NOTES ON REPRODUCTION IN THE SCALLOPED HAMMERHEAD, *SPHYRNA LEWINI*, IN NORTHEASTERN TAIWAN WATERS

The reproductive mode of hammerhead sharks (family Sphyrnidae) is placental viviparity, following Teshima's (1981) designations. Three species of hammerhead sharks are known from northeastern Taiwanese waters: *Sphyrna lewini* (Griffith and Smith), *S. mokarran* (Rüppel), and *S. zygaena* (Linnaeus). The scalloped hammerhead, *S. lewini*, commonly found from Pung-Chia Island to Guei-Shan Island (Fig. 1) is one of the most abundant shark species in this area. Based on data from the Nan Fan Ao Fish Market (located in northeastern Taiwan), 460–510 t year from 1982 through 1984 were landed, representing one-fourth of the total catches of sharks in this area (the total landing being 1,760–2,240 t year). Catches peaked in spring and winter and were lower in summer and autumn.

This species is also distributed in western and southern waters of Taiwan; however, the catch from those areas were smaller. The employees of the southern and western fish markets explained that the scalloped hammerhead is occasionally seen in small numbers in those areas, but there are no landing data. It is also common in coastal warm temperate and tropical seas throughout much of the world (Compagno 1984). Although

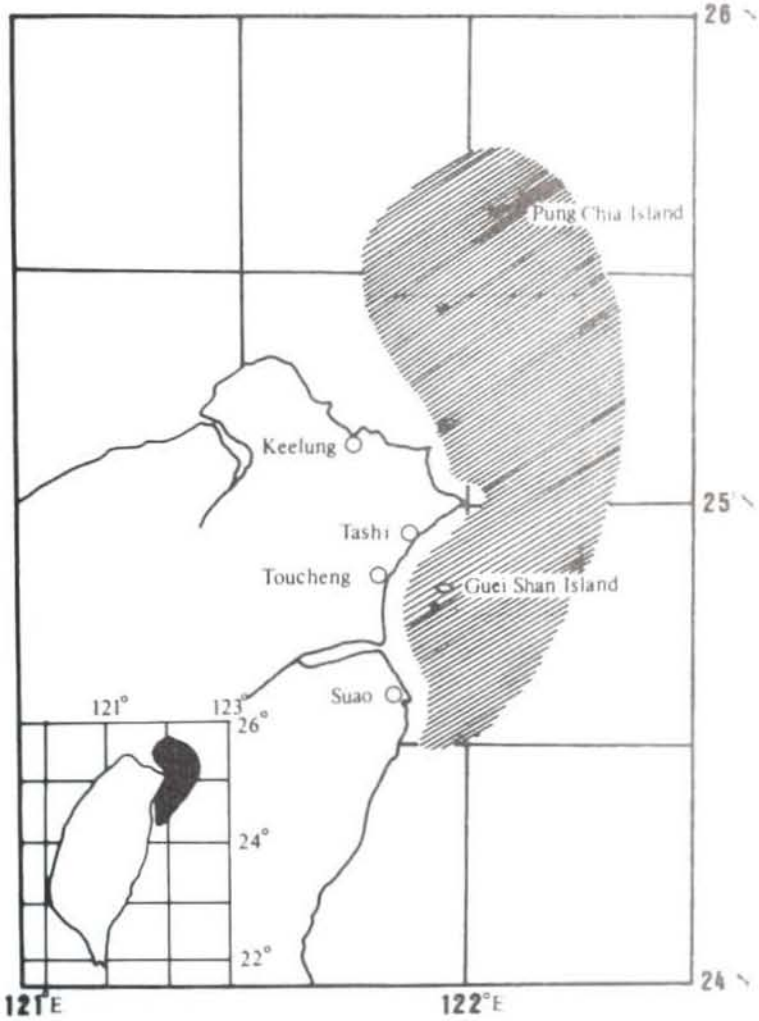

FIGURE 1.—Sampling area of *Sphyrna lewini*.

the scalloped hammerhead is one of the most valuable food resources in Taiwan, many facets of its life history, particularly reproduction, are not well known. This study provides information about certain aspects of reproduction in the scalloped hammerhead in northeastern Taiwan waters.

Materials and Methods

From September 1982 to June 1983 and from December 1983 to September 1985, shark specimens were examined and material collected monthly at Nan Fan Ao Fish Market. These sharks had been caught by drift longlines set near the surface to around 100 m, or by surface harpoon. A total of 674 scalloped hammerhead sharks were examined at the fish market (Table 1). Data recorded included total length measured from the tip of the snout to the tip of the upper lobe of the caudal fin (straight line measure), body weight, clasper length (measured from cloaca to the tip of claspers), ovarian egg diameter and number, and condition of the uteri. In addition, uterine embryos were counted, sexed, and measured for total length. Counts of litter size included any uterine eggs as well as embryos.

