The Basking Shark, *Cetorhinus maximus*, from Florida and California, with Comments on its Biology and Systematics

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The known range of the basking shark is extended to the Gulf of Mexico by an adult female taken alive at Sarasota, Florida. Comparisons of some characters of the specimens are made with those of an adult male from in Drake's Bay, California and those of an immature specimen from the east coast of Florida. Although the Sarasota specimen differs in denticle form and in some other respects from basking sharks of the eastern North Atlantic and elsewhere, it is provisionally identified as *Cetorhinus maximus* (Gunnerus), here regarded as the only extant species of its genus and family. Reasons for the presence of the Sarasota specimen in warm shallow water 190 km from the continental shelf edge are postulated.

The basking shark, *Cetorhinus maximus* (Gunnerus), with lengths at maturity of 6 to 10 m or more, is the second largest species of living sharks exceeded only by the whale shark, *Rhincodon typus* (Smith). Most of the current knowledge of *Cetorhinus* biology comes from studies of specimens taken in sporadic and small-scale fisheries located in European waters. The most significant contributions are those of Matthews and Parker (1950), Matthews (1950), van Deinse and Adriani (1953), Parker and Boeseman (1954) and Parker and Stott (1965). Comparable information on the basking sharks of other areas is meager and usually limited to reports on specimens accidentally enmeshed in nets or stranded in shallow water under circumstances that precluded detailed study. For this reason morphological data on two basking sharks from Florida and one from California, are presented here and compared to data from other specimens reported in the literature. Certain aspects of the biology and systematics of the family *Cetorhinidae*, especially those that require further study, are discussed.

A basking shark, the first ever recorded for the Gulf of Mexico, was taken alive 2 April 1969 in shallow water about 75 m off Grassy Point, Sarasota County, Florida (Figs. 1 and 2). The shark, an adult female 8.285 m total length and 1980 kg weight, was captured in a gill net by James Rogers, assisted by Ralph and Victor Smith. The net, set in 3-4 m of water, was of monofilament nylon with 12 cm stretched mesh, 50 meshes deep. With the assistance of Gene Wagner and Neil Sanders of the Kiekhaefer Mercury Testing Station, the basking shark was brought to the Mote Marine Laboratory where it died before physiological tests could be made. The Sarasota basking shark was very thin, its girth at the posterior end of the pelvic fin only 28.2% of total length. Matthews and Parker (1950) measured a female almost as long with a girth 37.4% of its total length. The slenderness of the Sarasota specimen may have been in part due to the relatively small volume of liver. While the posterior tips of the liver reached to the end of the body cavity, the lobes were slender. The oil content, however, was comparatively high. The oviducts were large and flaccid and the stomach contained about 15 liters of amorphous, paste-like material.

An adult male, 8.46 m long, was measured by James L. Squire and Stewart Springer on 28 November 1963 after it had been on the beach at Drake's Bay, California, for an undetermined period. Internal organs were not examined. The St. Augustine shark was an immature female, 3.589 m long, caught in a shrimp trawl off St. Augustine, Florida on 21 February 1970 in water about 17 m deep. It was brought to Marine Studios at Marineland and was measured by F. Martini.

**Morphometrics**

Measurements of the three sharks, made as outlined by Bigelow and Schroeder (1948) are expressed here in percentages of the total length. In the following series of proportional measurements, the first figure in each group refers to the Sarasota shark, the second to the Drake's Bay Shark, and the third to the St. Augustine shark.

Tip of snout to: Anterior margin of upper lip, 4.7, 5.0, 6.5; anterior margin of eye, 4.7, 5.2,
Fig. 1. The Sarasota basking shark, 8.3 m long, weighed 1980 kg. The significance of the light colored tip of the second dorsal fin is not known. Basking sharks taken in other areas commonly have some irregular mottling of lighter and darker color. Photo—Neil Sanders, Kiekhaefer Mercury.

7.2; origin pectoral fin, 22.4, 21.6, 24.1; first gill opening, —, 15.6, —; origin first dorsal fin, 33.1, 34.0, 37.2; origin pelvic fins, 52.7, 39.7, 56.6; second dorsal fin, 62.6, 67.2, 64.6; anal fin, 68.7, —, 72.1; upper caudal pit, 82.8, 80.5, —; posterior margin of caudal fin at level of body axis (fork lengths), —, 88.9, —.

