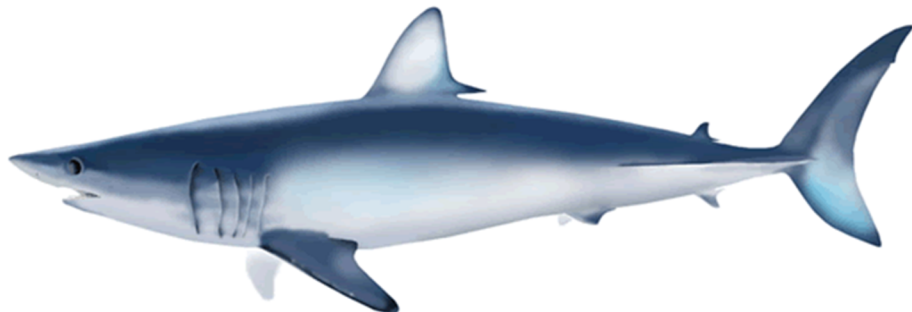# The relation between weight and length of the shortfin mako shark in the North Pacific Ocean

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Abstract

The whole weight (W) and precaudal length (PCL) relationships of the shortfin mako shark, *Isurus oxyrinchus*, in the North Pacific was estimated based on the data provided by Japan, US, and Taiwan. The majority of Japanese and US length data ranged from 60 cm to 200 cm PCL with weight ranging from 1.36 to 162 kg. While Taiwanese data covered wider ranging from 60 cm to 313 cm PCL with weight ranging from 3 to 441 kg. The maximum likelihood ratio test indicated that sex-specific W-PCL relationships are significantly different for combined data. Thus, the W-PCL was estimated as: $W = 4.62 \times 10^{-5} PCL^{2.77}$ for males (n = 1147, $p < 0.05$) and $W = 3.4 \times 10^{-5} PCL^{2.84}$ for females (n = 1561, $p < 0.05$).

Introduction

Many marine species exhibit considerable sexual dimorphism. Growth and mature patterns in marine fishes are often sex-specific (Sun *et al*., 2002, 2009; Wang *et al*., 2003; Portnoy *et al*., 2007; Semba *et al*., 2009, 2011; Tsai *et al*., 2011). The shortfin mako sharks, *Isurus oxyrinchus*, are sexually dimorphic in size, growth and size at maturity (Joung and Hsu, 2005). Tsai *et al*. (2011) further concluded that biological reference points of shortfin mako in the northwest Pacific Ocean are especially sensitive to changes in weight-length relationship and the growth equation. Thus, the lacking of information on the sex-specific relationships between weight and length may hinder the accuracy of stock assessment and management of this stock. In the last Age and Growth of Shortfin Mako Shark Workshop, Shark Working Group decided to estimate the weight-length relationship using the combined data from each country. Thus, this paper represents the estimation of the whole weight (W) and precaudal length (PCL) relationships of the shortfin mako shark in the North Pacific based on the data provided by Japan, US, and Taiwan.

Materials and Methods

US data were derived from fishery independent methods, while as Japanese data were obtained through loneline fishing vessels. Convert equations used are: $PCL = 0.816TL + 0.784$ and $PCL = 0.894FL + 1.139$ for US individuals; $PCL = 0.84TL - 2.13$ and $PCL = 0.91FL - 0.95$ (Semba *et al.*, 2009) for Japanese data.

Taiwanese length and weight data were collected from 1995 to 2016 at the Nanfangao fish market in northeastern Taiwan. These sharks were caught primarily by small-scale longline fishing vessels (< 50 tonnages), which operate on a 7-14 days per trip and some were caught by larger fishing vessels (50-100 tonnages) operating on more than 30 days per trip (Liu *et al*.,

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2001). All sharks were weighed before being auctioned and processed, enabling us to obtain accurate catch statistics (numbers) and individual body (whole) weights (W, in kg) from sales records. Measurements on total length (TL, in cm), fork length (FL), and pre-caudal length (PCL) were taken on the specimens opportunistically sampled and the sex of each specimen was identified. For those specimens that PCL is not available, the PCL was estimated using the following converting equations (Joung and Hsu, 2005): $PCL = 0.784 + 0.816TL$ (n = 1240, $r^2 = 0.986$) and $FL = 0.952 + 0.890TL$ (n = 1236, $r^2 = 0.986$).

