blue, while half-grown males are black, with only a faint tinge of chocolate to forecast the color of the adult.

The previous records for this species for the western Atlantic have been scattered along the slope, from the Grand Banks of Newfoundland to the offing of Nantucket. It is therefore interesting — as it was unexpected — that the three caught by "Cap'n Bill II" were all taken between the offings of New York and Delaware Bay, as follows:

Length in mm.	Sex	Lat.	Long.	Depth in fathoms
1035	♀	38°41′N	73°01′W	570-610
690	♂	39°09′N	72°21′W	485-520
555	♂	38°43′N	72°56′W	630-675

Our failure to take *coelolepis* off Georges Bank, or off Nova Scotia, where it was reported so often by the halibut fishermen years ago (Bigelow and Schroeder, 1948a, p. 498), and where about 90 successful hauls were made in 1949, 1952 and 1953 at depths greater than 200 fathoms, including about 40 hauls deeper than 400 fathoms, is something we cannot explain.

Earlier captures of *coelolepis* in American waters were from depths of 150-250 fathoms — all of them made with hook and line. But we have already noted the likelihood that it would be found much farther down the slope in the western side of the ocean, as it is in the eastern, if fished for there with suitable gear. And the "Cap'n Bill II" trawlings bear out this expectation, by extending its known range in American waters down to 630 fathoms at least.

BATOIDS
Family RAJIDAE
Skates

Raja bathyphila Holt and Byrne 1908

The capture by "Cap'n Bill II" of a female *R. bathyphila*, 360 mm. long, on the seaward slope of Georges Bank (Lat. 40°04′N, Long. 68°34′W), at 370-450 fathoms in 1952, and of a

juvenile male of 370 mm. at a neighboring station (Lat. 40°10′N, Long. 68°16′W) at 490 fathoms, added to earlier locality records for it at one station off Chesapeake Bay, at 3 stations off southern New England, and at one station off Browns Bank, in depths of 885 to 1188 fathoms,[1] show that this deep water skate is generally distributed along the mid zone of the continental slope, between the offings of Chesapeake Bay and of southern Nova Scotia. Knowledge as to its status farther to the northeastward along the American slope is to be desired to tell us how wide the gap may be between the geographic ranges occupied by it in the western side of the Atlantic, and in the eastern, where it is known only from the Irish slope (type specimen), so far as we are aware.

The depths of capture recorded for it so far (370-1188 fathoms on the American slope, 673 fathoms on the Irish) suggest that its center of population lies deeper than 400-500 fathoms, with the upper limit little shoaler, if at all, than 350 fathoms.

The most distinctive character of *bathyphila* is that its entire lower surface is darker than the upper surface. Indeed, it is unique in this respect, among the skates that are known from the North Atlantic outside of the Gulf of Mexico. Within the Gulf it is paralleled in this respect by the newly described *R. fuliginea* Bigelow and Schroeder 1954. But the latter differs from *bathyphila* so sharply in a more convex anterior outline as well as in the prickliness of the lower surface of its tail and of the upper sides of its pelvic fins that there is little likelihood that the one species could be taken for the other. For a comparison of *bathyphila* with the several skates of the Pacific and Indian Oceans that are similarly dark colored below, see Bigelow and Schroeder 1953, p. 161.

A character, almost equally diagnostic for *bathyphila* among skates of its geographic province, but one that has not been stressed previously, is the narrowness of its mouth. In the four specimens that we have measured[2] the breadth of the mouth ranges from 4.9 to 5.9 per cent as great as the total length. The only other skates known from the northwestern Atlantic, outside of the Gulf of Mexico, that approach it closely in this respect are *Raja garmani* Whitley 1939 (about 5.7-5.9 per cent); *R. fyllae*

[1] For details, see Bigelow and Schroeder, 1953, p. 159.

[2] The two "Cap'n Bill II" specimens, and two others, the proportional dimensions of which are given in Bigelow and Schroeder 1953, p. 161.

Lütken 1887 (5.8 per cent in eastern Atlantic specimen, 6.1-7.0 per cent in four of the "Cap'n Bill II" specimens, 397-497 mm. long); and *Breviraja plutonia* (Garman) 1881 (5.1, 5.6 per cent, in two specimens taken off Jacksonville, Florida). And there is no likelihood of confusing *bathyphila* with any of these, quite apart from its coloration. Thus the anterior contour of the disc of *bathyphila,* half-grown and larger, differs widely from that of *fyllae,* and the arrangement of thorns and prickles is noticeably different in the two species, as we have pointed out elsewhere (1953, p. 159). The plain coloration of the upper surface of *bathyphila* contrasts as strikingly with the pattern of dark rosettes on *garmani* as does the dark lower surface of *bathyphila* with the pale lower surface of *garmani.* And no one, we fancy, would be likely to mistake a *bathyphila,* wedge shaped in front, with tail only moderately long, and a hard snout, for a *plutonia,* with its much more convex anterior outline, much longer tail and soft snout.

The male *bathyphila* taken in 1953 has six large thorns along the mid line of the back from the scapular region to the level of the axils of the pectorals, with the single median row reaching back as far as the axils of the pelvics; the female has seven large medians between scapular region and level of axils of pelvics, rearward from which there are 2-3 less regular rows. Thus these specimens, 370 and 360 mm. long, respectively, represent a stage in development between the 463 mm. female pictured by us in Part 2 of Fishes of the Western North Atlantic and the somewhat smaller (323 mm.) male (1953, Figs. 30, 31A). They agree so closely with our earlier account of this species in all other respects that no further discussion of them seems needful from the taxonomic standpoint.

Raja fyllae Lütken 1887

This skate was included in our general survey of the rajids of the western North Atlantic (Bigelow and Schroeder, 1953, p. 194) because of its presence in west Greenland waters, where it has been known for many years, as it has in boreal and subarctic latitudes in the eastern side of the Atlantic. The cruises of "Cap'n Bill II" have now extended the known range of *fyllae* to the Nova Scotian slope, and even to the southwestern slope of

Georges Bank, in depths of 290-600 fathoms. It must, indeed, be very generally distributed (though in small numbers) along this depth zone between the offing of Halifax and the seaward slope of Browns Bank (longitudes 63°47′W to 65°06′W) for it was taken in 8 of the 19 successful hauls that were made there in 1952 (16 specimens) as well as in 8 of the 16 successful hauls

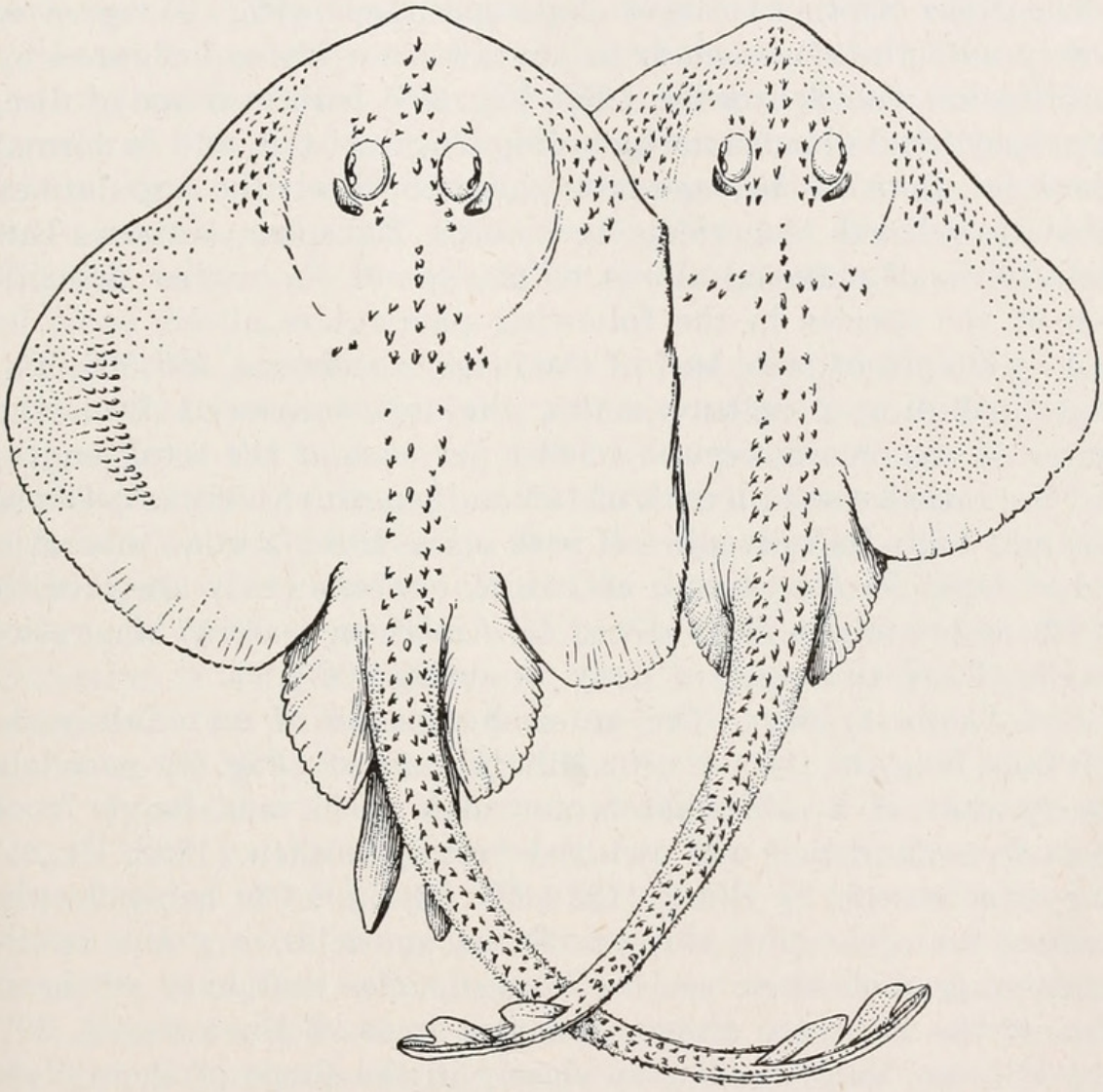

Fig. 3. *Raja fyllae*. *Left*, male, 505 mm. long, off La Have Bank, M.C.Z. No. 37905; and *right*, female, 430 mm. long, same general locality, M.C.Z. No. 37898.

made there in 1953 (13 specimens). And we may expect it to prove equally widespread around the Newfoundland Banks when the 300-600 fathom depth zone has been explored there more fully. But it seems to be much less numerous farther to the westward — unless at a considerably greater depth — for only

three hauls (3 specimens) yielded it on the Georges Bank slope (longitudes 67°02′W to 68°54′W), out of the 24 successful hauls that were made in 1952 and 1953, combined, at depths greater than 300 fathoms, between longitudes 66°W and 70°W. And it was not taken at all in the many hauls made farther to the westward and southward.