Horizontal diameter of eye, 0.7, 0.7, —. Minimum distance between nasal apertures, 2.7, —, —. Mouth width, 10.4, —, —.

First dorsal fin: Length base, 9.1, 10.8, 8.6; length free inner margin, 3.7, 4.3, —; height, 12.9, —, 7.5. Second dorsal fin: Length base, 4.7, 3.4, 2.6; length free inner margin, 3.7, 3.3, 2.2; height, 4.3, —, 2.6. Anal fin: Length base, 2.1, 2.7, 2.1; length free inner margin, 2.8, 1.4, 2.3; height, 2.2, 2.4, 2.3. Pectoral fin: Length anterior margin, 16.1, 16.5, 15.6; free inner margin, 4.6, —, 3.3. Caudal fin: Anterior margin, upper caudal lobe, 20.6, 20.1, 21.0; anterior margin, lower caudal lobe, 11.4, 12.9, 11.6.

Girth: At posterior end dorsal fin, 28.2, —, —; at caudal pit, 9.7, —, —.

Distance between fin bases: First and second dorsal fins, 22.5, 22.5, 18.1; second dorsal and upper caudal, 10.4, —, 8.8; anal and lower caudal, 7.5, —, 6.8.

Clasper proportions: Length along outer margin, not applicable, 12.0, not applicable; distance of clasper reach past pelvic fin tips, not applicable, 8.1, not applicable.

The preceding proportional measurements
show moderate individual differences in the three specimens but only two differences are trenchant: 1. the proportionally longer snout in the young basking shark, which is undoubtedly the usual condition in young and immature specimens and agrees with the descriptive accounts and illustrations in the literature (Bigelow and Schroeder, 1948), and 2. the distance from the tip of the snout to the origin of the pelvics, which reflects chiefly a shorter abdominal segment of the trunk in the adult male. A shorter abdomen may characterize adult male basking sharks but is not evident in proportional measurements of a series of five females and four males (Matthews and Parker, 1950). The series included specimens with fork-lengths between 6.2 and 7.4 m but whether the specimens were mature or immature was not indicated.

**SKIN, DERMAL DENTICLES, TEETH AND GILL RAKERS**

The skin of most of the body surfaces of these specimens is crisscrossed by narrow, deep and close set channels, less prominent on the branchial region than on the flanks. These channels form somewhat rectangular islets and in some random areas they form whorls. The islets are about 6–12 mm wide or long, the channels 2–3 mm wide and less than 5 mm deep. The islets, the ridges and the channels are all covered with dermal denticles. These tiny skin channels,
characteristic of all basking sharks, are less prominent on the Sarasota specimen.

Denticles on the flanks are small and conical with indistinct ridges extending from their bases to their tips. The denticles of the Sarasota shark are longer and more slender than those of the other specimens and the denticles of its branchial region (Fig. 3) are longer and more slender than those on its flanks (Fig. 4). Widely scattered pairs of enlarged denticles protect the openings to the pit organs and small, flattened, leaf-shaped denticles are sparsely and randomly distributed on the palate.

Bigelow and Schroeder (1948), Matthews and Parker (1950) and Siccardi (1961) all described the denticles as small with points directed caudally and the skin consequently smooth when stroked posteriorly. However, the denticles of the Sarasota shark pointed in all directions and the skin was exceedingly rough when stroked in any direction. It was impossible to determine the direction of the denticles of the Drake's Bay specimen, for the projecting points were missing, perhaps worn away by sand and surf.

The teeth (Fig. 5) of the Sarasota specimen were hooked, similar in both upper and lower jaws, and very small, the largest about 4 mm long. They did not differ markedly from basking shark teeth described in other publications.

The Sarasota specimen had well developed gill rakers (Fig. 6), up to 150 mm long, but the Drake's Bay Shark lacked them. Decomposition did not seem to have progressed sufficiently to account for their loss. Other specimens of basking sharks have also lacked gill rakers (van Diense and Adriani, 1953) but their loss and replacement is of uncertain significance despite much speculation (Matthews, 1962).

