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Three Species of Hammerhead Sharks in the Southwestern Waters of Japan

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Abstract Three species of hammerhead sharks are distributed in the southwestern waters of Japan. They are *Sphyrna mokarran* (Rüppell), *S. zygaena* (Linnaeus), and *S. lewini* (Griffith and Smith). A key to the Japanese species of *Sphyrna* is presented. In the surveyed areas catch records show that *S. lewini* is most abundant whereas *S. mokarran* is least in number. The density distribution expressed as hook rates by small statistical quadrates indicates that the distribution of these species is almost confined to the west of lines connecting southern Kyushu, the Nansei Islands, and Formosa. They rarely occur far out at sea. The density distribution also shows that they do not make south-north migrations on an extensive scale. Main populations of these species appear to dwell within the East China Sea.

Introduction

Fishermen and dealers of sharks in Kagoshima Prefecture, Kyushu, distinguish three species of hammerhead sharks because of differences in the commercial value of the flesh. These sharks are called shiro-kase (white hammerhead), aka-kase (red hammerhead), and hira-kase (flat hammerhead).* The staff of the Nanseikai Regional Fisheries Research Laboratory, who collected catch records of sharks, employed the above local names in lieu of scientific or Japanese common names. In fact, until recently only a single species of hammerhead shark was described in the scientific literature. Thus, the Japanese standard common name "shumokuzame" referred to *Sphyrna zygaena* (Linnaeus) which Temminck and Schlegel (1850:306) described first from Japan as *Zygaena malleus*. Matsubara (1955:111) pointed out the possibility that one or two species of *Sphyrna* should be added to the Japanese ichthyofauna, citing figures of inner and outer narial grooves and head shape of ten species given by Fraser-Brunner (1950) to aid in future identification. Soon afterwards, *S. lewini* (Griffith and Smith in Cuvier) was recorded from Japan and was given the Japanese common name, akashumoku (Tanaka and Abe, 1955). Recently, Gilbert (1967:31) reported in his revisional work on hammerhead sharks that *S. mokarran* (Rüppell) occurred in southern Japan without mentioning the reference source and the locality. I made several visits to fish markets of Kagoshima, Kushikino, and Nagasaki, all of which are adjacent to the East China Sea, and identified shiro-kase as *S. zygaena* (Linnaeus), aka-kase as *S. lewini* (Griffith and Smith), and hira-kase as *S. mokarran* (Rüppell). The three species of hammerhead sharks are also found in Formosa (Teng, 1962; Chen, 1963).

Teng (1962: 74~82) gave the following Japanese common names to the three species of *Sphyrna* in Formosa: *S. zygaena*, shumokuzame; *S. lewini*, akashumoku; *S. mokarran*, yabireshumoku. I do not prefer these Japanese names for two reasons. First, the Japanese name "shumokuzame" has been used for hammerhead sharks in general, and shiro-kase, aka-kase and hira-kase have been in use for a long time in Kagoshima areas. Second, it is better to use "shumokuzame" which describes all members of the family Sphyrnidae, in the last part of the common names.

Thus I propose here the following Japanese standard common names for the three species: *S. zygaena*, shiro-shumokuzame; *S. lewini*, aka-shumokuzame; *S. mokarran*, hira-shumokuzame.

* Colours such as white and red refer to the appearance of the flesh. In Nagasaki fish market *S. zygaena* is called kuro-kase (black hammerhead) because of the black color of the trunk region in a fresh state.

Material and methods

Specimens of *S. zygaena* and *S. lewini* deposited in the shark collection of the University Museum, University of Tokyo (SCUM) were used in this study. A specimen of *S. mokarran* was available at Kushikino, Kagoshima Prefecture, Kyushu.

S. zygaena: SCUM 513, off Nagasaki, Nov. 15, 1967; SCUM 507, East China Sea, Nov. 15, 1967.

S. lewini: SCUM 515, off Kushikino Nov. 9, 1967; SCUM 530, off Kushikino, Nov. 9, 1967.

S. mokarran: Photos and measurements taken at Kushikino, Oct. 17, 1966.

Measurements followed Bigelow and Schroeder (1948).

Fishing data of sharks landed at Kagoshima fish market were obtained from the logbook records of commercial long line vessels operating in the waters of southwestern Japan (22°∼34°N latitude, 122°∼138°E longitude) through the courtesy of the Nanseikai Regional Fisheries Research Laboratory. The fishing grounds were arbitrarily divided into small statistical quadrates (Fig. 1), each of which was composed of two degrees square latitude and longitude. Hook rates were expressed as the number of sharks caught per thousand hooks.