The Nova Scotian-Georges slope specimens (Fig. 3) agree so closely with the specimen from southwest of Ireland, figured by us (Bigelow and Schroeder, 1953, Fig. 39), both in shape of disc, in proportional dimensions including length of tail, and in dermal armature, that no cleavage is apparent between the populations inhabiting North American and north European waters. But the additional material allows us to expand our earlier description of the species in the following particulars.

A — Length of tail. In 7 of the larger specimens, 407-505 mm. long, including 2 mature males, the tail, measured from the center of the cloaca, occupies 58-61 per cent of the total length, and the ratio between length of tail and length of body is between 1.35 and 1.56. In 5 juveniles of both sexes, 198-272 mm., this ratio is 1.69-1.80. In *R. erinacea* and in *R. ocellata* (only skates with which *fyllae* might be confused in American waters) the ratio, length of tail to length of body, is about 1.00-1.35.

B — Shape of disc. The anterior contour of an adult male 505 mm. long, in the "Cap'n Bill II" series (Fig. 3) parallels closely that of a somewhat larger male (555 mm. long) from West Greenland that was pictured first by Lütken (1898, Pl. 2), and subsequently by Clark (1926, Pl. 22, fig. a) in being deeply concave on each side, abreast of the spiracles, a point worth mentioning since these are the largest males that have yet been seen, so far as we are aware. Females from off Nova Scotia, 397 and 430 mm. long, agree very closely in the shape of their discs with a female of 452 mm. taken southwest of Ireland that we have pictured elsewhere (Bigelow and Schroeder, 1953, p. 195, Fig. 39).

Students of skates have learned, long since, to expect considerable variation in dermal armature from specimen to specimen in nearly every species, both for the larger thorns and for the smaller prickles as well, though each species shows a basic arrangement that is characteristic of it. Our predecessors have

observed, already, that *fyllae* is no exception to this rule; and the Nova Scotian specimens afford an additional illustration. Thus the areas bare of prickles that tend to develop on the upper surface of its disc, as this skate grows, vary considerably in their extent among the females, independently of the sizes of the latter. In one, 430 mm. long, there is a bare area behind each spiracle, reaching rearward to the shoulder region, and there are no prickles on the upper surface of the pelvics. But the regions rearward from the spiracles are prickly on another female of 397 mm., and also the upper surface of the posterior lobe of each pelvic fin, much as they are on a female of about this same size taken off Ireland (Bigelow and Schroeder, 1953, Fig. 39), and in all of the smaller specimens of both sexes taken off Nova Scotia.

The males, as they mature, tend to lose any prickles they may have had earlier on the pelvics, and also to lose part of the larger thorns from the mid-dorsal belt of the disc between the levels of the pectoral girdle and of the axils of the pectorals.

It was known, previously, that the upper surface of the tail, which is set with prickles (besides the thorns) on small specimens, loses most of these prickles with growth. It now seems that this alteration is a more regular one than previous observations had suggested, for while the tail is uniformly and densely prickly above on the Nova Scotian juveniles, to 270 mm. long, it is wholly bare of prickles along a definite median band throughout its length back to the first dorsal fin on the larger Nova Scotian specimens of 397-505 mm. The shape, too, of the tail alters in *fyllae* with growth, from arched above in the young to flat above in adults, along the median band that has become bare of prickles.

A feature which seems to have escaped scientific attention is that the mucous pores on the nuchal region of *fyllae* are arranged in a pattern that is conspicuous on small specimens as well as on large. The only other skate of the western North Atlantic in which the pores in this region are noticeable is *R. laevis*, but they are black pigmented in the latter, whereas they are pale in *fyllae*.

Thirty to thirty-eight series of teeth have been recorded for *fyllae*. In the larger of the Nova Scotian specimens, 397-505 mm. long, the number of series varies more widely in the upper jaw (30-38) than in the lower jaw (30-32). It is not known whether

this same disparity obtains for the European population of this species.

The northeastern Atlantic and west Greenland representatives of *fyllae* so far seen have been ashy gray to chocolate brown above, the adults uniform, the young marked more or less distinctly with darker spots. One of the larger of the Nova Scotian females 430 mm. long, and 2 others half to three-quarters grown, are similarly of a uniform ashy gray tint above. But 5 other females are conspicuously marked, above, with an oblong whitish blotch, longer than wide, between the eyes, and with a similar but vaguely outlined pale blotch on the inner posterior part of each pectoral fin, a pattern of which we find no previous report for *fyllae*. One large male and 1 half grown lack these blotches but 1 large and 2 half to three-quarters grown males are so marked for *R. fyllae*. The lower surface is uniformly grayish white on the largest Nova Scotian male (505 mm.) both on tail and on disc. But the lower surface of other large specimens is more or less smoky around the outer posterior edges of the pectorals, in the region of the cloaca, and on the anterior parts of the pelvics; their tails are variously dark-blotched or mottled below; the region of the gill openings is smoky on one of them; and there is a smoky prepelvic blotch on three of them. Thus the dark markings on the lower surface vary as widely from specimen to specimen in extent and in arrangement among the Nova Scotian population as among the Greenland and eastern Atlantic populations.

The fact that the claspers are small, still, on one "Cap'n Bill II" male of 442 mm., but seem ready to function on another of 505 mm., on which the alar thorns have also developed in 2-3 rows, suggests that males of the Nova Scotian population mature, sexually, at a length of perhaps 475-500 mm.

The only other western North Atlantic skates that *fyllae* resembles closely in shape of disc, and in the general arrangement of its dermal armature, are *R. erinacea* Mitchill 1825, and *R. ocellata* Mitchill 1815. We have pointed out already (1953, p. 196) that it differs from both of these in a longer tail. But the measurements of the *fyllae* that we now have at hand show that the distance from the axils of the pelvics to the first dorsal fin as employed in our key (1953, p. 150) is not as reliable a criterion

as it seemed. Thus, while this distance is greater than from axils of pelvics to fronts of orbits in most of our *fyllae*, it is only about as great as to the mid levels of the orbits in a few, and is somewhat shorter than to the rear edge of the orbits in one adult male,[1] as it is in *erinacea* and *ocellata* also. And while the total length of the tail (measured from center of cloaca) is the greater relative to the length of the body in *fyllae*, there is virtually no discontinuity in this respect, as appears from the following table.

Ratio, total length of tail (from center of cloaca) to length of body

	max.	min.	average	number of specimens	total lengths mm.
fyllae	1.80	1.35	1.57	12	198—505
erinacea	1.35	1.06	1.22	9	209—505
ocellata	1.10	0.97	1.05	4	414—809

The distance, however, from the origin of the first dorsal fin to the center of cloaca is longer than from the cloaca to the tip of the snout in all the specimens of *fyllae* that we have measured, but shorter than from cloaca to snout both in *erinacea* and in *ocellata*, as follows:

Ratio, distance from first dorsal to cloaca relative to distance, cloaca to tip of snout

	max.	min.	average	number of specimens	total lengths mm.
fyllae	1.36	1.03	1.19	10	202—505
erinacea	0.97	0.81	0.88	5	209—505
ocellata	0.79	0.71	0.74	5	423—641

The interorbital space is narrower on *fyllae*, averaging 6.73 per cent (6.12-7.30) of the width of disc on 13 specimens examined, than it is on *erinacea* with an average of 8.01 per cent (7.32-8.50) on 11 specimens, or *ocellata* with an average of 9.12 per cent (8.82-9.32) on 4 specimens.

For specimens that cannot be identified, positively, by length of tail alone, the teeth should usually prove diagnostic, for there are only 30 to 38 series in the upper jaw in *fyllae* contrasted with

[1] Abnormal?

38 to 64 in *erinacea,* and 72 to 110 in *ocellata.* And the arrangement of the thorns on the tail usually is distinctive for large specimens, and in most cases for half grown, for *ocellata* and *erinacea* of these sizes usually have a narrow naked band along the mid line which has not been the case in any *fyllae* we have seen. But we must admit that specimens might come to hand for which depth of capture would be the only reliable criterion for identification that we have been able to discover.

In any case there is little danger of confusing *fyllae* either with *erinacea* or with *ocellata* in the field, for it has never been taken in North American waters shoaler than 290 fathoms, and neither of the others deeper than 85-87 fathoms (two *erinacea* trawled by "Cap'n Bill II" off the southern edge of Georges Bank in July 1953).

Raja jenseni Bigelow and Schroeder 1950

The captures of a female *jenseni,* 625 mm. long and in good condition, by "Cap'n Bill II" on the slope of Browns Bank, Lat. 42°19′N, Long. 64°59′W, in a trawl haul at 390-440 fathoms, and of a second female, of 695 mm., off Delaware Bay (Lat. 38°47′N, Long. 72°54′W) at 585-595 fathoms, call for mention, for the only specimens of this deep water skate that had been reported previously were a male, of 223 mm. from the slope of Georges Bank, 1255 fathoms; a female (the type) of 541 mm. off southern New England, 1043 fathoms; and a female of 850 mm. (now fragmentary) from off Halifax, Nova Scotia, brought in by a fisherman from 200 fathoms;[1] all are now in the U. S. National Museum, and all were taken many years ago.

The "Cap'n Bill II" specimens agree so closely with the type specimen (Bigelow and Schroeder, 1950, Pl. 1; 1953, Fig. 45) that their specific identity is evident at a glance. There are 29 large thorns in the mid dorsal row on the 625 mm. female, 8 of them anterior to the level of the axils of the pectorals. On the 695 mm. specimen, the total number in the median row is 26, 6 of which are anterior to the level of the axils of the pectorals, so spaced as to suggest that 3 or 4 others had been lost. These counts contrast with a total of 24 or 25 on the type (7 anterior to

[1] For the nomenclatural history of *jenseni,* description, and illustrations, see Bigelow and Schroeder, 1950, p. 385, Pl. 1; 1953, p. 213. Figs. 45, 46.

the axils of the pectorals) and with a total of 31 on the smaller male (8 anterior to the axils of the pectorals). Evidently there is a small variation in number from specimen to specimen, independent of the sizes of the latter. Enough specimens have been seen to show that it is characteristic of *jenseni* for the mid-dorsal thorns to be widely spaced anterior to the pelvic girdle, but increasingly closely spaced thence rearward onto the tail. On the 625 mm. female the thorns on the disc are about 20 mm. apart; those abreast of the axils of the pelvics about 10 mm. apart. The next 8 thorns along the tail are in contact at their bases, but the thorns thence rearward are separated, one from the next, by short interspaces. Also, the thorns are successively smaller, rearward along the posterior third of the tail. As on the type, there is no thorn in the interspace between the two dorsal fins on either of the "Cap'n Bill II" specimens, but only a few prickles.

