

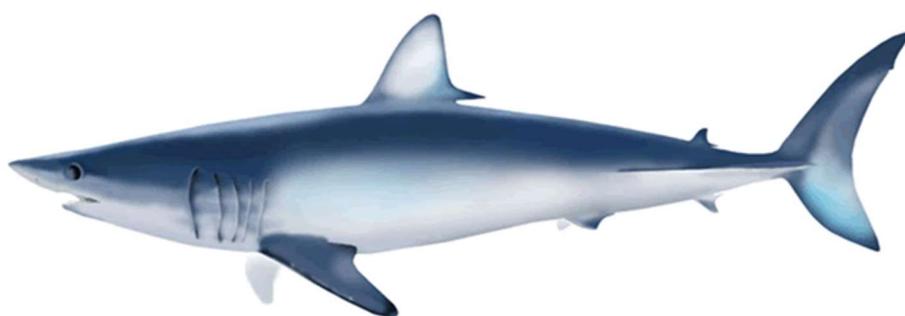
Revised integrated analysis of maturity size of shortfin mako (*Isurus oxyrinchus*) in the North Pacific.

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Abstract

In this document, we estimated the length at 50% maturity of male and female shortfin mako in the North Pacific, based on the integrated data of maturity from Japan and Taiwan. The maturity ogive was fitted to PCL using a logistical model for 622 males and 1,100 females. The estimated 50% maturity size was 166 cm PCL for males and 233 cm PCL for females. Given that there may be sampling bias due to ontogenetic spatial segregation and sampling strategy in each study, estimates based on integrated data from two studies would be best for the stock assessment of this population.

Introduction

For the stock assessment of shortfin mako (*Isurus oxyrinchus*) in the North Pacific, sex-specific maturity size is necessary to estimate the maturity age of each sex, and furthermore, the productivity of this population. In the North Pacific, several estimates are available from western, central and eastern area. In the northeastern Pacific, Coonde-Moreno and Galbán-Magaña (2006) estimated male maturity size as 180 cm Total Length (indicated as TL, hereafter) based on specimen collected from the south-west coast of Baja California, but they did not estimate female maturity size, mainly due to lack of adult specimen. Joung and Hsu (2005) estimated male and female maturity size as 210 cm TL and 278 cm TL, respectively based on sharks collected in the water off northeastern Taiwan. Semba *et al.* (2011) estimated 50% maturity size for males as 156 cm Precaudal length (indicated as PCL, hereafter) and for females as 256 cm PCL. When estimates by Joung and Hsu (2005) were converted into PCL using conversion equation indicated in the paper, males and females mature at 172 cm PCL and 228 cm PCL, respectively. When Mexican estimate was converted into PCL in same way, male maturity size was estimated as 148 cm PCL.

In comparison under the common body length criteria of PCL, Taiwanese male maturity size is 16 cm larger than Japanese estimate, while Japanese female maturity size is 28 cm larger than Taiwanese estimate. Male maturity size in Mexican water was close to Japanese estimate and thus the difference in estimates between Japanese and Taiwanese study was focused on the discussion on the biological parameter for the stock assessment (ISC 2017). Given that it is unlikely that the sharks in each sampling area are genetically differentiated (at least between Japanese and Taiwanese sampling area) and that the criteria of maturity in each study was similar, synthesis of Japanese and Taiwanese data and re-estimation of 50 % maturity size were requested in the Aging Workshop convened by ISC Shark working group in October 2017 (ISC 2017).

Materials and methods

Data

Individual-based body size and maturity status (0 for immature and 1 for mature) were provided for the analysis. Japanese data from Semba *et al.* (2011) consisted of 123 males (61.6 to 204.9 cm PCL, mean: 145.1 cm PCL, SD: 39.74) and 353 females (66 to 310 cm PCL, mean: 175 cm PCL, SD: 45.42). Taiwanese data consisted of 499 males (65.0 to 225.0 cm PCL, mean: 148.3 cm PCL, SD: 25.03) and 747 females (65.0 to 305.0 cm PCL, mean: 165.3 cm PCL, SD: 45.03).

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Analysis

To estimate the length at 50% maturity for each sex, the maturity ogive was fitted to PCL (at 10 cm intervals) using a logistical model for each sex: $Y = [1 + \exp\{-(a+bX)\}]^{-1}$, where Y is the fraction of mature individuals at, X is PCL (cm), and a and b are parameters. To estimate the parameters, we used a generalised linear model with a binomial distribution. With regard to the link function, logit and complementary log–log transformations were applied to the calculation for both sexes, and then one or the other of two link functions was selected based on the AIC for each sex. The 95% confidence interval (CI) was calculated assuming that the estimate followed a lognormal distribution after the protocol used in Semba *et al.* (2011). Statistical analyses were conducted using the R statistical software (R 3.4.1: R Core Team 2017).