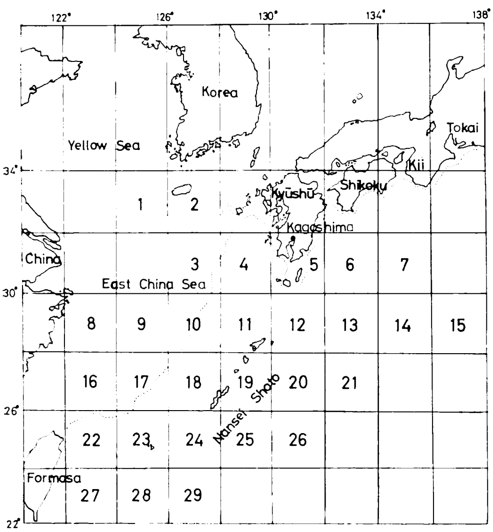

Fig. 1. Chart of fishing area and statistical quadrates. The numeral in each quadrate indicates quadrate number. A dotted line shows 200 m isobath.

Key to the species of *Sphyrna* of Japan

Ia. Inner narial groove absent; anterior contour of head almost straight with median notch*; corner of mouth behind conjunctive part of head and throat; anterior margin of 1st dorsal fin sloped gently, apex of 1st dorsal behind posterior extension; 2nd dorsal fin high, its distal margin deeply notched, its posterior margin less than 1.5 times of height; teeth on both jaws strongly serrated, 17 teeth on either side of upper jaw, excluding small central teeth······························hira-shumokuzame, *S. mokarran* (Rüppell, 1835) (Fig. 2).

Ib. Inner narial groove present; anterior contour of head convex; corner of mouth at level of conjunctive part of head and throat; anterior margin of 1st dorsal fin sloped abruptly; apex of 1st dorsal in front of posterior extension; 2nd dorsal fin low, its distal margin concave but not notched deeply, its posterior margin twice or more as long as height; teeth on both jaws not serrated or only weakly serrated, fewer than 16 teeth on each side of upper jaw.

IIa. Anterior margin of head convex without median notch; 2nd dorsal bluntly tipped but anal fin sharply tipped; inner narial groove long, reaching level of conjunctive part of head and throat; first several teeth on both jaws almost erect and long, 12∼14 teeth on each side of lower jaw···shiro-shumokuzame, *S. zygaena* (Linnaeus, 1758) (Fig. 3).

IIb. Anterior margin of head convex with median notch; 2nd dorsal fin sharply tipped but anal fin bluntly tipped; inner narial groove short, not reaching level of conjunctive part of head and throat; first several teeth on both jaws notched and short, 15∼16 teeth

* In juveniles the anterior margin of head is not as flat as in adults. See Bigelow and Schroeder (1948; 409) or Gilbert (1967: 27).

on each side of lower jaw········ aka-shumokuzame, *S. lewini* (Griffith and Smith in Cuvier, 1834) (Fig. 3).

Proportional dimensions of specimens studied are presented in Table 1.

Abundance and density

Table 2 shows the catch in 1953 of the three species of hammerhead sharks in the waters of southwest Japan. Figures in parentheses represent relative availability of each species because the same fishing gear was used to capture the three species. It is evident that *S. lewini* was most abundant whereas *S. mokarran* was least in number. Seasonal ratios of each species were nearly constant except for the third quarter (Jul. to Sep.). On the average, the abundance of *S. lewini* was about seven times greater than *S. zygaena* and about fifty times greater than *S. mokarran*. Considering the density by two degrees quadrates, *S. lewini* also showed higher density than the other species in almost all the quadrates irrespective of season.

The density distribution by quadrate and quarter of the year is shown in Fig. 4. As indices of density, hook rates were employed. The catch of the threes pecies was almost en-