Vertebrae and Age

Vertebrae of the Sarasota shark differed little from those described by Ridewood (1921) with the exception that in the Sarasota specimen the median trunk vertebrae had short but well developed diagonal calcified lamellae similar to those in some carcharhinid sharks. The vertebrae at the base of the caudal fin were more extensively calcified than those of either the anterior trunk or the distal area of the caudal fin.

The centrum radius of a pelvic vertebra of the Sarasota specimen measured only 55 millimeters. Preactural vertebrae from four female Cetorhinus of comparable size measured 61 to 72.5 mm (Parker and Stott, 1965).

Vertebrae of the Sarasota basking shark had a maximum of 16 complete calcified rings (Figs. 7 and 8) whereas female basking sharks of comparable size (7.63-8.77 m) from the eastern North Atlantic showed 21-22 complete rings (Parker and Stott, 1965). If one accepts Parker and Stott's hypothesis that the age of basking sharks can be calculated from the number of concentric rings of calcification in the vertebrae, one must infer that the Sarasota basking shark is younger than the Eastern Atlantic specimens of similar size.

Distribution

Bigelow and Schroeder (1948) limited the range of Cetorhinus maximus to the temperate and subpolar parts of the Atlantic, Pacific, and
Indian oceans and indicated there was no evidence of their occurrence in the tropical Atlantic. Briggs (1960) concluded that the occurrence of basking sharks in both the Northern and Southern Hemispheres indicated some movement across equatorial regions. Later, Cadenat (1962) reported the capture of two immature basking sharks from the coast of Senegal. Wood (1957) reported the first basking shark from Florida, and the captures reported here suggest a more extensive southern range than heretofore known.

Many large sharks of species usually inhabiting temperate waters have been caught on long lines in tropical seas below the thermocline at depths up to several hundred meters. Due to their food preferences, basking sharks cannot be caught with such fishing gear and are only accidentally vulnerable to any of the gear currently in use except harpoons. Since tropical submergence is common among other species of sharks, it is possible that it may figure in the distribution of basking sharks. Data on the distribution of basking sharks are so sparse that it is impossible to determine whether or not a tropical deepwater population exists. Basking sharks may normally be midwater inhabitants and appear in surface waters only when conditions such as food and temperature are especially favorable, or, equally likely, the few tropical or subtropical specimens reported may be waifs from colder seas. The appearance of occasional basking sharks in warmer waters might be explained by the direct movement of individuals into the warm surface waters of lower latitudes. Or perhaps by following favorable isotherms into deeper waters towards the equator they subsequently rise and adapt to the warm surface waters. This would presuppose the presence of sufficient food, plankton or possibly small fish, to support them.

The Sarasota specimen was remarkable not only because it was caught in relatively warm (20°C) water about 160 km from the nearest continental slope but also because the specific gravity of the whole liver oil was 0.851 at 20°C, subnormal for the species. Moreover the liver oil contained 63.8% squalene, a higher percentage than commonly reported for commercial samples of basking shark liver oils. The presence of large quantities of the low density hydrocarbon, squalene, in the liver oil (Tsujimoto, 1932) could substantially increase the shark’s...
buoyancy (Bone and Roberts, 1969). This "hepatic float" may be a factor in the leisurely surface basking so typical of this species and, from the point of energy conservation, such a buoyancy mechanism would minimize reliance on the energy-expensive hydrodynamic lift mechanism to support their great bulk in the water. If, however, through some hepatic malfunction, they could or should become positively buoyant (Baldridge, 1972), they would encounter serious difficulties, including loss of swimming control. Such a condition could conceivably be responsible both for the stranding of basking sharks and for their appearance far inshore in unsuitably shallow, warm water.