The presence, on each side, of 3 or 4 thorns on the scapular region on the small male of 223 mm., and of 3 on the type, 541 mm. long, but of 2, only, on both of the "Cap'n Bill II" specimens of 625 mm. and 695 mm. indicates that one or two of the thorns in this group are lost with growth. There may be either two postocular thorns or three on different specimens,[1] but every specimen that has been seen has had one preocular thorn, only, on each side. The tip of the snout and the rostral ridge are about as rough on the "Cap'n Bill II" specimens as on the type, and the small prickles are about as densely distributed and cover about the same areas. A point worth emphasis is that while the sides of the tail of *jenseni* are densely prickly there are no prickles on the lower surface of its tail below the level of the lateral folds. The lower surface of the disc is naked everywhere.

Fifty-eight and sixty-six series of upper teeth have been reported previously, for the two specimens for which they have been counted. The "Cap'n Bill II" female 625 mm. long has 60, but the 695 mm. specimen has only 51. Evidently the number is widely variable on this species, irrespective of size, much as in *R. erinacea,* and in *R. ocellata.* The teeth resemble those of the type specimen closely (Bigelow and Schroeder, 1953, Fig. 46D) both in shape and in arrangement.

[1] Three on the 850 mm. female; two on each of the other specimens that have been examined.

We have forecast already that the dark markings on the lower surface of the disc, in *jenseni*, would prove widely variable (Bigelow and Shroeder, 1953, p. 216), and the "Cap'n Bill II" specimens corroborate this expectation. The ground-tint in both cases is yellowish white. On the 625 mm. specimen this is clouded with ashy gray around the posterior marginal zone of the pectorals and on the outer posterior parts of the pelvics; in the region of the cloaca and forward on either side of the abdomen; also over an irregular area on each side close behind the mouth. On the 695 mm. female the lower surfaces of the pelvics, the abdominal region in general, the lower surfaces of the pectorals, an irregular area on either side inward and forward from the gill region, and another smaller, inward from the nostril, are dark sooty gray. This pattern simulates, rather closely, the dark markings on some specimens of *R. hyperborea* (Bigelow and Schroeder, 1953, p. 209, Fig. 44), from which *jenseni* differs quite sharply by having a more simple dermal armature and fewer teeth (Bigelow and Schroeder, 1953, p. 213). The lower surface of the tail has been plain dark ashy gray on all the specimens of *jenseni* that have been seen thus far.

The localities whence *jenseni* has been reported (see above) are scattered sufficiently to show that it is generally distributed along the upper part of the slope between the offings of middle Nova Scotia and of Delaware Bay. But we have yet to learn how much farther its geographic range may extend in either direction. And the paucity of captures, with the great depths at which the "Albatross" specimens were taken, suggests that while a sparse population exists as shoal as 200-600 fathoms, the center of abundance for this species lies deeper down the slope than has been sampled yet by adequate methods of fishing.

Raja laevis Mitchill 1817
Barn Door Skate

This skate has been recorded as deep as 235 fathoms, but it occurs most regularly, and in greatest numbers on the continental shelf in depths shoaler than 70-80 fathoms. Hence captures of it by "Cap'n Bill II" at 265-305 fathoms off Nova Scotia (2 specimens in 2 hauls, Lat. 42°23′—42°28′N; Long. 64°31′—

64°52′W), and at 300-410 fathoms off Nantucket (1 specimen in 1 haul, Lat. 39°54′N, Long. 69°56′W) are of interest, as extending the known depth-range of the species downward, somewhat.

Other records of it, from the trawlings of 1952 and 1953 were from 220-255 fathoms on the seaward slope of Georges Bank (1 specimen, Lat. 40°11′N, Long. 68°20′W), and from 175-225 fathoms off southern New England (1 specimen, Lat. 40°04′N, Long. 72°12′W, 190-225 fathoms, and 2 specimens in 1 haul, Lat. 39°56′N, Long. 71°22′W, 175-200 fathoms).

Raja mollis Bigelow and Schroeder 1950

The type—and only known—specimen of this species, trawled on the slope off southern Nova Scotia, Lat. 41°53′N, Long. 65°35′W, at a depth of 858 fathoms by the "Albatross" in 1883, had rested, unnoticed, in the U. S. National Museum until 1950. We can now add three more records for *mollis* from that same general region, namely, a juvenile male, in the neighborhood of 195 mm. long (tip of tail lost) taken by the "Caryn" in June 1949, at Lat. 41°25′N, Long. 65°54′W, in a trawl fishing between 415 and 490 fathoms; a second male, of 267 mm. taken by "Cap'n Bill II," July 26, 1952, at Lat. 42°40′N, Long. 63°51′W, from 465-480 fathoms; and a third, 298 mm. long, July 12, 1953, from Lat. 42°40′N, Long. 63°52′W, at 415-420 fathoms.

The fact that "Caryn" and "Cap'n Bill II" took only three specimens of *mollis* in the 39 hauls they made at depths deeper than 300 fathoms in the Nova Scotian sector during the three summers combined, coupled with the depth (850 fathoms) at which the type specimen was trawled, makes it likely that the center of population for this species is along the lower part of the continental slope. But it is anyone's guess how far its geographic range may extend, either to the northeastward, or to the southwestward.

Mollis falls in the moderately short-tailed subdivision of the genus, the distance from the level of the axils of its pelvics to the first dorsal fin being much shorter than from the axils of the pelvics to the tip of the snout, and the total length of its tail from the cloaca being only about 1.1 times as long as the body from center of cloaca to tip of snout. Its most noticeable external characteristics are that it has no large thorns anywhere, posterior

to the scapular region, but that the upper surface of its disc and tail are densely prickly, except close along the outer posterior edges of the pectorals, and that the entire breadth of the lower surface of its tail is also densely prickly, except for the extreme tip.[1] The only slight differences worthy of mention between the larger of the two "Cap'n Bill II" specimens and the type is that the former has two minute thorns close in front of each eye (only one in front of each eye on the type); and that while there is a very small postocular thorn (as on the type) on one side of its head, none is to be seen on the other side among the close-set prickles that roughen the skin there. There are 54 series of teeth in the upper jaw of the "Caryn" specimen about 195 mm. long, 60 in both the "Cap'n Bill II" specimens of 267 and 298 mm., and 60 on the type specimen.

On the type specimen, the rostral projection from the cranium, reaching nearly to the tip of the snout (easily felt) is soft throughout its length. It is soft on the "Cap'n Bill II" specimens also and this state is so unusual, among the members of the genera *Raja* and *Breviraja*, that we considered it as perhaps the outstanding feature of the species *mollis*, in our earlier discussion (1953, p. 237). But the rostral cartilage of the very small specimen (195 mm. long) collected by "Caryn" in 1949 is rather stiff to the touch, raising the question as to whether its degree of firmness is a matter of the stage in growth, or whether it perhaps is affected by preservation.

Raja radiata Donovan 1807
Thorny Skate

Previous knowledge of the range of the thorny skate, and the numbers in which it has been taken on the Newfoundland Banks, in the inner parts of the Gulf of Maine, and on Georges Bank (Bigelow and Schroeder, 1953, p. 262) had led us to expect a plentiful representation of this species among the catches that were made off Nova Scotia, and along the seaward edge and slope of Georges Bank by the "Cap'n Bill II" in 1952 and 1953. But the results proved otherwise for it was taken in 10 hauls, only, in these two sectors combined, out of a total of 51 hauls that fished

[1] For detailed comparison with other species of *Raja*, see our earlier account (1953, p. 237).

successfully there between 120 fathoms and 400 fathoms and none was caught in 34 deeper hauls. The total number of specimens, too, was only 12, the maximum catch in one haul only 2. This, contrasted with the large catches that have been made on the Newfoundland Banks, on Georges, and in the western side of the Gulf of Maine (Bigelow and Schroeder, 1953, p. 262) is evidence that while it has been taken as deep as 430-490 fathoms off New York by "Cap'n Bill II" (Lat. 39°26′N, Long. 72°12′W, July 1953) and at 459 fathoms near Spitzbergen, its center of abundance lies shoaler than the zone along which the great majority of the "Cap'n Bill II" hauls were made. But the sizes of the specimens taken at different depths make it likely that the thorny skate reproduces itself, indifferently, down to the greatest depth to which it occurs, for those taken shoaler than 300 fathoms ranged from 196 mm. to about 860 mm. in length, those taken deeper, from 145 mm. to about 865 mm. And while one from 240-270 fathoms contained an egg about ready for deposition, another from 400-460 fathoms contained a mass of immature eggs.

This skate was taken at 8 stations out of 44 along the 120-400 fathom depth zone off southern New England in the two years combined; but, again, the largest catch was only 2 specimens, the total catch 11 and only 1 was caught in 26 stations deeper than 400 fathoms. Five specimens, also, were taken in 3 hauls fishing between 253 and 490 fathoms off Long Island, New York (longitudes 72°12′-72°19′) in June-July 1953 (it had been reported nearer land there, previously). But it seems that the so-called "Hudson Trough" off New York about marks the boundary to its regular occurrence in that direction at any depth, for "Cap'n Bill II" did not take it in any of the hauls that she made southward thence to the offing of Virginia in the summer of 1953, though we have seen a specimen from 74 fathoms off Charleston, South Carolina (Bigelow and Schroeder, 1953, p. 263).

Raja senta Garman 1885

This skate, ranging from the Newfoundland Banks and the inner part of the Gulf of St. Lawrence to the offing of South Carolina, was already known to occur widespread, though in small numbers, from the offing of western Nova Scotia to the offing of

New Jersey; chiefly between 50 fathoms and 250 fathoms, but recorded as deep as 478 fathoms off South Carolina. Therefore, it was no surprise to take 1-2 specimens in each of 6 hauls at 125-340 fathoms along the slope of Georges Bank (Long. 66°51′W and 69°43′W), 1 or 2 in each of 7 hauls at 150-225 fathoms off southern New England (Long. 70°-72°01′W), 1 off Maryland (Lat. 38°38′N, Long. 73°10′W), at 190-200 fathoms, and 1 off Virginia (Lat. 37°38′N, Long. 74°14′W) in 1952 and 1953. The series ranges from 120 mm. in length to about 577 mm.; the largest is a male with well developed claspers.

Raja spinicauda Jensen 1914

Definite locality records for this cold-water skate had been limited, previously, to Barents Sea, to the waters east of Iceland, to southwestern Greenland and the Greenland side of Davis Strait, to the continental slope off eastern Newfoundland, and to Hermitage Bay on the southern Newfoundland coast. But the fact that an egg case, apparently of this species to judge from its external sculpture and from the embryo contained within it, had been brought in from Banquereau Bank, and that a similar case (empty) had been trawled on the southwestern slope of Georges Bank,[1] had made it likely that the range of *spinicauda* extended southward and westward along the upper part of the continental slope as far as the general offing of Cape Cod. And this likelihood has now been corroborated by the capture of a juvenile male 392 mm. long by "Cap'n Bill II" on the slope of Georges Bank (Lat. 42°17′N, Long. 65°06′W) at 320-360 fathoms, besides two egg cases (one with identifiable embryo) off southern Nova Scotia (Lat. 42°44′N, Long. 63°17′W, 410-420 fathoms) in 1952, and of a third egg case, with well advanced embryo, on the slope of Georges (Lat. 40°43′N, Long. 66°42′W, 405-430 fathoms) in 1953.