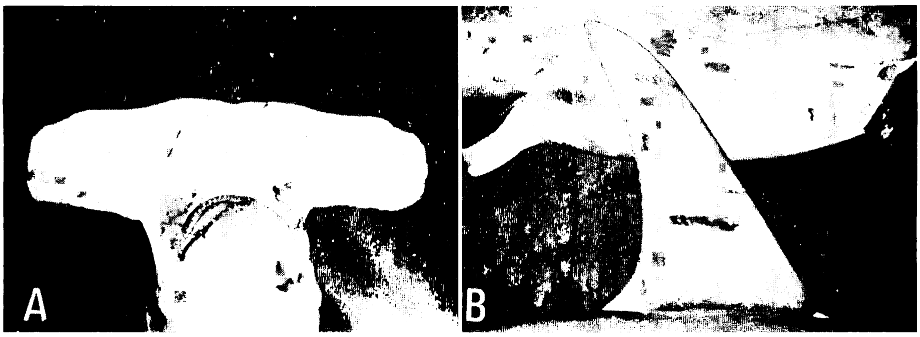

Fig. 2. *Sphyrna mokarran*, an adult male, 3270 mm in total length, from the East China Sea. A, head. B, 1st dorsal fin.

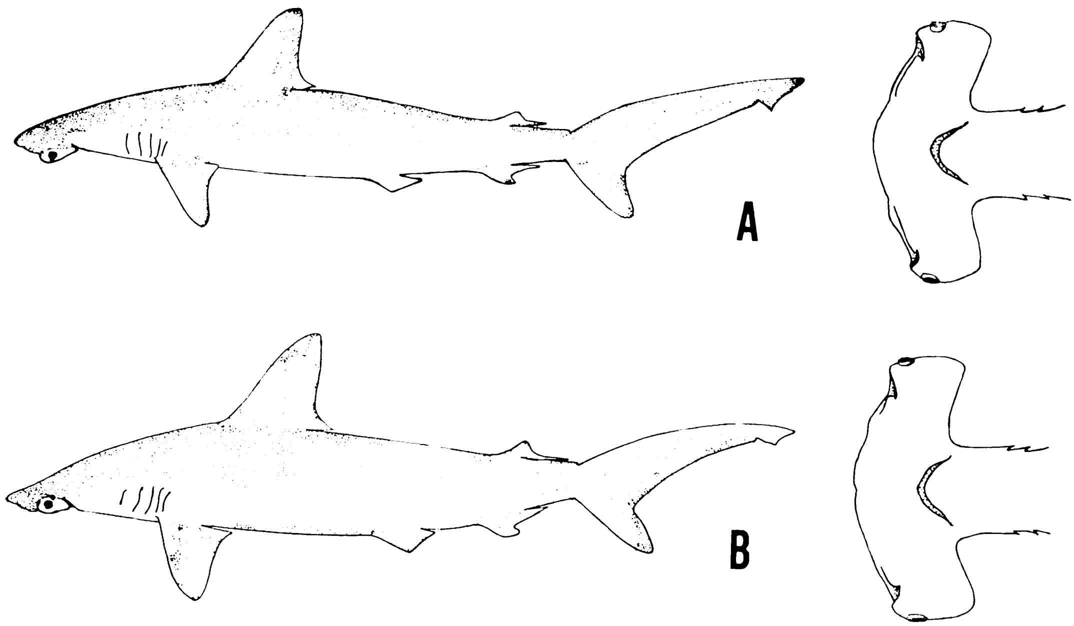

Fig. 3. Two species of *Sphyrna*. A, *Sphyrna zygaena*, a young male, 876 mm in total length, from off Nagasaki. B, *Sphyrna lewini*, a young female, 746 mm in total length, from off Kushikino, Kagoshima Prefecture.

Table 1. Proportional dimensions in percent of total length of three species of *Sphyrna* taken in the southwestern waters of Japan.