The relationship between W and PCL for the combined data (including Japan, US, and Taiwan) was expressed using an allometric model: $W = \alpha \times PCL^{\beta}$, where α, β are parameters to be estimated. A maximum likelihood ratio test (Kimura 1980) was used to examine the difference on W-PCL relations between sexes.

Results and Discussion

In total, 281 (130 female and 151 male) specimens from the eastern Pacific were provided by US. The PCL ranged from 58.4 cm to 197.8 cm with weight ranging from 1.36 to 121 kg (Fig. 1). The data provided by Japan include 70 females and 53 males, ranging from 57.2 – 227 cm PCL and 1.74-162 kg (Fig. 2). Taiwanese data include 2304 specimens (1361 females and 943 males). The PCL of females ranged from 66 cm to 313 cm, and males ranged from 58 – 247 cm. The weight range of female and male are 3.5 – 441 kg and 3 – 226 kg respectively (Fig. 3). The combined data include 2708 specimens (1561 females and 1147 males) with PCL range from 57.2 to 313 cm and weight 1.36 – 441 kg (Fig. 4). These data showed that the shortfin mako shark larger than 250 cm PCL are females.

The maximum likelihood ratio test indicated that sex-specific W-PCL relationships are significantly different for combined data. Thus, the W-PCL was estimated as: $\alpha \pm SE = 3.4 \times 10^{-5} \pm 2.91 \times 10^{-6}$, $\beta \pm SE = 2.8467 \pm 0.0158$ for females (95% CI of α: $2.8 – 4.0 \times 10^{-5}$, and 2.82 – 2.88 for β; n = 1561, p < 0.05) (Fig. 5), $\alpha \pm SE = 4.7 \times 10^{-5} \pm 5.57 \times 10^{-6}$, $\beta \pm SE = 2.7741 \pm 0.0227$ for males (95% CI of α: $3.6 – 5.8 \times 10^{-5}$, and 2.73 – 2.82 for β; n = 1147, p < 0.05) (Fig. 6). The β of females is larger than that of males suggesting that the female is heavier than male for the same length. Additional ANOVA tables is given in Appendix 1.

The PCL used in this study cover wide size range (57.2 to 313 cm) and the sample size is large (n = 2708) suggest that the W-PCL relation derived in this study is robust and representive.In conclusion, the allometric equations derived from this study can properly describe the W-PCL relation for the shortfin mako sharks in the North Pacific.

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[1]Working document submitted to the ISC Shark Working Group Workshop, 28 November -4 December 2017, Shimizu, Shizuoka, Japan
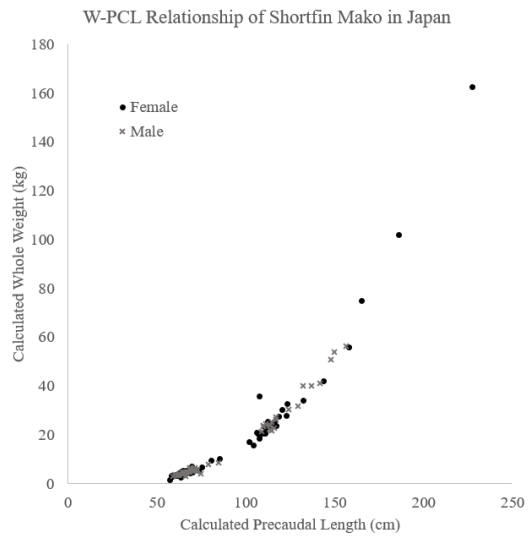
Fig. 1. The relationship between whole weight and precaudal length of shortfin mako shark from Japan (n = 123).
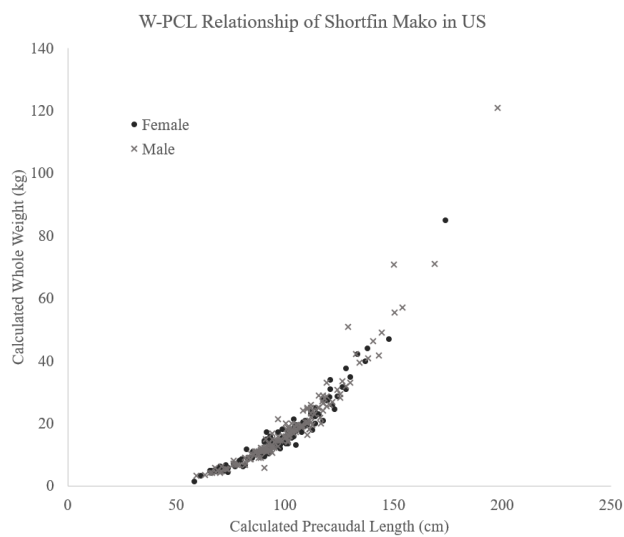