Result

In both datasets, body size of specimen covered from neonate to adult in each sex (Table 1). For males, many neonates was observed in Japanese dataset, in which appeared as one clear mode between 60 and 70 cm, while length distribution in Taiwanese dataset was close to normal distribution (Figure 1). For females, both mean and median in Japanese dataset was larger than those in Taiwanese dataset (Figure 2, Table 1).

For both sexes, logit was selected as link function in the GLM rather than complementary log-log transformation (Table 2).

For males, estimated maturity ogive was between ogives estimated based on Japanese and Taiwanese dataset, but much closer to ogive based on Taiwanese dataset (Figure 3). The estimated 50% size at maturity and its confidence interval (indicated as CI hereafter) was 166 cm PCL (CI:165-169).

For females, estimated maturity ogive was between ogives estimated based on Japanese and Taiwanese dataset, but much closer to ogive based on Taiwanese dataset as observed in males (Figure 3). The estimated 50% size at maturity and its CI was 233 cm PCL (CI:231-238).

Detailed parameter and statistical value were shown in Appendix 1-2.

Discussion

This document provided 50% size at maturity based on combined dataset from two study in the northwestern and central Pacific. In both sexes, sample size in Taiwanese dataset was much larger than that in Japanese dataset. This may partly explain the reason why estimated maturity ogives were much closer to estimates based on Taiwanese dataset rather than Japanese dataset in both sexes.

Semba *et al.* (2011) suggested the model structure (such as link function), maturity criteria and low sample size in particular size class (such as adults) may cause the difference in the maturity size among studies and that further study is necessary to determine if this difference is a result of true differences between populations, or other reason including size-specific distributional patterns and artificial factor (e.g., difference of maturity criteria, sampling bias and so on). The collaborative work enabled to further discuss this issue by comparison of the size frequency of each dataset with common criteria and modelling approach.

For males, there is clear mode in neonates in Japanese dataset which does not appear in the Taiwanese dataset.

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Biased size distribution may be caused by the sampling strategy and location in Japanese study in which sampling was mainly conducted in nursery area of this population and thus the ratio of neonates was suggested to be high. This might affect the estimation of maturity ogive and provided smaller 50% maturity size compared to Joung and Hsu (2005).

For females, frequency of juveniles in Japanese dataset was higher than Taiwanese dataset in some size class, but not so prominent as in case of males. Mean and mode of female size in Japanese dataset was larger than that in Taiwanese dataset. In Japanese research, collection of large female sample was developed in wide area via Research and Training Vessel and commercial longline vessel and thus the ratio of juveniles might be lower than males.

In conclusion, given the ontogenetic distribution pattern of this population, effect of sampling strategy in each study, analysis based on integrated data from Japan and Taiwan would provide reliable estimates for the maturity size and contribute to the reliable stock assessment of this population.

References

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Table 1. Key statistics on the size data used in the analysis by sex and data source.

Male								
Source	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	SD	N
Japan	61.6	129.2	156.9	145.1	171.2	204.9	39.7	123
Taiwan	65	135	145	148.3	165	225	25.0	499

Female								
Source	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	SD	N
Japan	66	145	175	175	200	310	45.4	353
Taiwan	65	125	155	165.3	185	305	45.0	747

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Table 2. AIC derived for the logistic model with different link function in the GLM analysis for male and female.

Male		
Link function	df	AIC
Logit	2	307.7464
Complementary		
log-log transformations	2	314.1076
Female		
Link function	df	AIC
Logit	2	119.3823
Complementary		
log-log transformations	2	129.1995

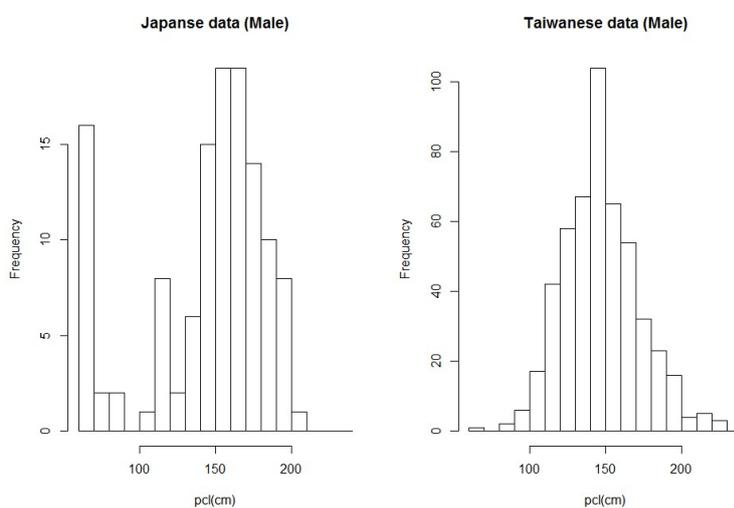


Figure 1. Size frequency of male shortfin mako used in the analysis by data sources.