Species	*S. mokarran*	*S. zygaena*		*S. lewini*	
Cat. No. (SCUM)		513	507	530	515
Sex	♂	♂	♂	♀	♀
Total length (mm)	3270	876	928	716	746
Snout tip to:					
outer nostrils	2.0	3.8	3.4	2.9	3.2
eye	2.4	4.6	4.5	5.8	6.7
mouth	5.1	5.7	5.4	6.0	6.8
1st gill opening	15.4	16.8	15.8	16.8	15.7
5th gill opening	20.5	21.1	19.8	21.9	21.6
pectoral origin		20.0	18.1	19.7	20.0
pelvic origin	43.7	46.5	44.6	46.4	45.7
1st dosal origin	26.0	25.5	25.3	28.1	26.5
2nd dorsal origin	56.9	61.8	60.3	60.9	58.3
anal fin origin	57.4	59.6	57.4	59.2	58.7
upper caudal origin	65.4	72.5	70.4	71.4	69.0
Distance between inner corners of nostrils	16.4	19.3	18.6	19.1	18.5
Mouth:					
width	6.9	6.8	6.6	7.3	6.3
length	3.1	3.8	3.0	3.5	3.1
Length of 3rd gill opening		3.2	2.9	3.7	4.3
Horizontal diameter of eye	0.9	1.8	1.6	2.0	1.7
1st dorsal fin:					
length of base	8.7	10.3	8.9	10.1	10.1
length of post. margin	3.1	3.1	3.2	4.2	3.8
height	16.2	10.5	10.6	12.8	11.7
2nd dosal fin:					
length of base	4.6	3.0	2.8	3.6	3.1
length of post. margin	5.5	4.9	4.8	5.7	5.2
height	4.6	2.1	2.0	2.6	2.4
Anal fin:					
length of base	5.8	4.6	3.9	5.3	4.7
length of post. margin	3.8	4.2	4.0	4.6	4.3
height	4.1	2.7	2.8	3.6	3.2
Pectoral fin:					
length of base	5.4	5.3	5.4	5.4	5.6
length of ant. margin	13.6	12.2	11.5	12.8	11.3
length of dist. margin	12.2	8.7	8.3	10.5	8.4
length of post. margin	3.7	3.7	3.4	3.5	3.2
Pelvic fin:					
length of base	4.4	4.2	5.1	5.9	5.4
length of ant. margin	8.1	4.4	4.4	5.6	5.4
length of dist. margin		5.3	5.0	6.7	6.4
length of clasper		1.7	1.8		
Caudal fin:					
length of upper lobe	29.4	29.3	28.9	32.1	30.8
length of lower lobe	12.5	11.5	11.1	11.6	11.1
depth of notch	1.6	2.3	2.2	2.5	2.8

Table 2. Catch of species of *Sphyrna* landed at Kagoshima Fish Market in 1953. Numbers in parentheses show ratios of each species to total catch for each quarter and for the entire year.

	1st quarter (Jan.-Mar.)	2nd quarter (Apr.-Jun)	3rd quarter (Jul.-Sep.)	4th quarter (Oct.-Dec.)	total
S. lewini	812 (0.83)	1597 (0.85)	166 (0.57)	4424 (0.88)	6999 (0.86)
S. zygaena	142 (0.15)	256 (0.14)	124 (0.43)	495 (0.10)	1017 (0.12)
S. mokarran	24 (0.02)	35 (0.02)	0 (0)	95 (0.02)	154 (0.02)

