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**Observation on reproduction biology of blue shark (*Prionace glauca*) in the Indian Ocean**

Jiangfeng Zhu, Xiaojie Dai

*College of Marine Sciences, Shanghai Ocean University;*

*Key Laboratory of Sustainable Exploitation of Oceanic Fisheries Resources, Ministry of Education, Shanghai Ocean University, 999 Hucheng Huan Road, Shanghai 201306, China*

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## Ocean

### Abstract

In recent years, China has successfully conducted scientific observer program for tuna longline fishery in the Indian Ocean. This working paper reported reproductive information of blue shark (*Prionace glauca*) based on specimens sampled during an observer trip in the tropical water of western Indian Ocean. Size distributions of juvenile, maturing, ovulating, and gravid females, and immature and mature males were estimated. Proportion of specimens in different maturation stages by month was also investigated.

### 1. Introduction

Blue sharks are viviparous and their reproductive biology has been well studied in the Atlantic Ocean (e.g., Pratt 1979; Hazin et al. 1994; Henderson et al. 2001) and Pacific Ocean (e.g., Nakano 1994; Francis and Duffy 2005; Zhu et al. 2011). Litter size of blue shark has also been reported in the Indian Ocean (Gubanov and Grigor'yev 1975). Length- and age-at-50% maturity and pregnant information were recently reported for blue sharks captured from South African waters, the areas near south Indian Ocean (Jolly et al. 2013). However, the reproductive information of blue sharks within the Indian Ocean is still few.

In recent years, China has successfully conducted scientific observer programs among its tuna longline fleets in the Atlantic, Pacific, and Indian Oceans. Biological observation (and sampling) is one of the key tasks for onboard observer, which helps estimate population parameters for species associated with the pelagic tuna fisheries, including tunas, sharks, and other bycatch species. The objective of this working paper is to report some reproductive characteristics of Indian Ocean blue shark based on a Chinese tuna longline observer trip in 2012.

### 2. Material and methods

#### 2.1 Specimen collection

All blue shark specimens analyzed in this study were collected in a tuna longline observer trip for the year 2012 in the tropical Indian Ocean (Figure 1). The sampling time of the trip was between October 2012 and January 2013. Because blue sharks are valuable and retained for commercial purpose, they are processed by fishermen soon after landed on deck. Biological information of blue sharks landed on deck was then measured by observer, including sex, length, weight, etc.

#### 2.2 Observation of maturation

Blue shark specimens were dissected for macroscopic inspection of reproductive organics. Inferences on stages of maturation were made according to definitions

provided in previous studies (e.g. Springer 1960, Pratt 1979, Branstetter 1981). Depending on the development of the oviducal gland, uteri, maximum ovarian follicle diameter and ovary, female blue sharks were separated into 4 stages (Hazin et al. 2001): Juvenile, Maturing, Ovulating, and Gravid. Juveniles were defined as those with undeveloped sexual organs, filiform uteri, and no vitellogenic activity in their ovaries. Maturing females had enlarged oviducal glands and showed evidence of vitellogenesis. Ovulating females had uterine eggs and mature oocytes in their ovaries. Gravid specimens had pups or embryos observed in the uteri. For male blue sharks, only two stages were considered: immature and mature. The males were considered mature when claspers were calcified and rotated freely forward (Lucifora et al. 2005).

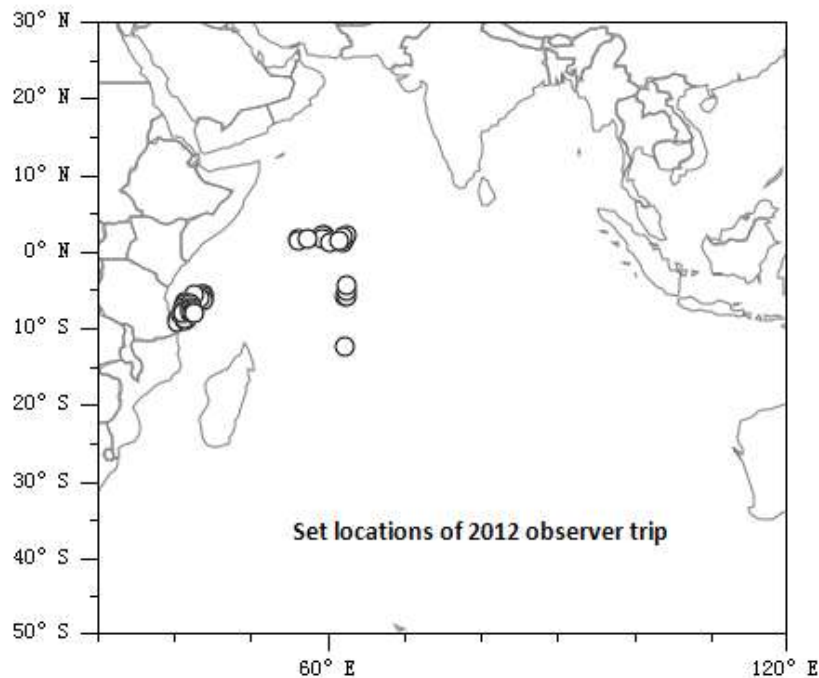


Fig. 1 Set locations at which the blue shark specimens were collected by longline observer