Spinicauda had been recorded previously from 77-88 fathoms (140-160 meters) off Iceland, 120-404 fathoms off west Greenland, and 120-140 fathoms in Newfoundland waters. The depths recorded for the partly grown male taken by "Cap'n Bill II" in 1952 (320-360 fathoms), as well as for the egg cases taken

[1] See Jensen (1948, pp. 50-52, and 53, Fig. 3) for records for Barents Sea, Iceland and Greenland; Bigelow and Schroeder (1953, p. 272, 276) for those for American waters.

by "Caryn" in 1949 (260-350 fathoms) and by the "Cap'n Bill II" in 1952 and 1953 (405-430 fathoms) suggest that *spinicauda* occupies a somewhat deeper zone in the southernmost part of its range than in the northern part.

The bottom temperature was 3.3° in 1953, at the only locality where *spinicauda* was taken (egg case with embryo) that summer, and 3.9°-4.4° along the general depth zone where either free-living *spinicauda,* or its egg case, was taken in 1949 or in 1952, years when the temperature was not recorded. These values suggest that the upper limit to its thermal range may be slightly higher off Georges Bank and off Nova Scotia than off the east coast of Newfoundland, where the bottom water, at the depth where it was taken (91-127 fathoms) was between −1.5° and +0.65°, or in west Greenland and Icelandic waters where it has been found in temperatures of 1.7° to 3.8°.

Spinicauda is given so distinctive an aspect by its wedge shaped anterior contour with very long snout, and by a generally prickly upper surface, but with larger thorns confined to a single row of 21-26 (three examined by us had 22, 23 and 24 thorns, respectively) along the mid line of the tail with one between the first and second dorsal fins, that it could hardly be mistaken for any other skate known from the western North Atlantic. The only noticeable respect in which our juvenile male differs from the adult is in a somewhat longer tail, a growth feature that also is known for several other skates. More in detail, the distance from the center of the cloaca to the first dorsal fin, relative to the distance from center of cloaca to tip of snout, is about 1.2 times as great on the "Cap'n Bill II" juvenile male, as on the mature male, 1,236 mm. long, from Newfoundland, the proportional dimensions of which are given in Part 2 of "The Fishes of the Western North Atlantic" (Bigelow and Schroeder, 1953, p. 272). And this divergence between small specimens and large is about what might have been expected; the corresponding ratio, for example, in length of tail between young and adult (measured similarly) is about 1.2-1.3 for *R. erinacea;* about 1.2 for *R. fyllae;* about 1.1 for *R. laevis;* 1.1-1.3 for *R. radiata;* and 1.1-1.3 for *R. senta.*

In the adult *spinicauda* the rostral projection from the front of the cranium (reaching very nearly to the tip of the snout)

is slender and rodlike along the anterior ¾ of its length, and its cartilaginous nature is evident, if the skin above it be slit, and its sheath of fibrous tissue be spread apart. It is of the same shape in our juvenile male. But in this case the histologic nature of its anterior part remains to be learned, for it is only close to the cranium that it is visible on an X-ray photograph. And we have not felt free to dissect the single specimen, or to treat it with a stain selective for cartilage.

Ishiyama (1952, p. 2) has already pointed out that X-rays must be used with caution as tests for cartilaginous skeletal elements in rajids. We have found, for example, that while the outlines of the cranium, of the jaw cartilages, of the vertebral column, and of the basal cartilages of the paired fins show clearly in our X-rays of various skates and rays, those of the pectoral fins may, or may not. Thus, the pectoral radialia are sharply outlined on our X-rays of *Gymnura,* but the only visible evidence of them on X-rays we have studied of various species of *Raja, Breviraja, Cruriraja, Psammobatis* and *Sympterygia* is along the narrow axial strands of calcification. Consequently, X-ray photographs can be relied on as tests for the length of the rostral cartilage only if they show its anterior termination sharply.[1]

The egg cases trawled by "Cap'n Bill II" in 1952 and 1953 — identity established by the embryos contained in them — resemble those referred provisionally to this species by Jensen (1914, p. 33; 1948, pp. 55, 56) and by us (1953, p. 272) very closely. They are unique so far as known, among the egg cases of Atlantic skates, in the sculpture of their surfaces with a large number of low, longitudinal ridges, each close-set with a single series of several hundred stiff rod-like structures with complexly dissected tips (Fig. 4).

The three egg cases we have examined measure about 90 by 130 mm.; about 92 by 135 mm.; and about 86 by 136 mm., not counting the terminal horns. The embryo that one of them contained, 185 mm. long to its first dorsal fin, and 242 mm. to the tip of its tail, still bears the large yolk sac. But it is so nearly ready for birth that its identity as *spinicauda* is obvious. Embryonic characters — still persisting — apart from the yolk sac are that only the tips of the single line of caudal thorns (22 in

[1] See, for example, Bigelow and Schroeder, 1948, Figs. 1, 2; 1953, Fig. 62.

number) show through the skin; that the length of the tail, from center of cloaca to first dorsal fin, relative to the distance from center of cloaca to snout, is about 1.2 times as great as in the

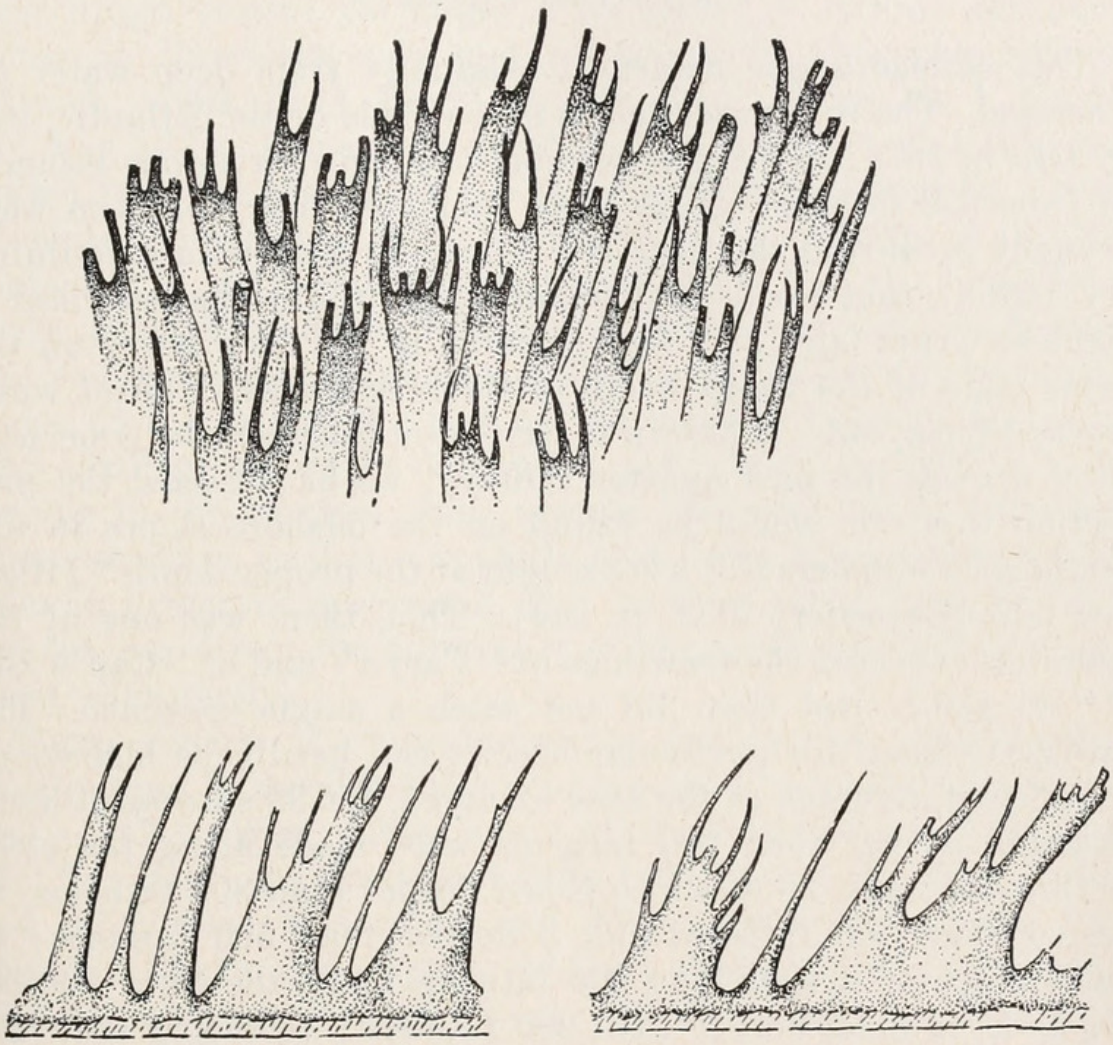

Fig. 4. *Raja spinicauda*. Portion of egg case trawled on the Nova Scotian slope in 410-420 fathoms, Lat. 42°44′N, Long. 63°17′W, M.C.Z. No. 37691, to show sculpture; above, about 7 x, below, about 11 x.

juvenile male of 390 mm.; that the tip of the tail still carries the embryonic filament which with the caudal fin fold extends 35 mm. from the rear base of the second dorsal; and that the thorn is not yet visible between the two dorsal fins.

CHIMAEROIDS

Family CHIMAERIDAE

Hydrolagus affinis (Brito-Capello) 1867
Deep Water Chimaera

This chimaera was described originally from deep water off Portugal. The first report of it, on our side of the Atlantic, was by Gill in 1878 (as *Chimaera plumbea* n. sp.), from one brought in from 350 fathoms off La Have Bank. So many of them were brought in during the next few years, by schooners long-lining for halibut, that Goode and Bean (1895, p. 31) characterized it eighteen years later as "very common in the deep water on the outer edge of the banks north of Georges Banks."[1] And while one specimen, only, is known to have been taken on the American slope during the past quarter century, we have risked the prediction that "it would be found on the offshore slopes in undiminished numbers if it were sought at the proper depth" (Bigelow and Schroeder, 1953, p. 544). This, then, was one of the fishes we expected the trawlings of "Caryn" and of "Cap'n Bill II" to yield. But they did not catch a single specimen. The failure to take this particular species can hardly be blamed on insufficient coverage of the zone explored, for 38 successful hauls reaching deeper than 200 fathoms were made along the slope of Georges Bank, 26 of which fished deeper than 300 fathoms, 19 deeper than 400 fathoms and 3 deeper than 500 fathoms; 49 hauls reaching deeper than 200 fathoms along the Nova Scotian slope, 39 of them deeper than 300 fathoms; 21 deeper than 400 fathoms and 7 hauls deeper than 500 fathoms, in the summers of 1949, 1952, and 1953 combined.