Fig. 2. The relationship between whole weight and precaudal length of shortfin mako shark from US (n = 281).
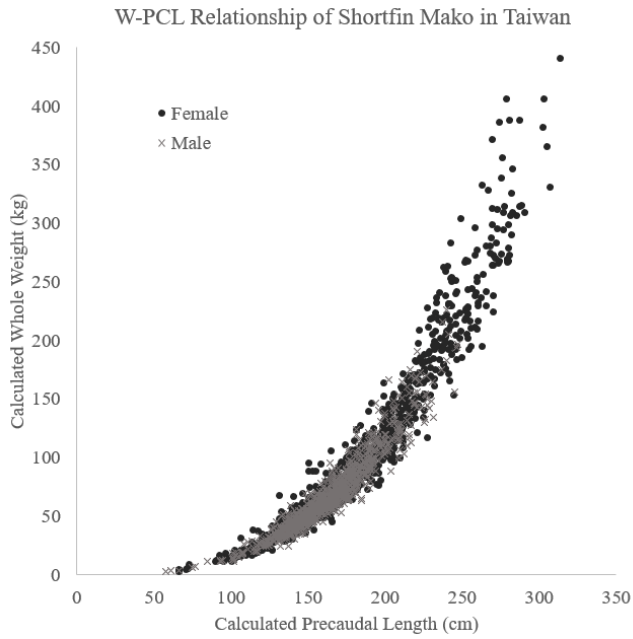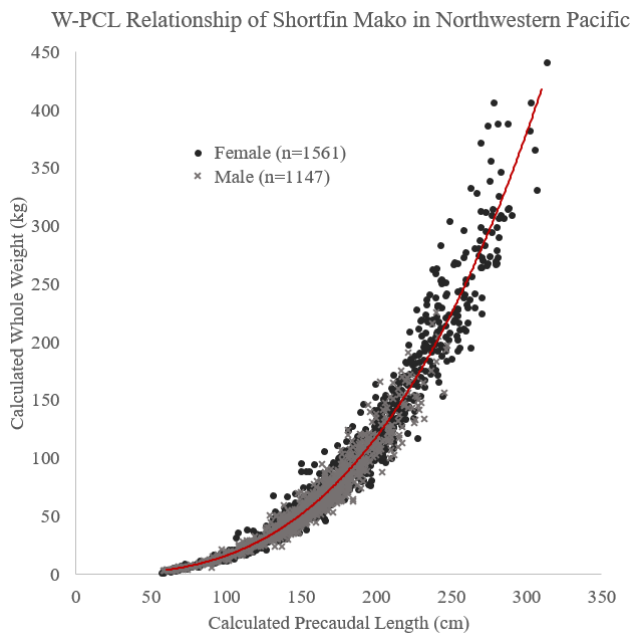
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Fig. 3. The relationship between whole weight and precaudal length of shortfin mako shark from Taiwan (n = 2304).

Fig. 4. The relationship between whole weight and precaudal length of shortfin mako shark (sexes combined) in the North Pacific (n = 2708).