Table 1 Number of specimens and sampling days by month during the observer trip

Month	Number of specimens		Number of sampling days	
	female	male	female	male
October	2	0	2	0
November	5	9	4	8
December	24	12	16	10
January	28	9	12	7
Total	59	30	34	25

### 3 Results and discussion

#### 3.1 Size distribution of sample

A total of 89 blue sharks were sampled in the observer trip, including 59 female and 30 male sharks (Table 1). Most were sampled in December and January. The size range of females was between 165 cm and 280 cm (fork length, FL) (mean=224 cm, S.D. =32 cm), and the size range of males was between 150 cm and 280 cm FL (mean=226 cm, S.D. =34 cm) (Fig. 2). There was no significant difference in fork length distributions between females and males (Two-sample Kolmogorov-Smirnov test,  $P=0.8261$ ).

#### 3.1 Reproductive characteristics

No juvenile female was observed among the sampled sharks. The number of female specimen with maturation stage of Maturing, Ovulating, and Gravid was 21, 26, and 12, respectively. The sizes distributions of females belong to the three stages were shown in Table 2 and Fig. 3. Among the 30 male specimens, only one immature shark was observed (150 cm FL). Sample size was too small to estimate length-at-50% maturity using logistic model.

The maximum diameter of oocyte in ovary was between 5 and 30 mm (mean=17 mm,  $n=16$ ) for maturing female, and between 19 and 28 mm (mean=24 mm,  $n=11$ ) for ovulating female. For gravid females, the number of embryos in uteri varied in the range of 14-48 (mean=34, S.D. =11).

For males, relationship between inner clasper length (ICL) of male and fork length was investigated (Fig. 4). The ICL ranged 13-25 cm (mean=20 cm, S.D. =2.9). The only immature male had ICL of 14 cm (150 cm FL). Except for two specimens (ICL=13, 14 cm), ICLs of all other mature specimens were longer than 14 cm (Fig. 4). Size at maturity was not estimated because mature males dominated the sampled size classes.

To understand the seasonal pattern of reproductive activities, proportion of blue shark specimens in different maturation stages was estimated for each sampling month, and the result was shown in Fig. 5. All the female specimens sampled in October and November were in ovulating, however, the sample sizes in these two months were very small (see Table 1).

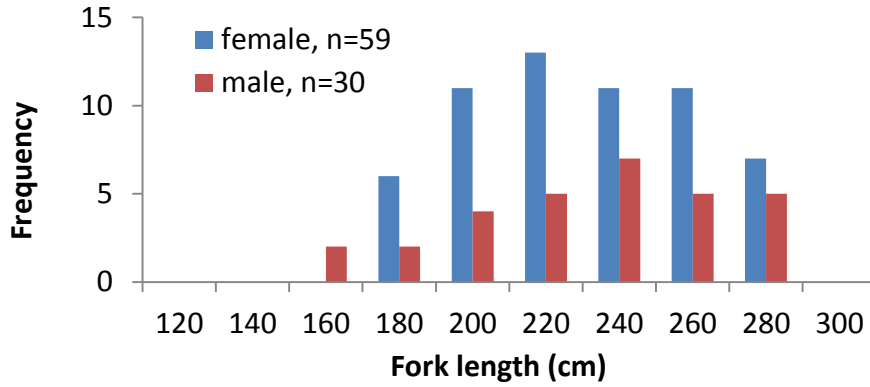
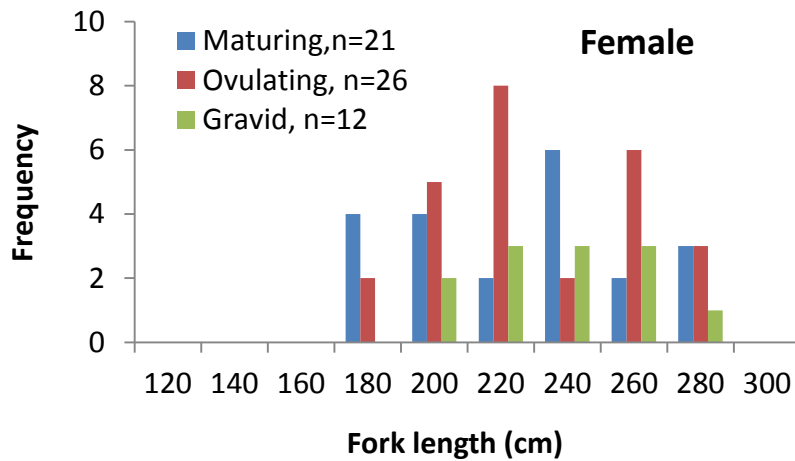


Fig. 2 Size distribution for blue sharks sampled in the observer trip

Table 2 Sizes for blue sharks (fork length, cm) in different maturation stages

	Female		Male
	Maturing	Ovulating	Mature
Max.	280	275	280
Min.	165	173	160
Mean	221	224	229
S.D.	37.4	30.1	31.2
n	21	26	29