**Systematics of *Cetorhinus***

Three characteristics, reproduction, skin structure and gill rakers, set the basking shark apart from all other elasmobranchs and warrant their placement in a separate family, the *Cetorhinidae*. Unlike most species of sharks, which produce relatively small numbers of large yolked eggs, basking sharks produce millions of tiny eggs. Matthews (1950) estimated the single functional ovary contained 6 million ova about 0.5 mm in diameter. In the ampulla ductus deferentis of the male he found several gallons of spermatozoa 2-3 cm in diameter. Nothing is known of the development of the young, and except for a 30 cm embryo reportedly found about 200 years ago, no embryos and no young smaller than 2 m have ever been recorded. The skin of basking sharks, with islets separated by narrow channels on most of its surface, is completely different from all other sharks. Bigelow and Schroeder (1948), unaware of their unusual reproduction, classed them as a distinct family based on "the presence of horny rakers on their gill arches (which) makes them unique among modern sharks."

The inclusion of basking sharks in the family Lamnidae is unjustified not only because these three characters are distinctive but also because the gill openings are very much larger (they almost encircle the body) and the teeth are far smaller and more numerous than those of the lamnids.

*Cetorhinus maximus* was long considered the monotype of its genus and family but Siccardi (1961) recognized four species of *Cetorhinus*, two from the North Atlantic-Mediterranean (*C. rostratus* and *C. maximus*), one from the Australian (*C. maccoyi*), and one from the South Atlantic regions (*C. normani*). She separated them chiefly on differences in body proportions which occur commonly in growth. In Siccardi's (1961) summary of characteristics of *Cetorhinus* species, she described *C. maccoyi* of the Australian region, as having a shorter snout than *C. maximus* with the dorsal interspace nearly as great as the distance from the snout tip to the
first dorsal origin. In her diagnosis of *C. normani*, she listed the distinctive features as teeth in two to five functional files (transverse files); body compressed, very high; weight great but inferior to the Australian form; distance from snout tip to second dorsal a little less than in other forms; and precaudal distance less than in the Australian and Mediterranean forms. One of the species from the North Atlantic–Mediterranean, *C. rostratus* was obviously based on young specimens which typically have much longer snouts than the adults.

Siccardi's 22 specimens ranged from 2.859 m to 9.271 m in total length. Of these, only two are mature, unless some of them represent populations that mature at appreciably shorter lengths than *Cetorhinus* of the eastern North Atlantic. At present there is no evidence of smaller mature *Cetorhinus* anywhere in the world. The proportional differences indicated by Siccardi support her view of four distinct species only if proportional changes that generally occur during growth are disregarded. In our judgment, reasons for the recognition of *C. maccoyi*, *C. normani* and *C. rostratus* as separate species are presently insufficient.

Bini (1967) illustrated the snouts of adult basking sharks from the eastern North Atlantic and compared them to the "pointed prominences or beaks" of the young sharks. Matthews and Parker (1950) also illustrated the various snout forms in young basking sharks.

Except for a few stuffed specimens no entire basking sharks are preserved in museum collections and, due to the rarity of sightings and gargantuan proportions of the subject, it is unlikely that any large specimens will be preserved in toto. This paucity of material has hampered studies not only of their taxonomy but also of their life history and biology.

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Sexual Dimorphism and Geographic Variation in the Bronze Darter, Percina palmaris (Pisces: Percidae)

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The study indicates that males of Percina palmaris have significantly higher fin counts and longer depressed second dorsal and anal fins than females. This sexual dimorphism is more significant on specimens from the Tallapoosa than the Coosa River drainage. Females from the Tallapoosa are 94.4% separable from 88% of the males on the basis of anal soft ray count, while the average divergence in dorsal soft rays and anal soft rays for both drainages ranges from 72.8 to 73.5%.

Tubercles and tubercular ridges are described from male specimens.

**Percina palmaris**, Bailey, is presently recorded from the Coosa and Tallapoosa tributaries of the Alabama River drainage in Alabama and Georgia (Fig. 1). A comparison of Alabama and Georgia specimens for lateral line scales and pectoral rays is found in Crawford (1954) and vertebral counts are given in Bailey and Gosline (1955).

Examination of approximately 400 specimens reveals extensive sexual dimorphism in several meristic counts. Collette (1962) reports a significant difference between sexes of *Etheostoma f. fusiforme* in total lateral line scales. My studies indicate consistent and highly significant differences between the sexes of *P. palmaris* with regard to several scale counts and soft ray counts. The type and extent of differences varies in samples from the Coosa River in Georgia and those from the Tallapoosa River in Alabama. Population samples (sexes com-