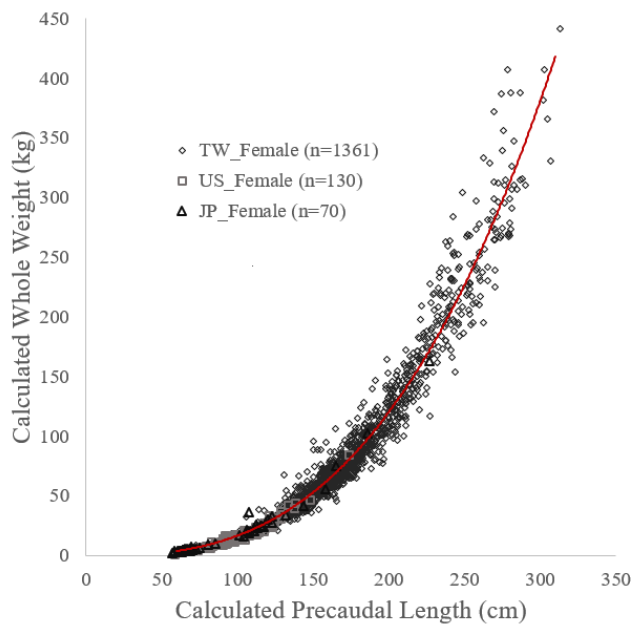**W-PCL Relationship of Female Shortfin Mako in Northwestern Pacific**

Fig. 5. The relationship between whole weight and precaudal length of female shortfin mako shark in the North Pacific (n = 1561).

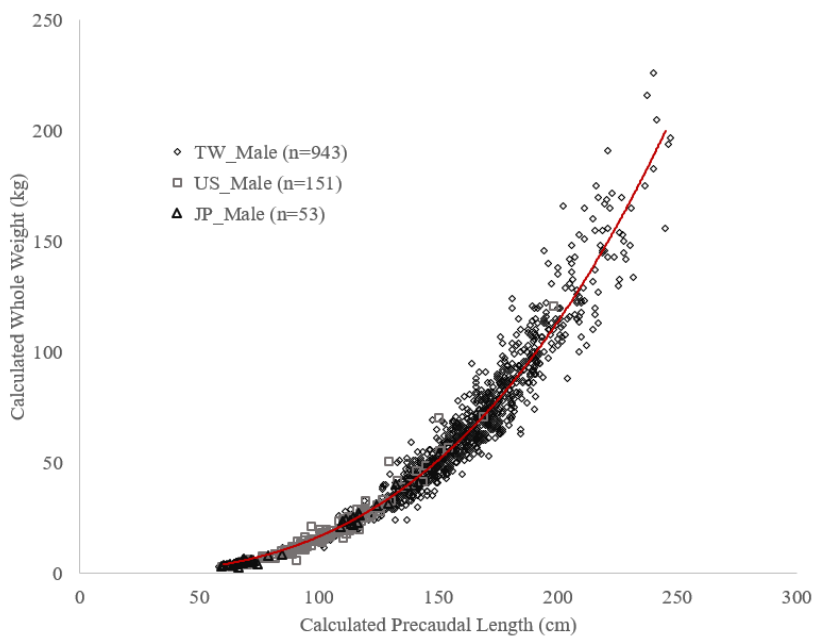**W-PCL Relationship of Male Shortfin Mako in Northwestern Pacific**

Fig. 6. The relationship between whole weight and precaudal length of male shortfin mako shark in the North Pacific (n = 1447).

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Appendix

Appendix 1(a). ANOVA table of female shortfin mako sharks.

Source	df	SS	MS	F	Prob > F
Model	2	18360443	9180222	46483.0	<.0001
Residual Error	1559	307897	197.5		
Total	1561	18668340			

Appendix 1(b). ANOVA table of male shortfin mako sharks.

Source	df	SS	MS	F	Prob > F
Model	2	5555892	2777946	37426.3	<.0001
Residual Error	1145	84987.0	74.2245		
Total	1147	5640879			