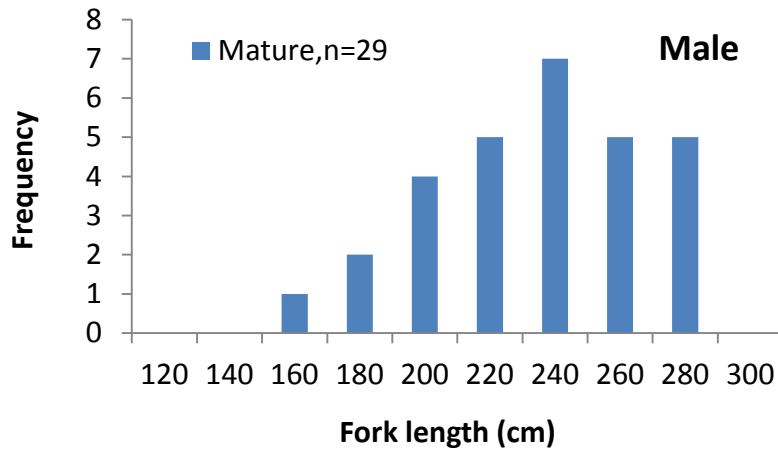


Fig. 3 Size distributions of female and male blue sharks in different maturation stages

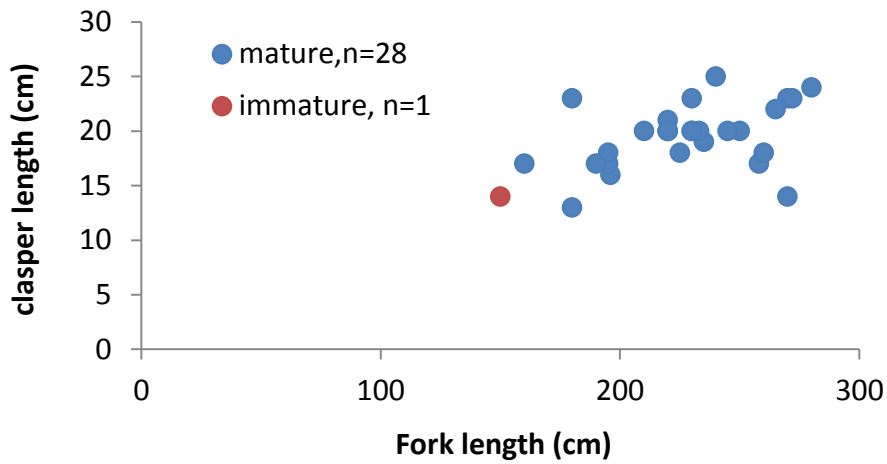
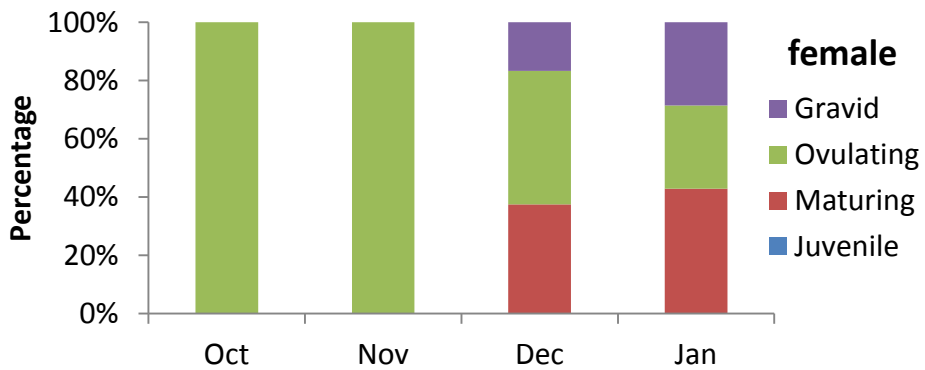


Fig. 4 Relationship between clasper length and fork length for male blue shark specimens



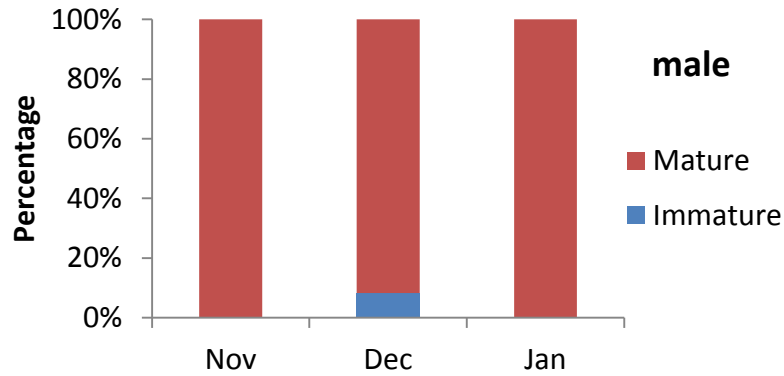


Fig.5 Proportion of blue shark specimens in different maturation stages by month

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