Stages of maturity for both females and males were categorized simply as "mature" or "immature". Females having threadlike uteri and tiny ovarian eggs were called immature, while those with eggs larger than 25 mm in diameter, with uteri containing embryos or eggs or with empty but expanded and flaccid uteri, were designated as mature. Males with rigid claspers were classified as being mature. Clasper length relative to total length also gave an indication of maturity.

TABLE 1.—The number of specimens examined in this study.

	Number of specimens			
	Immature		Mature	
Month	Male	Female	Male	Female
Jan.	13	11	18	93
Feb.	3	3	17	43
Mar.	4	13	4	44
Apr.	8	34	16	68
May	3	6	9	33
June	3	2	4	20
July	4	3	11	60
Aug.	3	1	6	19
Sept.	0	7	3	15
Oct.	0	1	1	3
Nov.	0	6	1	38
Dec.	1	8	1	10
Total	42	95	91	446

Results

The reproductive organs of scalloped hammerhead closely resemble those of the bonnethead shark, *S. tiburo* (described by Schlernitzauer and Gilbert 1966).

As with the bonnethead shark, only the right ovary of the scalloped hammerhead is functional, supplying both oviducts. As the ovarian eggs mature (>25 mm diameter), they pass through the common ostium into the oviducts, where they are fertilized. The eggs then become encased in the embryonic membrane as they pass through the nidamental gland and descend into the uterus. In the uterus, embryonic development proceeds, nourished by a yolk sac. After a period, the uterine compartments develop, which enclose the embryo, and a yolk-sac placenta is implanted. After the yolk is exhausted, the embryo is nourished until birth by the placenta through the umbilical stalk.

Based on the condition of the uterus and ovary, female scalloped hammerheads became mature at a larger size, around 210 cm, than males. All females over 230 cm were mature.

Based on the rigidity of the claspers, male scalloped hammerheads reached their first maturity at a total length of 198 cm, while all those over 210 cm were mature.

The clasper length of males increases rapidly relative to total length, until the sharks reach around 200 cm, at which size the clasper length/total length relationship plateaus, suggesting that sexual maturity has been attained (Fig. 2). Also, this size marked the approximate transition point from flaccid to rigid claspers (Fig. 2).

It takes roughly 10 months of development from egg formation to ovulation (Fig. 3). In October and November, eggs were very small, measuring about 2 mm in diameter. By July they had increased in size to about 30–38 mm and numbered 40–50 per female, and by August and September they had grown to about 40–45 mm. In one mature female, in September we counted 28 uterine eggs and 4 ovarian ones measuring 45 mm in diameter. This suggested that the 4 ovarian eggs were ready for ovulation. Because ovarian eggs larger than 30 mm in diameter seemed near ovulation, we concluded that ovulation occurred between July and October.

The parturition season lasts from May to July, and the gestation period of this species was estimated to be roughly 10 months (Fig. 4). No em-

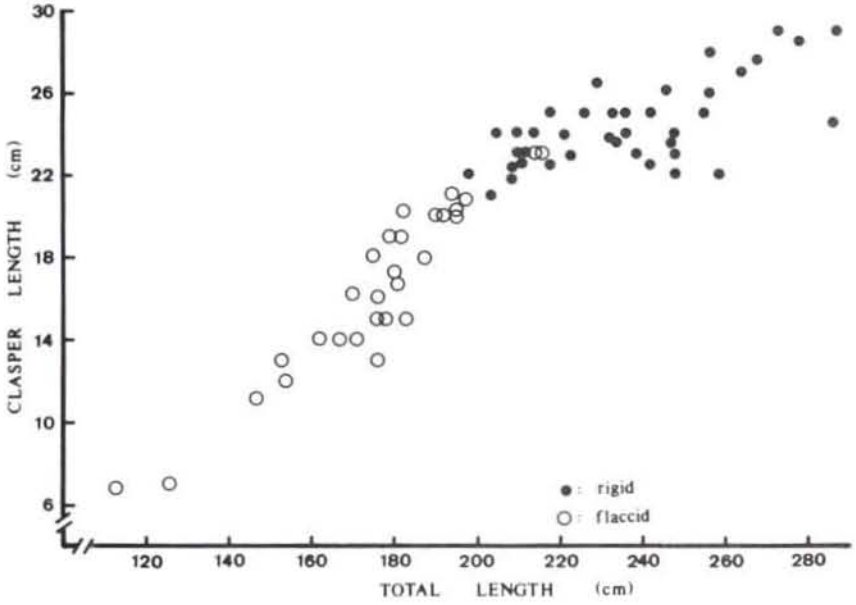

FIGURE 2.—Relationship between total length and clasper length in *Sphyrna lewini*.