The fact that all reports of *affinis,* for the western side of the Atlantic, have been based on specimens caught with hook and line might suggest that our method of fishing was at fault. But the otter trawl is so efficient an apparatus that we think it more likely that *affinis* actually is far less numerous along the Georges Bank and Nova Scotian slopes today than it was, there, 50-70 years ago.

[1] For reports of it, in the Western Atlantic previous to 1953, see Bigelow and Schroeder, 1953, p. 544.

Family RHINOCHIMAERIDAE

Rhinochimaera and Harriotta

The most striking feature of these bizarre chimaeroids is their very long pointed snout, supported chiefly by the correspondingly long upper rostral cartilage. This cartilage follows the same course in *Harriotta* as is pictured for it in *Rhinochimaera* by Garman (1904, Pl. 1, fig. 2) and by Dean (1904, Pl. 1, fig. 4). We may add to our earlier account (1953, p. 549) that it is separated from the skin along the inner part of the snout by a mass of white, semigelatinous, pulpy tissue. The cartilage is in close contact with the overlying skin toward the tip of the snout for a short distance in *Rhinochimaera* of both sexes, also in females and young males of *Harriotta*, and for a longer distance in mature males of the latter, the tips of the snouts of which are hard. The cartilage as we have pointed out (1953, p. 549) is more flexible in the vertical plane around the crest of its curvature than elsewhere, so that it is easily bent down there mechanically, even on preserved specimens. But we have yet to learn whether the fish can direct the outer part of the snout upward or downward voluntarily.

Three genera of rhinochimaerids are known: *Neoharriotta* Bigelow and Schroeder 1950, type species *N. pinnata* (Schnakenbeck) 1929[1] (West Africa south of the equator), with separate anal fin; *Harriotta* Goode and Bean 1895 (North Atlantic, Japan, and off lower California) and *Rhinochimaera* Garman 1901 (North Atlantic and Japan), without separate anal. Characters that we have accepted previously (1953, p. 549) as alternative between *Harriotta* and *Rhinochimaera* are the nature of the dental plates (smooth in *Rhinochimaera* but with grinding ridges and knobs in *Harriotta*), and whether the upper margin of the caudal fin is smooth (*Harriotta*) or is armed with a longitudinal row of denticulate structures (*Rhinochimaera*). Examination of the representatives of each that were taken during the recent trawling trips of "Caryn" and of "Cap'n Bill II" shows that the first of these criteria can be relied upon, except for newly hatched specimens, the dental plates of which are smooth, or very nearly so in *Harriotta* as well as in *Rhinochimaera*. In fact we

[1]Given erroneously as 1931 in Bigelow and Schroeder 1953, p. 550.

have found no reliable feature to separate newly hatched specimens of the North Atlantic representatives of *Harriotta* and of *Rhinochimaera* generically, though it is easy to do so specifically. It proves, also, that the presence of denticulations along the upper side of the caudal fin is reliable as a distinctive criterion for adult males of *Rhinochimaera,* as contrasted with *Harriotta,* but not for young males, or for females, as is pointed out below (p. 80). And it must remain an open question, until growth series of *Rhinochimaera* can be studied, as to how early these denticulations develop. All we can say, in this regard, is that while the upper margin of the caudal is so thick and fleshy in adult *Rhinochimaera* of both sexes that the horny rays are entirely concealed, it is so thin on a female *R. atlantica* 457 mm. long that these rays are clearly visible. The development, also, of a double series of hard knobs along the terminal $\frac{1}{5}$-$\frac{1}{4}$ of the snout of maturing males in *Harriotta raleighana* and in its close relative *H. chaetirhamphus* (Tanaka) 1909, of Japan,[1] but not in *Rhinochimaera* seems more properly a generic character than a specific. Another character, not proposed previously as alternative, between *Harriotta* and *Rhinochimaera,* but which seems to be so, is the shape of the outer part of the long upper rostral cartilage which is subtriangular (base uppermost) in cross section in *Harriotta* but is nearly as thick along its lower side as along its upper side in *Rhinochimaera.*

Rhinochimaera atlantica Holt and Byrne 1909

This chimaeroid, previously known from the type specimen only, from the Irish Atlantic slope, and from a few empty egg cases presumably referable to it, was represented by 8 specimens in the "Cap'n Bill II" collections. These range from a newly hatched male, 151 mm. in total length, to large adults of both sexes 1060-1315 mm. long. According to Holt and Byrne (1910, p. 19, Pl. 3) *atlantica* differs from *pacifica* (Mitsukuri) 1895, of Japan, in a relatively shorter second dorsal fin, which they picture as shorter than the distance from the gill openings to the origins of the pelvic fins, but which they characterize as longer

[1] The illustration of the only other member of the genus, *H. curtis-jamesi* Townsend and Nichols 1925, from off lower California (Townsend and Nichols, 1925, Fig. 2) suggests that the specimen was a female; and in any case it was too small (6 inches) to show this character, even if actually a male.

than that distance in *pacifica*, as it is shown on Dean's (1904, Pl. 1, fig. 1) illustration. But the second dorsal of *pacifica* is shown as only about as long as from gill opening to pelvic origin by Mitsukuri (1895, Pl. 1), and as shorter than that distance by Garman (1904, Pl. 1, fig. 1). The ratios, tabulated below, between length of base of second dorsal and distance from gill opening to pelvics, for the "Cap'n Bill II" series of *atlantica*, and for two specimens of *pacifica* in the Museum of Comparative Zoology (one of these was the basis of Garman's illustration) are further evidence that the Atlantic population cannot be separated from the Japanese on this basis. And we may note, in passing, that the point of origin cannot be located with precision either for the second dorsal, or for the pelvics because of the shapes of these fins.

Species	Length, to rear base of 2nd dorsal mm.	Sex	Ratio, base 2nd dorsal to distance gill opening to pelvics
atlantica	727	♂	1.0 : 0.98
"	755	♂	1.0 : 1.09
"	770	♀	1.0 : 1.0
"	825	♀	1.0 : 1.08
"	856	♀	1.0 : 1.0
"	880	♀	1.0 : 1.0
pacifica	575	♂	1.0 : 1.0
"	590	♂	1.0 : 1.0

According to Holt and Byrne (1910, p. 19, Fig. 3, and Footnote) a second difference between *atlantica* and *pacifica* is that the "posterior limbs" of the forked canal that runs rearward along the lower surface of the snout, end blind in *atlantica*, but join the median anterior loop of the angular canal[1] in *pacifica*. Examination, however, of the two specimens of *pacifica* in the Museum of Comparative Zoology shows that they actually end blind in that form, as they do in *atlantica*, though the blind termination may lie very close to the median loop of the angular canal, on one side of the head or the other, on some specimens, both of *pacifica* and of *atlantica*, perhaps on both sides in some cases. Garman's (1904, Pl. 2, fig. 2) illustration of the lower

[1] Nomenclature according to Garman (1888) and Bigelow and Schroeder (1953, p. 530, Fig. 119A).

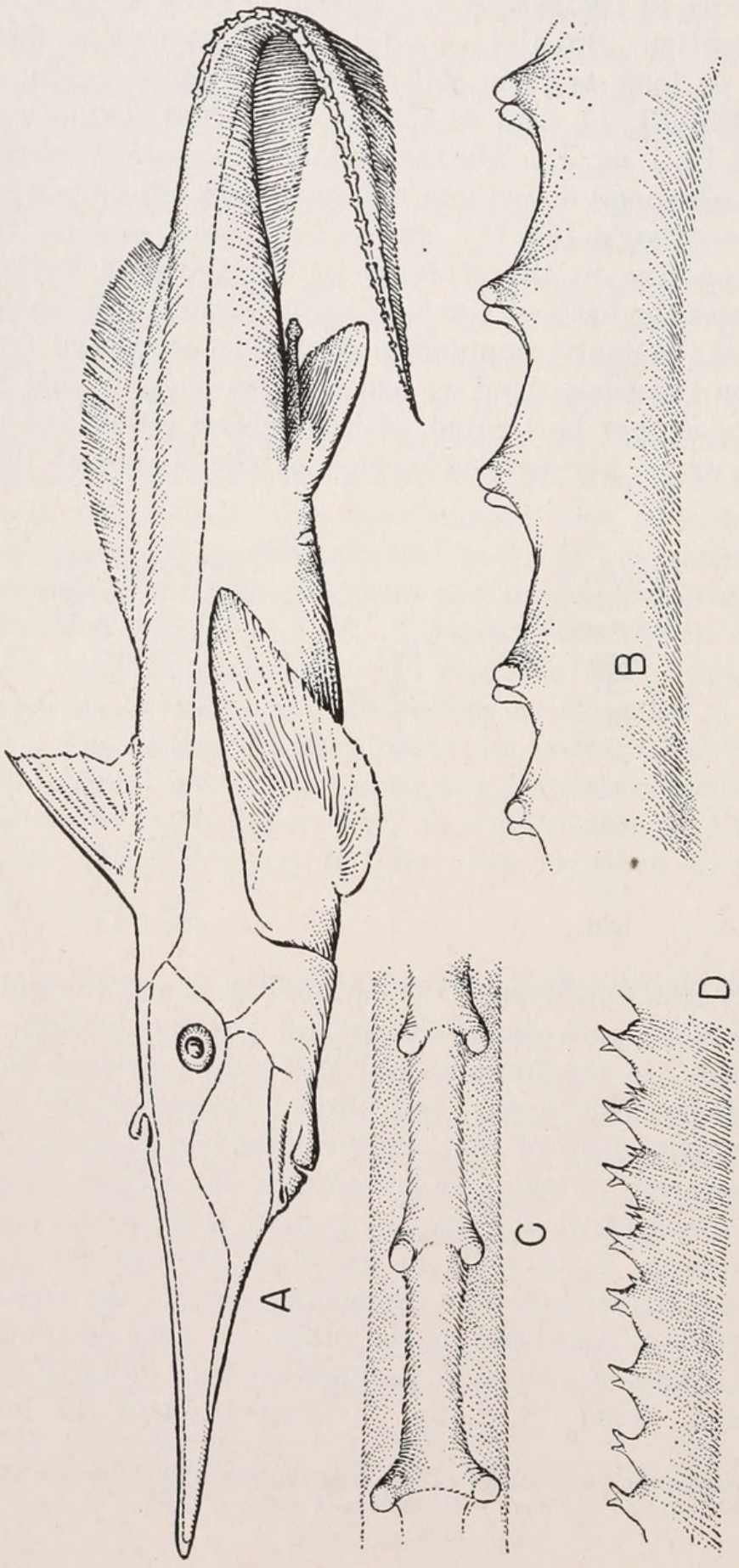

Fig. 5. *A, Rhinochimaera atlantica* Holt and Byrne, 1909, adult male, 1130 mm. long to upper termination of caudal fin. Nova Scotian slope. M.C.Z. No. 38244. *B* and *C*, Lateral and dorsal views of upper margin of anterior part of caudal fin of same, to show the tubercles, about 1.7 x. *D, Rhinochimaera pacifica*, adult male, 885 mm. long, Japan, M.C.Z. No. 1314, side view of upper margin of anterior part of caudal, about 1.7 x.

surface of the snout of *pacifica* is not clear in this respect.