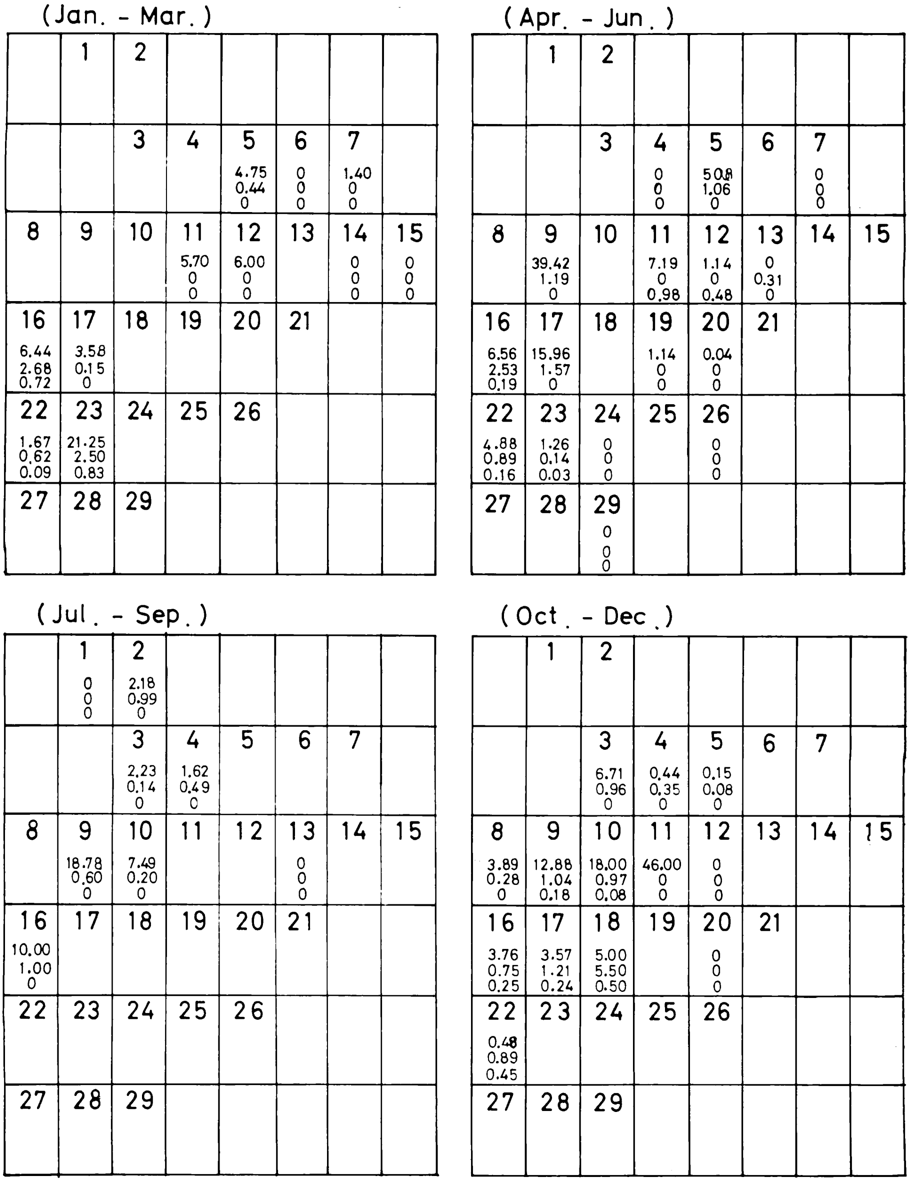

Fig. 4. Seasonal density of three species of *Sphyrna* in the southwestern waters of Japan. ***Density*** is expressed as hook rates. Large numerals identify the quadrate (see Fig. 1) while small numerals show hook rates of *S. lewini* (upper), *S. zygaena* (middle), and *S. mokarran* (lower).

tirely confined to the west of imaginary lines connecting southern Kyushu, the Nansei Islands, and Formosa. Particularly, the density in quadrates which included the 200 m isobath or shallower waters (No. 5, 10, 16, 17, 18, and 22) exhibited high hook rates throughout the year. The catch of hammerhead sharks in the oceanic region beyond the Nansei Islands were rare (quadrates 6, 7, 19, 20, and 24). Fishing effort was also low in this region. On the other hand, it is possible to infer from the density of quadrate 1 which showed no catch records in the third quarter (Jul. to Sep.), that the three species did not enter the Yellow Sea. These data suggest that the main populations of these species live within the East China Sea. although the possibility exists that they could move north-eastward and/or south-westward.

Density of *S. lewini* was high in quadrates 9, 10, 11, 16, and 17 all the year whenever there was fishing effort, and 5 and 12 in the first half of the year. Seasonally, the density was generally high in the second and fourth quarter. However, since the density in each quadrate did not show such extreme differences between quarters. extensive emigration and immigration of hammerhead sharks are not considered to occur between the East China Sea and other areas. Further. *S. lewini* did not seem to show remarkable south-north migrations. If this species moved toward the north in the warm season (3rd quarter), the density in the most northerly quadrates (No. 1 and 2) should be higher than those in quadrates 3, 9, 10, and 16. The fact was, however, that gradient of density from south to north is not shown in the data for the third quarter. Seasonal changes in density would be expected if this species migrated within the East China Sea.

The distribution of *S. zygaena* was almost the same as *S. lewini* except that it was not caught in quadrates 11 and 16. In general, *S. zygaena* showed high density in the southern part of the East China Sea (quadrates 9, 10, 16, 17, 18, and 22). It is likely that some parts of the population of *S. zygaena* moved northward in the third quarter because the most northerly quadrate (No. 2) showed higher density than quadrates 3, 4, 9, 10, and 13.

The catch of *S. mokarran* was concentrated chiefly in the southwestern part of the East China Sea (quadrates 16, 17, 22, and 23). No individuals of this species were captured in the third quarter. It is likely that this species makes northeast-southwest migration within the East China Sea because the density was high in the northeastern part during the second quarter and in the southwestern part during the fourth quarter.

Concerning vertical distribution, I observed in fish markets that *S. zygaena* was caught in great numbers by harpoon. This means that it is a surface dweller in the East China Sea. On the other hand, *S. lewini* and *S. mokarran* were seldom harpooned, but were caught with floating long line gear. The depth of this gear in the area was from 15 m to 60 m (Furukawa et al, 1957). In addition. juveniles of *S. lewini* are often captured by bottom trawls. It is thus possible to infer that *S. zygaena* inhabits the surface layer while *S. lewini* and *S. mokarran* are commoner between the surface and the midwater.