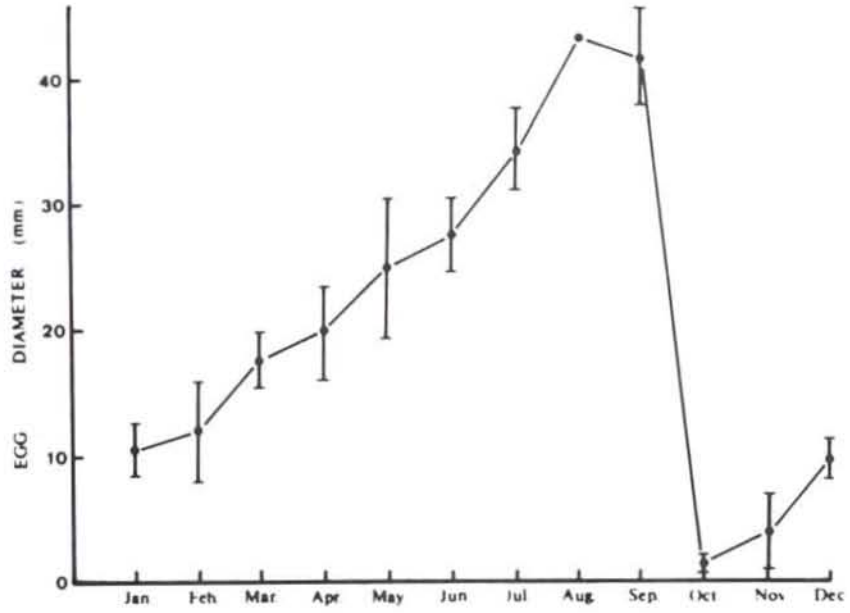

FIGURE 3.—Monthly increase in the ovarian egg diameter of *Sphyrna lewini*. Error bars represent 2 SD; numerals, sample size.

bryos were found in July and August, though some mature sharks had large ovarian eggs measuring about 30–40 mm in diameter during those months. The first uterine eggs, and embryos measuring around 2 cm were found in September. Uterine eggs were observed until November. After nine more months of rapid growth, the embryos attained a total length of around 45 cm in the period between May and June. These embryos were regarded as full term because they were easily separated from placenta implying that parturition would occur soon.

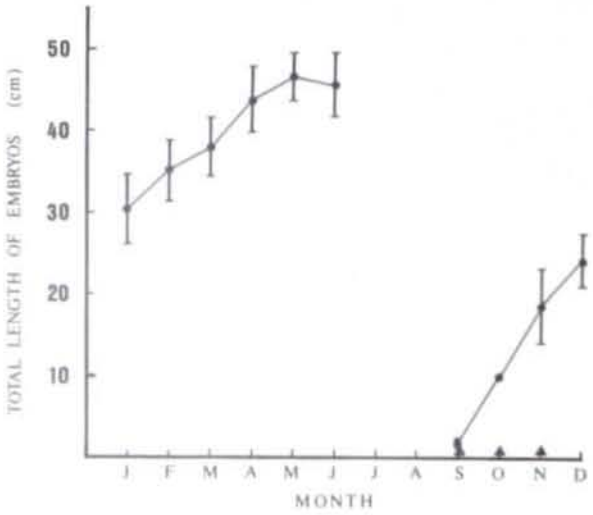

FIGURE 4.—Monthly growth of embryos of *Sphyrna lewini*. Solid triangles indicate the uterine eggs. Error represent 2 SD; numerals, sample size.

Counts of the number of uterine embryos as well as eggs of 110 gravid females (230–320 cm TL) ranged between 12 and 38 (mean 25.8). The relationship between the total number of uterine embryos or eggs and the size can be described by the regression equations (Fig. 5):

$$N = -26.105 + 0.179L,$$

where N is litter size, and L is total length in cm of the female. There is considerable variation in number of embryos with length, and the correlation coefficient r is low (0.567), but obviously fecundity is related to the size of the parent.

Examination of all females carrying developing embryos showed that occasionally some uterine eggs failed to develop. The number of nondeveloping uterine eggs carried by a single female was 1–4.

As with litter size, the number of ovarian eggs increased with the length of the adult female.

The embryos from 51 gravid females were sexed; of a total of 1,281 embryos, 637 were females. The sex ratios of embryos differed by litter; for instance, some individuals had predominantly male (13:5) or predominantly female (23:10) litters. But, as a whole, sex ratio was about 1:1.