Neither have we found anything to differentiate the Atlantic form (Fig. 5) from the Japanese, either in proportional dimensions, in the shapes, sizes or relative positions of the fins, in the nature of the dorsal spine (described for *atlantica* on p. 76), or in the shapes of the dental plates, which are as free from any trace of grinding prominences in the one as in the other. But our specimens do suggest that the caudal filament may average significantly longer on Japanese specimens than on Atlantic. Thus it is almost as long as the second dorsal fin in one of our *pacifica* and is pictured as about 70 per cent as long as that fin by Dean (1904, Pl. 1, fig. 4), whereas it is only about 10 per cent as long as the base of the second dorsal on one of our *atlantica* specimens on which it seems to be intact, while it is pictured as very short, indeed, by Holt and Byrne (1910, Pl. 3) for the type specimen. It seems, too, that the denticulations (single or paired) with which the upper margin of the caudal fin is armed, on large specimens, are not only more numerous on the Japanese form than on the Atlantic, but that they are regularly present on the females of the former, as well as on the males, but only on some of the females of the latter. Thus there are 47 and 52 series, respectively, on the two adult males of *pacifica* that we have examined, with "over fifty" reported for it by Dean (1904, p. 6), while his illustrations of an adult female (Dean, 1904, Pl. 1, figs. 1, 4) show them as rather prominent and as distributed continuously all along the caudal. But they number only 25 and 30, respectively, on our two adult Atlantic males; only one of our four large Atlantic females shows traces of them all along the caudal; the caudals of two of them are perfectly smooth; and they are much smaller on females where they are to be detected at all than they are on adult males. On the other hand, they are larger, relatively, on the large Atlantic males (Fig. 5) than on the Japanese.

In estimating the taxonomic significance of these differences, we face the puzzling fact that the caudal denticulations of one of the Japanese males resemble those of the Atlantic males in their low, rounded form, with the interspaces smooth edged between them. But they are sharp pointed (whether single or in pairs) on the other Japanese male of about the same size, with the interven-

ing spaces interrupted, in most cases, by 1-3 much smaller, pointed denticles, as pictured by Garman (1904, Pl. 4, fig. 2) many years ago for this same specimen, and by us more recently (1953, Fig. 122).

It must remain an open question, until half-grown males can be examined, whether this difference between two specimens, both of which seem to be mature, represents two extremes of individual variation, or whether one of these conditions (and if so, which of them) precedes the other, as a given male becomes active, sexually.

To sum up, the North Atlantic population of *Rhinochimaera* seems to differ certainly from the Japanese only in a secondary sexual character that is subject to considerable variation from specimen to specimen, and perhaps in the proportional length of a structure (caudal filament) so susceptible to damage that estimates of its length are largely a matter of guesswork for a large proportion of the specimens that have come to hand. Were we facing the question *de novo* we would hesitate to separate the Atlantic form from the Pacific, specifically, on such slender bases. However, since the name *atlantica* is in use already, we are content to let it stand for the time being. Reduction to the rank of subspecies may be its ultimate fate.

The general morphology of *Rhinochimaera pacifica,* internal as well as external, was made well known by Garman's (1904) and Dean's (1904) studies, accompanied by beautiful illustrations. The following details for *atlantica,* additional to Holt and Byrne's (1910) account, are based on the "Cap'n Bill II" specimens.

The rear edges of the dorsal fin-spine are perfectly smooth on all the large specimens, as noted by Holt and Byrne (1910, p. 18). But they are rough with minute serrations along the outer third of their length on a female 457 mm. long; evidently they are lost during later growth. Holt and Byrne's illustration (1910, Pl. 3) suggests, further, that the spine is attached to the fin right out to its tip (they do not comment on this), not free toward the tip as it is in *Harriotta* (p. 83). And this seems to be the normal state, being true of one of our large females, and of the largest male as well. But the union must be a feeble one, for the membrane is free from the fin along its outer ⅓-⅔ on all our

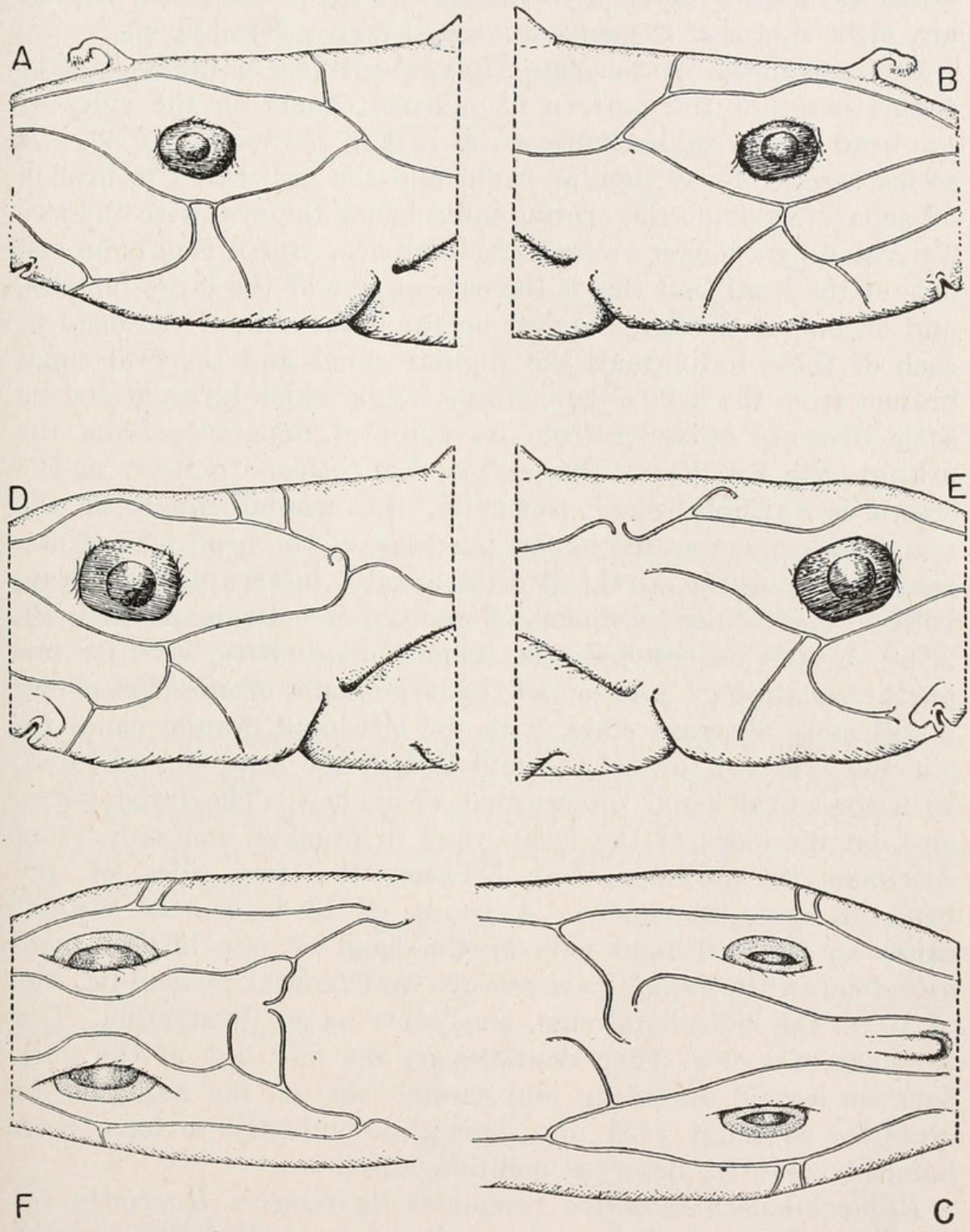

Fig. 6. Diagrams showing pattern of mucous canals on head. *A, Rhinochimaera atlantica,* same specimen as in Figure 5, left side. *B,* Same specimen, right side. *C,* Dorsal view of male, 1034, mm. long to upper termination of caudal fin, M.C.Z. No. 38243. *D, Harriotta raleighana,* female, 840 mm. long to upper termination of caudal fin, M.C.Z. No. 38247, left side. *E,* Same specimen, right side. *F,* Same specimen, dorsal view.

other specimens, including a female only 450 mm. long, without any clear sign that the separation had been a forcible one.

Our specimens corroborate Holt and Byrne's (1910, p. 21) suggestion that the pattern of mucous canals on the sides of the head is a variable character, as it is in *Harriotta* (p. 83). It seems usual for the jugular canal and the oral canal to branch off separately from the orbital canal below the eye, with the two separated by a longer or shorter interspace. But it is only on one side of the head that this is the case on one of the large females, and on one of the large males; on the other side of the head of each of these individuals the jugular canal and the oral canal branch from the orbital as a single trunk which bifurcates some little distance outward from its point of departure from the orbital (Fig. 6*A*, *B*). It proves, too, that the canal pattern on the crown is variable, also. Normally, the cranial canals of the two sides are connected across the back of the head by a cross-canal known as the aural.[1] But the aural is interrupted, midway, both on one of our specimens of *pacifica* (see Garman, 1904, Pl. 2, fig. 1) and on our 457 mm. female of *atlantica*, with its two parts overlapping. And one of the large males of *atlantica* shows a still more aberrant state, with the left-hand cranial canal recurving forward toward the mid line of the head to end blind, with the aural canal interrupted (Fig. 6*C*). The large pores, also, on the sides of the head, vary in number, not only from specimen to specimen, but between the two sides of the head on some specimens. A count of 13 below the cranial canal on the left-hand side of the head of our largest male *atlantica*, in the region between eye and frontal tenaculum, but of 10 on the right-hand side, may serve as an illustration. The presence of a few sharp denticles on the mid line of the back between second dorsal fin and caudal, also on the nape, on an *atlantica* so small (151 mm. long) as evidently to have been hatched recently, deserves mention, also.