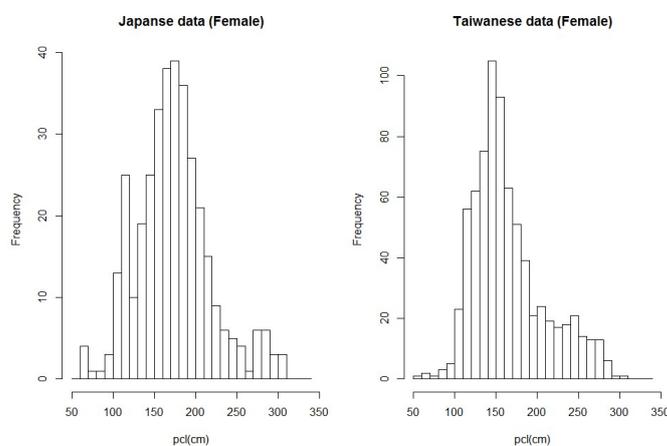


Figure 2. Size frequency of female shortfin mako used in the analysis by data sources.

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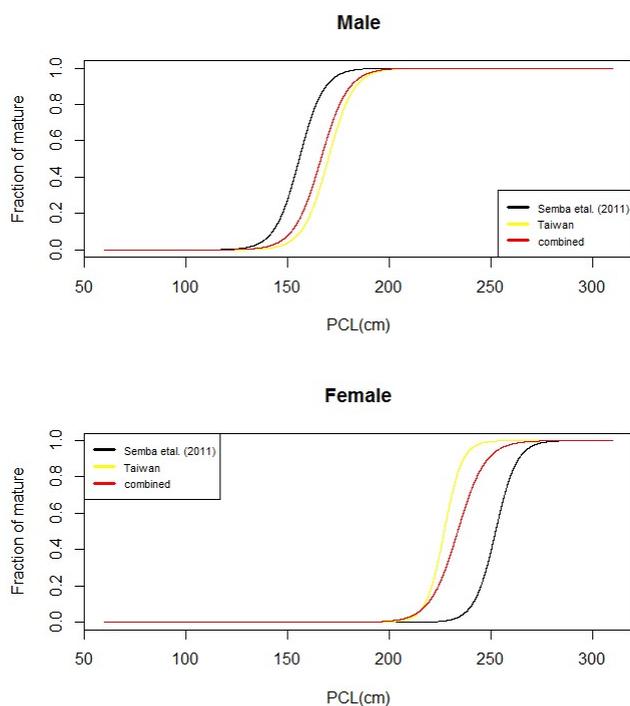


Figure 3. Maturity ogive estimated for males (top) and females (below) estimated based on the integrated data (red), Japanese data (black) and Taiwanese data (yellow).

Appendix 1. Summary on the results of GLM analysis for males.

#Call:

```
#glm(formula = maturity ~ pcl, family = binomial)
```

#Deviance Residuals:

#	Min	1Q	Median	3Q	Max
#	-2.21159	-0.34755	-0.09125	0.02473	2.39032

#Coefficients:

#		Estimate	Std. Error	z value	Pr(> z)
#(Intercept)		-25.06499	2.23833	-11.20	<2e-16 ***
#pcl		0.01373	10.98	<2e-16	***

#---

#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#(Dispersion parameter for binomial family taken to be 1)

Null deviance: 707.13 on 621 degrees of freedom

#Residual deviance: 294.53 on 620 degrees of freedom

#AIC: 298.53

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#Number of Fisher Scoring iterations: 7

Appendix 2. Summary on the results of GLM analysis for females.

#Call:

#glm(formula = maturity ~ pcl, family = binomial)

#Deviance Residuals:

#	Min	1Q	Median	3Q	Max
#-	-2.54558	-0.02228	-0.00308	-0.00043	2.18650

#Coefficients:

#	Estimate	Std. Error	z value	Pr(> z)
#(Intercept)	-34.23496	4.18538	-8.180	2.85e-16 ***
#pcl	0.14652	0.01807	8.106	5.22e-16 ***

#---

#Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

#(Dispersion parameter for binomial family taken to be 1)

Null deviance: 745.46 on 1099 degrees of freedom

#Residual deviance: 118.28 on 1098 degrees of freedom

#AIC: 122.28

#Number of Fisher Scoring iterations: 10