The ratio of males to females for immature sharks in northeastern Taiwan waters was about 1:2 (42:91), but decreased to about 1:5 (95:446) for mature individuals (Table 1). There was no apparent increase in the relative number of males in the catch during the parturition season.

Discussion

Scalloped hammerhead sharks are abundant in the coastal seas around northeastern Taiwan, especially during the spring and winter, and are captured by harpoon or drift longlines at or near the surface. Rarely individuals smaller than 120 cm TL are captured because fishing gear and strategy are likely selective for larger fish. Clarke (1971) reported that in Hawaii, scalloped hammerhead pups usually stay close to the bottom.

Approximately equal numbers of male and female scalloped hammerhead sharks are born, although a much higher proportion of females than males are caught in the studied area. We are uncertain whether scalloped hammerhead females are more vulnerable to the fishing gear or are simply more numerous in this area. Similar predominances in females in the catch have been found in the scalloped hammerhead in the Gulf of California (Klimley 1981; Klimley and Nelson 1981). During the summer in 1979 off Baja California, females outnumbered males by 1.6× at Isla Cerrolvo, 3.8× at the El Bajo Seamount, and

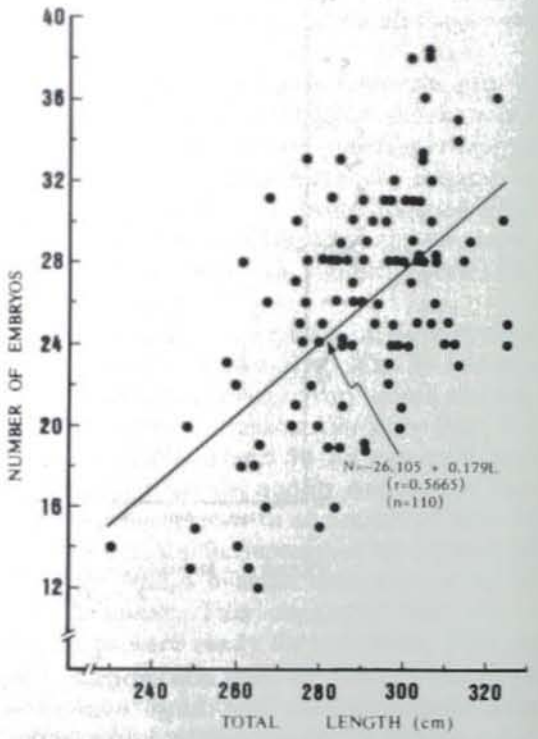

FIGURE 5.—Relationship between fecundity (number of uterine eggs or embryos) and total length of *Sphyrna lewini females*.

3.1× farther north at Isla Las Animas (Klimley 1981; Klimley and Nelson 1981). Similar disparities in sex ratios were also observed in sandbar sharks by Springer (1960). He felt that adult male sandbar sharks live over a large geographical and depth range, perhaps in deep cool oceanic waters inaccessible to the fishermen's gear, while females occur in warmer inshore water where they are more accessible to fishermen. He suggested that the males move inshore only to mate. We had insufficient data to test this suggestion in our sample area.

Castro (1983) reported that *S. lewini* from North American waters probably mature at about 180 cm; he did not mention whether this length referred to male, female, or both. Bass et al. (1975) reported that male scalloped hammerhead at Mozambique matured between 140 and 165 cm, reaching a maximum length of at least 295 cm; females matured at about 212 cm, reaching at least 309 cm. Compagno (1984) reported "maximum" sizes ranging from 370 to 420 cm. Our largest males were 305 cm TL, and the smallest mature male was 198 cm TL. The largest female observed was 324 cm, and the smallest mature female was 210 cm. It seems that in our sample area, males reached maturity at a somewhat larger size than in the other studied areas while females were about the same.

The close relationship of growth pattern of uterine embryos and ovarian eggs implies that eggs are transferred into the uterus and fertilized immediately after parturition. If the estimate of 10 month gestation period is correct, adult females give birth once each year.

The length at birth of scalloped hammerheads has been reported to be around 50 cm from Natal and southern Mozambique coastal waters (Bass et al. 1975), 43 cm from northeastern United States to Chesapeake Bay waters (Casey 1964), 38–45 cm in North American waters (Castro 1983), and 42–55 cm combined from all oceans (Compagno 1984). Our largest uterine embryos measured about 47 cm TL.

Pupping season appears to be during the summer in Taiwan as well as in Mozambique (Bass et al. 1975) and North America (Castro 1983). In Hawaii, Clarke (1971) found newborn pups throughout the year but with increased numbers in summer.

Acknowledgments

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