Discussion

It is not surprising that three species treated here are found near Japan since they are world-wide in distribution. It is also natural that these species are numerous in the East China Sea where their food such as fishes, molluscs, and crustaceans is abundant. The present data showing that three species rarely occur far out at sea, agree with those of Strasburg (1958) who demonstrated the scarcity of hammerhead sharks in the oceanic regions. According to fishermen, hammerhead sharks are seldom caught in the cool Yellow Sea. Additionally, in my personal visits to fish markets throughout Japan, landings of hammerhead sharks were greatest at those fish markets located adjacent to the East China Sea. It is thus likely that the main populations of three species live within the East China Sea, although there is the possibility that they move to the South China Sea through the Taiwan Isthmus.

It is not obvious why *S. lewini* was most abundant among three species in the southwestern waters of Japan. One plausible explanation is that the dominance in the catch of *S. lewini* was due to the bias caused by the long line fishing method which may not sample the three species equally. In the 1950's the long line fishery was aimed at bill-fishes and not sharks (Furukawa et al, 1957). Therefore, the fishing effort might not reflect true density distribution. If this is the case, it is possible that main populations of *S. zygaena* and *S. mokarran* dwell in areas where no fishing effort was made. However, judging from the present data and my observation in fish markets, it is likely that *S. lewini* is in fact more abundant than *S. zygaena* and *S. mokarran*, at least in the southwestern waters of Japan.

Bigelow and Schroeder (1948: 442～444) noted that hammerhead sharks including *S. zygaena*, *S. mokarran*, and *S. lewini* migrate northward in summer and southward in winter in the western north Atlantic. The northern part of the East China Sea is adjacent to the cool Yellow Sea and the southern part is bounded by the Nansei Islands, so that it is a narrow body of water. Further, the southern and eastern parts of the sea, where hammerhead sharks are numerous, are strongly influenced by the warm Kuroshio and Tsushima Currents. If these sharks prefer warm and shallow waters, they would neither migrate into the Yellow Sea nor into deeper waters than 200 m isobath. Therefore, they probably do not show south-north migratory habits on an extensive scale. Clarke (1971) reported inshore-offshore migration of *S. lewini* in Hawaii. However, this habit is not evident in the present study.

S. zygaena and *S. lewini* are widely distributed around Japan. I have seen the two species landed at fish markets of Shikoku, Kii Peninsula, Tokai District, and Kanto District, whereas I have neither seen *S. mokarran* nor heard of its capture in regions other than southwestern Japan. *S. zygaena* would be distributed farther north than *S. lewini*, having been reported from Hokkaido, the northernmost main island of Japan (Ueno, 1971).

It is interesting that only three species of *Sphyrna* among eight species and two subspecies found in the world (Gilbert, 1967) are distributed near Japan. These species are related to each other, constituting the subgenus *Sphyrna* together with *S. couardi* (Cadenat) found only in west Africa, whereas the other species, except *S. blochii* (Cuvier), are included in the subgenus *Platysqualus* (Gilbert, 1967). It is likely that the barrier discussed by Briggs (1961, 1964: 325) prevents species of *Platysqualus* from invading into the western Pacific because they inhabit coastal waters of north, middle, and south America.* If another species is found near Japan, it would probably be *S. blochii*, which is distributed in the Indo-Pacific region.

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本邦西南海域における 3 種のシュモクザメについて

谷内　透

3 種のシュモクザメが本邦西南海域に分布している，それらはヒラシュモクザメ，*Sphyrma mokarran* (Rüppell)，シロシュモクザメ，*S. zygaena* (Linnaeus)，アカシュモクザメ，*S. lewini* (Griffith and Smith) である．なお，上述の和名は本研究で改めて提唱するものである．また，3 種の同定のための検索表を作成した．3 種の浮延縄による漁獲データからみると，アカシュモクザメが最も数が多く，ついでシロシュモクザメで，ヒラシュモクザメが一番少なかった．釣獲率でみた密度分布によると，調査海域では 3 種ともほぼ分布が九州の南端，南西諸島，台湾を結ぶ線より浅い海域に限られているのがわかった．また，密度分布の季節変化からみて，3 種とも大規模な南北回遊をしている徴候が認められなかった．いろいろな証拠から，3 種の集団の主力はほぼ東支那海域に棲息しているものと推定された．

(113，東京都文京区，東京大学農学部水産学科)