Rhinochimaera atlantica resembles its relative *Harriotta raleighana* so closely in general appearance that the one might be mistaken for the other on cursory examination, especially since the two are likely to be taken together in trawl hauls at appropriate depths on the slope, as happened on "Cap'n Bill II"

[1] Nomenclature according to Garman (1888, Pls. 1, 2, 4) and Bigelow and Schroeder (1953, p. 530, Fig. 119).

on four occasions off southwestern Nova Scotia. But it is easy to tell partly grown specimens apart, on closer inspection. Thus the glossy smoothness of the dental plates of *Rhinochimaera* con-

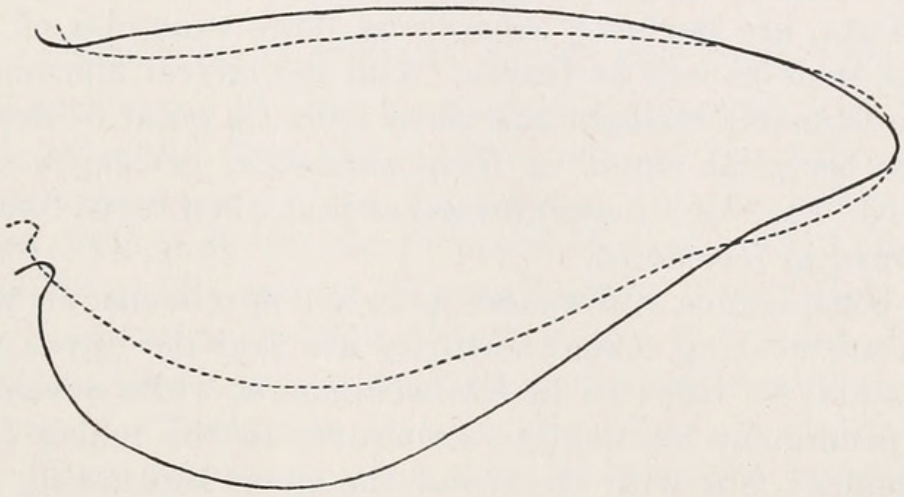

Fig. 7. Tracings of pectoral fins, adjusted to equal lengths along outer margin, to show difference in shape; solid line, *Harriotta raleighana*, female about 908 mm. long to upper termination of caudal fin, M.C.Z. No. 37726; broken line, *Rhinochimaera atlantica*, female about 1282 mm. to upper termination of caudal fin, M.C.Z. No. 37735.

trasts strongly with the grinding ridges and knobs that develop on the dental plates of *Harriotta*, soon after hatching; also, the eyes of *Rhinochimaera* are noticeably smaller than those of *Harriotta* at all stages in growth as appears from the following comparative table:

Species	Length, to termination of upper caudal[1] mm.	Sex	Ratio, horizontal diameter of eye to distance eye to base of dorsal spine
Rhinochimaera atlantica	1034	♂	1.0 : 2.80
	1130	♂	1.0 : 2.66
	1184	♀	1.0 : 3.17
	1282	♀	1.0 : 2.43
	1290	♀	1.0 : 3.03
	1295	♀	1.0 : 3.07
Harriotta raleighana	283	♀	1.0 : 1.78
	447	♂	1.0 : 1.65
	758	♂	1.0 : 1.63
	840	♀	1.0 : 2.00
	885	♀	1.0 : 1.85
	908	♀	1.0 : 2.13

[1] Approximate measurement

The pectoral fins are noticeably narrower toward the base in *Rhinochimaera* than in *Harriotta* but with more broadly rounded tip (Fig. 7). The rear edges of the dorsal fin-spine, which are serrate in small specimens of both fish, and are serrate to maturity in *Harriotta,* are perfectly smooth on large examples of *Rhinochimaera,* male as well as female. And the lateral mucous canal, which runs nearly straight rearward from its point of departure from the occipital canal in *Rhinochimaera,* or slopes slightly downward (Fig. 5*A*), bows upward at first, then turns downward — rearward in *Harriotta.*

More conspicuous differences between specimens of the two fish that are nearing sexual maturity are that the upper margin of the caudal fin thickens in *Rhinochimaera,* while developing a row of prominent denticulate structures in the males (also in some females), but with the tip of the snout continuing smooth and soft, whereas in *Harriotta* the upper caudal continues thin and smooth-edged in both sexes, but the tip of the snout stiffens in the males (not in females), bends upward, and develops a double series of rounded knobs.

It is probable that *R. atlantica* is more widespread and more plentiful in the eastern side of the Atlantic than the paucity of the previous records (one adult specimen and a few egg cases from the Irish Atlantic slope) might suggest, for this is certainly the case in the west, where "Cap'n Bill II" took it at 6 stations off southwestern Nova Scotia, at 1 station on the slope of Georges Bank, and at 1 station in the offing of New York. A table follows of localities, depths, and number, size and sex of the specimens:

Length to termination of upper caudal[1]	Total length	Sex	Lat. N.	Long. W.	Depth in fathoms	Date
151[2]	151	♂	42°22′	64°55′	290-340	7/15/53
436	457	♀	42°40′	63°51′	465-480	7/26/52
1034	1060	♂	38°52′	72°51′	415-440	6/27/53
1130[2]	1130	♂	42°40′	63°54′	520-545	7/12/53
1184	1202	♀	40°07′	68°30′	420-480	7/13/52
1282	1315	♀	42°14′	65°10′	490-530	7/28/52
1290	1315	♀	40°11′	68°16′	480-490	7/14/52
1295	1315	♀	42°38′	64°10′	460-475	7/13/53

[1] Approximate measurement
[2] Filament lost

It seems that *Rhinochimaera* is considerably less plentiful than *Harriotta* off Nova Scotia and off New England judging from the fact that four times as many specimens of *Harriotta* (32) as of *Rhinochimaera* (8) were taken by "Cap'n Bill II."

Harriotta raleighana Goode and Bean 1895

Nine specimens of this long-nosed chimaeroid had been reported previously from the western side of the Atlantic, from the trawlings made by the "Albatross" in the 1880's (Goode and Bean, 1895, p. 33), by the Prince of Monaco in 1913 (Roule and Angel, 1933, p. 75) and by "Caryn" of the Woods Hole Oceanographic Institution in 1949 (Bigelow and Schroeder, 1953, pp. 551, 552) at localities scattered along the continental slope from the offing of Chesapeake Bay to the offing of Halifax, Nova Scotia. Three specimens, also, were taken in the eastern side of the Atlantic by the "Michael Sars" in 1910 (Koefoed, 1927, p. 29), one of them near the Canaries, the other two west of Scotland. We can now report the capture, by "Cap'n Bill II," of 26 specimens of both sexes in 1952, and of 6 more in 1953, ranging from partly grown to adults.

Specimens of *Harriotta* taken by "Caryn" in 1949, and by "Cap'n Bill II" in 1952 and 1953, arranged in latitudinal sequence, south to north

Lat. N.	Long. W.	Depth fath.	Date	No.	Sex	Length in mm. to termination of upper caudal[1]	Length in mm. to tip of filament
38°43′	72°56′	630-675	June 30, 1953	1	♀	256	329
39°49′	70°05′	710-730	July 28, 1953	1	♂	375	456
40°07′	68°30′	420-480	July 13, 1952	1	♀	850	900
40°10′	68°16′	490	July 14, 1952	3	♂	702-748	742-837
41°25′	65°54′	415-490	June 19, 1949	2	♂ ♀	126-730	155-770
42°14′	65°10′	490-530	July 28, 1952	5	♂ ♀	157-447	283-550
42°16′	65°08′	370-420	July 28, 1952	2	♀	885-925	946[2]
42°22′	64°55′	290-340	July 15, 1953	1	♀	840	948
42°38′	64°04′	440-460	June 17, 1949	1	♂	735	773
42°38′	64°10′	460-475	July 13, 1953	1	♂	758	836
42°39′	63°58′	520	July 26, 1952	5	♂ ♀	283-756	373-870
42°39′	64°00′	610-625	July 12, 1953	1	♀	865	1025
42°40′	63°51′	465-480	July 26, 1952	3	♂ ♀	188-716	249-792
42°40′	63°54′	520-545	July 12, 1953	1	♂	?	775
42°40′	64°00′	440-450	June 17, 1949	1	♂	705	818
42°41′	63°49′	465-480	July 26, 1952	4	♂	250-721	295-815
42°41′	64°02′	385-400	July 27, 1952	3	♂ ♀	741-908	832-935

[1] Approximate measurement
[2] Tail lost on 925 mm. specimen

The fact that 30 of the total of 36 specimens were taken in the offing of southwestern Nova Scotia, and that 6 of the 12 successful hauls that were made there in 1952, at the appropriate depths, yielded *Harriotta*, shows that this chimaeroid is more plentiful along this part of the slope than earlier records for it might have suggested. The proportion of hauls yielding it in this region was somewhat lower in 1953 (4 out of a total of 10), though the trawlings of that summer seem to have been equally successful in general, to judge from the catches of fishes of other kinds. It appears to be less plentiful to the westward of longitude about 66°W than to the eastward, for "Cap'n Bill II" took it in only 4 hauls (6 specimens) along the slope of Georges Bank, and to the westward, out of a total of 41 hauls that she made there at 400 to 730 fathoms, in the summers of 1952 and 1953 combined.

On the Nova Scotian slope the upper limit to the regular occurrence of *Harriotta* appears to lie at about 400 fathoms although a few specimens were taken as shoal at about 340 fathoms. "Cap'n Bill II" took *raleighana* down to 710-730 fathoms, the Prince of Monaco at 728 fathoms (1332 meters, Roule and Angel, 1933, p. 75), the "Albatross" trawled it at 1081 fathoms off Marthas Vineyard, at 991 fathoms off New York, at 707 fathoms off New Jersey and at 781 fathoms off Chesapeake Bay. Depth records for it in the eastern Atlantic are 1014 fathoms (1853 meters) west of Scotland, and 1423 fathoms (2603 meters) near the Canaries (Koefoed, 1927, p. 29).

The external aspect of *H. raleighana* has been made well known by the successive studies of Goode and Bean (1895, p. 32), Koefoed (1927, p. 29), Roule and Angel (1933, p. 75), and Bigelow and Schroeder (1953, p. 551). Examination of the "Cap'n Bill II" series adds the following details.

A — Dermal denticles and dorsal fin-spine. No trace of the juvenile dermal denticles is to be seen (or felt) on specimens more than about 485 mm. long to the rearmost visible rays of the upper side of the caudal fin. A female of 300 mm. (measured similarly) still has one pair of supra-oculars, one pair on the midline of the back in the space between the first and second dorsal fins, and 4 pairs between the second dorsal and the caudal.

The increase in the size of the dorsal fin-spine with growth is not accompanied by a corresponding increase in the size of the

serrations along the rear margin of the spine, hence the latter does not feel any rougher, to the touch, on large specimens than on those of medium size. And the serrations may be partly obliterated by maturity, on some individuals, perhaps wholly so. The "Cap'n Bill II" series also verify earlier accounts of the spine as free from the margin of the fin along at least its outer half. This contrasts with the condition in *Rhinochimaera atlantica*, where the spine is smooth edged from a very early stage in growth, and where it is attached to the fin-margin, right out to its tip, or nearly so (p. 76).

B — Caudal filament. When intact, the caudal filament may be as much as 33-44 per cent as long as from snout to last visible caudal fin-ray among the smaller specimens (191-263 mm., total length). On three of our larger males (680-750 mm., total length) the filament is 111-116 mm. long, and 160 mm. on our largest female (1025 mm., total length). But it is so thread-like toward its tip that there is always a possibility that part of it may have been lost, even on specimens on which it seems to be intact.

C — Pattern of mucous canals on head. Cumulative evidence is conclusive, that the pattern of mucous canals on the head varies too widely to have much significance in taxonomy, not only between different individuals, but even between the two sides of the head of a single individual in many cases. On three of the larger males, for example, the jugular canal and the oral diverge jointly from the orbital canal on one side of the head, but separately on the other side with an interspace between them (Fig. 6*D*, *E*). When they arise jointly they may separate at once or they may run for a longer distance or a shorter as a joint trunk before they diverge, one from the other. On one specimen of each sex the jugular canal fails to connect with the orbital on either side of the head, while on one male it ends blind on the right-hand side but connects with the orbital on the left-hand side.

D — Snout, and sexual tenacula. In *H. raleighana* the snouts of the males are similar to those of the females, up to a length of 450 mm. or so (to last visible caudal rays); and no trace is to be seen of the frontal tenaculum, or of the prepelvic tenacula, although the prepelvic pockets are already formed on newly hatched specimens. But the tip of the snout has begun to curve

upward, its terminal knobs have formed, the sexual tenacula have developed in the males, and the claspers seem to be ready to function by the time a length of about 650 mm. (to last caudal rays) has been reached.

The largest male yet recorded is about 836 mm. in total length (758 mm. to last visible caudal ray). A female 990 mm. in total length including a caudal filament of about 125 mm. as scaled from Roule and Angel's (1933, Pl. 4, figs. 34-34a) illustration, and another 1025 mm. in total length, including caudal filament of 160 mm. (Cap'n Bill II'' specimen) are the largest yet seen of that sex.

REFERENCES

Bigelow, Henry B., and William C. Schroeder

1948. New genera and species of batoid fishes. Journ. Marine Research, vol. 7, no. 3, pp. 543-566.

1948a. Fishes of the western North Atlantic. Part 1. Mem. Sears Foundation for Marine Research, no. 1, part 1, pp. 59-576.

1950. New and little known cartilaginous fishes from the Atlantic. Bull. Mus. Comp. Zool., vol. 103, pp. 385-408, 7 pls.

1953. Fishes of the western North Atlantic. Part 2. Mem. Sears Foundation for Marine Research, no. 1, part 2, x+ 562 pp., plus index.

1954. A new family, a new genus, and two new species of batoid fishes from the Gulf of Mexico. Breviora, Mus. Comp. Zool., no. 24, 16 pp., 4 figs.

Bigelow, Henry B., William C. Schroeder, and Stewart Springer

1953. New and little known sharks from the Atlantic and from the Gulf of Mexico. Bull. Mus. Comp. Zool., vol. 109, no. 3, pp. 213-276, 10 figs.

Bocage, Jose Vincente Barboza du, and Felix de Brito Capello

1864. Sur quelques especès inédites de Squalidae . . . Proc. Zool. Soc. London, pp. 260-263.

1866. Apontamentos para a ichthyologia de Portugal. Peixes Plagiostomos. Pt. 1. Esqualos. Lisboa. 40 pp., 3 pls.

Brito Capello, Felix de

1867. Descripçao de dois peixes novos provenientes dos mares de Portugal. Jorn. Sci. Math. Phys. Nat. Acad. Lisboa, vol. 1, no. 4, pp. 314-317, pl. 3, fig. 1, pl. 5.

CLARK, ROBERT S.

1926. Rays and skates . . . Sci. Invest. Fisher. Board Scotland, 1926, no. 1, 66 pp. Atlas, 36 pls.

COLLETT, R.

1878. Fiske fra Nordhaus-expeditionens sidste togt, Sommeren 1878. Vidensk. Selsk. Christiania, Forhand. (1878) 1879, no. 14, 106 pp.

1904. Diagnoses of four hitherto undescribed fishes from the depths south of the Faroe Islands. Videns. Selskabs. Forhand. Christiania, 1904, no. 9, 7 pp.

1905. Fiske . . . "Michael Sars" togter i Nordhavet 1900-1902. Rept. Norwegian Fisher. and Marine Invest., vol. 2, part 2, no. 3, 147 pp., 2 pls.

DEAN, BASHFORD

1904. Notes on the long snouted chimaeroid of Japan. Journ. Coll. Sci. Imp. Univ. Tokyo, vol. 19, art. 4, 20 pp., 2 pls.

DONOVAN, EDWARD

1807. The natural history of British fishes . . . 5 vols., 120 pls., London.

GARMAN, SAMUEL

1881. Report on the selachians. Bull. Mus. Comp. Zool., vol. 8, pp. 516-523.

1885. Notes and descriptions taken from selachians in the U. S. National Museum. Proc. U. S. Nat. Mus., vol. 8, pp. 39-44.

1888. On the lateral canal system of the Selachia and Holocephala. Bull. Mus. Comp. Zool., vol. 17, pp. 57-119, 53 pls.

1901. Genera and families of the chimaeroids. Proc. New England Zool. Club, vol. 2, pp. 75-77.

1904. The chimaeroids . . . Bull. Mus. Comp. Zool., vol. 41, pp. 245-272, 15 pls.

1906. New Plagiostomia. Bull. Mus. Comp. Zool., vol. 46, pp. 201-208.

1913. The Plagiostomia (sharks, skates, and rays). Mem. Mus. Comp. Zool., vol. 36, xiii, 515 pp., and atlas, 75 pls.

GILL, THEODORE

1878. A new species of chimaera found in American waters. Bull. Philos. Soc. Washington, vol. 2, (1874-1878), 1875-1880, p. 182.

GOODE, G. B., and T. H. BEAN

1895. Oceanic Ichthyology . . . Smithsonian Contrib. Knowl., vol. 30, xxxv+26*+553 pp.; vol. 31, Atlas, 123 pls.

GÜNTHER, ALBERT

1878. Report on the deep sea fishes. "Challenger" Rept. Zool., vol. 22, part 57, lxv+268 pp., 66 pls.

HERTWIG, OSCAR

1874. Ueber Bau und Entwickelung der Placoidschuppen und der Zähne der Selachier. Jena Zeitschr. Naturw., vol. 8, pp. 331-404, pls. 12, 13.

HOLT, E. W. L., and L. W. BYRNE

1908. Second report on the fishes of the Irish Atlantic slope. Fisheries Ireland Sci. Invest. (1906), no. 5, 63 pp., 5 pls., 2 figs.

1909. Preliminary note on some fishes from the Irish Atlantic slope. Ann. Mag. Nat. Hist., ser. 8, vol. 3, pp. 279-280.

1910. Third report on the fishes of the Irish Atlantic slope. Fisheries Ireland Sci. Invest. (1908), no. 4, 26 pp., 4 pls.

ISHIYAMA, REIZO

1952. Studies on the skates and rays . . . found in Japan and adjacent regions. Journ. Shimonseki Coll. Fisheries, vol. 2, no. 2, 34 pp., 4 pls.

JENSEN, A. S.

1914. The selachians of Greenland. Mindeskr. Jap. Steenstrup, vol. 2, no. 30, 40 pp., 1 pl.

1948. Contributions to the ichthyofauna of Greenland. Spolia Zool. Mus. Hauniensis, Skrifter . . . Universitetets Zoologiske Museum København, vol. 9, 182 pp., 4 pls.

KOEFOED, EINAR

1927. Fishes from the sea bottom. Rept. Sci. Res. "Michael Sars." N. Atlant. Exped. 1910, vol. 4, part 1, 147 pp., 6 pls.

LÜTKEN, CHR.

1887. Korte Bidrag til Nordisk ichthyographi. 4. Vidensk. Medd. naturh. Foren. Copenhagen, pp. 1-4, pl. 1.

1898. The ichthyological results of the expeditions of the "Ingolf". Danish "Ingolf" Exped., vol. 2, part 1, 39 pp., 4 pls.

MITCHILL, S. L.

1815. The fishes of New York, described and arranged. Trans. Lit. Philos. Soc. New York, vol. 1, pp. 355-492, pls. 1-6.

1817. The fishes of New York . . . Supplement . . . Amer. Monthly Mag. Crit. Rev., vol. 2, pp. 241-248, 321-328.

1825. The hedgehog-ray. Amer. Jour. Sci., vol. 9, pp. 290-293, pl. 6.

MITSUKURI, K.

1895. On a new genus of the chimaeroid group *Harriotta*. Zool. Mag., Tokyo, vol. 7, no. 80, pp. 97-98, pl. 16.

MOREAU, EMILE

1891. Histoire naturelle des poissons de la France. Supplement, 144 pp. Paris.

RADCLIFFE, LEWIS

1916. The sharks and rays of Beaufort, North Carolina. Bull. U. S. Bur. Fisher., vol. 34, pp. 239-284, pls. 38-49.

REGAN, C. T.

1906. Descriptions of some new sharks in the British Museum collection. Ann. Mag. Nat. Hist., ser. 7, vol. 18, pp. 435-440.

REINHARDT, JOHANNES

1825. Ichthyologiske Bidrag . . . Overs. Dansk. Vidensk. Selsk. Forh. København (1824-1825), pp. 2-3.

ROULE, LOUIS, and FERNAND ANGEL

1933. Poissons provenant des campagnes du Prince Albert I de Monaco. Résult. camp. Sci. . . . Albert I^{er}, Prince Souverain de Monaco . . . Fasc. 86, pp. 1-78, 4 pls.

SCHNAKENBECK, W.

1929. Uber einige Meeresfische aus Südwestafrika. Mitt. Zool. Staatsinst. Zool. Mus. Hamburg, vol. 44, pp. 23-45.

TANAKA, SHIGETO

1909. Descriptions of one new genus and ten new species of Japanese fishes. Journ. Coll. Sci. Tokyo, vol. 27, art. 8, 27 pp., 1 pl.

TORTONESE, ENRICO

1952. Studi sui Plagiostomi . . . Arch. Zool. Ital., vol. 37, pp. 383-398.

TOWNSEND, C. H., and J. T. NICHOLS

1925. Deep sea fishes of the "Albatross" Lower California expeditions. Bull. Amer. Mus. Nat. Hist., vol. 52, pp. 1-20, pls. 1-4.

VAILLANT, L.

1888. Expéditions scientifiques du "Travailleur" et du "Talisman" pendant les années 1880-1883, Poissons, part 1, 406 pp., 28 pls. Paris.

WHITLEY, GILBERT P.

1939. Taxonomic notes on sharks and rays. Australian Zool., vol. 9, part 3, pp. 227-262.