ISC/17/SHARKWG-1/03

Brief summary of biological parameters for the stock assessment of blue shark (*Prionace glauca*) in the North Pacific[1]

Hiroki Yokoi, Yuki Fujinami, and Yasuko Semba

National Research Institute of Far Seas Fisheries
Japan Fisheries Research and Education Agency
5-7-1 Orido, Shimizu-ku, Shizuoka 424-8633, JAPAN

Email: yokoih@affrc.go.jp; fuji925@affrc.go.jp; senbamak@affrc.go.jp

[1]Working document submitted to the ISC Shark Working Group Workshop, 17-24 March 2017, NOAA Southwest Fisheries Science Center, La Jolla, California U.S.A.
Document not to be cited without author's permission.

Summary

In this document, we briefly explain the materials and methods to estimate von Bertalanffy growth parameter and intrinsic population growth (r) of blue shark in the North Pacific. The each parameter was accepted to use in the upcoming stock assessment of blue shark in the North Pacific in the last ISC shark WG held in the November.

1. Growth parameter

Vertebral samples were collected between 2010 and 2016 in the North-western Pacific (17° N to 42° N, 129° E to 169° W). A total of 1,279 samples (659 males and 620 females) were used for growth analysis. The size ranges of male and female were 33.4–258.3 cm in precaudal length (PCL) and 33.4–243.3 cm PCL, respectively. For sharks smaller than 200 cm PCL, we used burn method (Fujinami et al., Unpubl. manuscript) for enhancement of the growth bands. We burned the centra around 250 °C using a drying oven. For sharks larger than 200 cm PCL, thin sectioning method (stained with arizarin red) was applied to count growth bands.

We estimated the period and periodicity of growth band formation based on the monthly proportion of convex and concave structures observed on the margin of vertebral centra for individuals smaller than 200 cm PCL. The proportion of the convex structure increased from autumn to winter and then decreased to the lowest in summer (Figure. 1). The periodicity of band formation was verified using the model described by Okamura and Semba (2009). Their model showed that the most probable periodicity was annual (annual; AIC: 1014.0, biannual; AIC: 1238.1, no cycle; AIC: 1290.3). These results suggested that growth band forms once a year during December and February.

The von Bertalanffy growth function was fitted to observed length at age data using a software of R for Bayesian approach (Rstan). Three Markov chains were simulated with a total of 20,000 iterations. We set 2,000 times burn-in and three thinning. Growth parameters were L_∞ = 284.8 cm PCL, k = 0.117 years^{-1}, t_0 = –1.34 years for males, and L_∞ = 256.3 cm PCL, k = 0.147 years^{-1}, t_0 = –0.97 years for females, respectively (Table 1, Figure. 2). Theoretical longevity using Taylor's function (Taylor, 1958) was estimated as 24.3 years for males, and 19.4 years for females. The age at 50% maturity for males was 5.9 years, and that for females was 5.3 years, respectively.

2. Intrinsic rate of natural increase (r)

The intrinsic rate of natural increase was estimated using two-sex age structured matrix model (Caswell 2001; Tsai et al. 2014). Figure 3 shows a scheme of this model. This model is described as follows

Working document submitted to the ISC Shark Working Group Workshop, 17-24 March 2017, NOAA Southwest Fisheries Science Center, La Jolla, California U.S.A.

$$\mathrm{N}_{t+1} = \mathbf{A}N_t,$$

A

$$= \begin{pmatrix} 0 & 0 & \cdots & F_{mat,\mathrm{m}} & \cdots & F_{max-1,\mathrm{m}} & 0 & 0 & \cdots & F_{mat,\mathrm{f}} & \cdots & F_{max-1,\mathrm{f}} & 0 \\ S_0 & 0 & \cdots & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 & \cdots & 0 & 0 \\ 0 & S_{1,\mathrm{m}} & \cdots & \vdots & \cdots & 0 & 0 & 0 & \cdots & 0 & \cdots & 0 & \vdots \\ 0 & 0 & \cdots & S_{mat,\mathrm{m}} & \cdots & 0 & 0 & 0 & \cdots & 0 & \cdots & 0 & \vdots \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & \cdots & S_{max-1,\mathrm{m}} & 0 & 0 & \cdots & 0 & \cdots & 0 & 0 \\ S_0 & 0 & \cdots & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & \cdots & 0 & 0 & S_{1,\mathrm{f}} & \cdots & 0 & \cdots & 0 & \vdots \\ 0 & 0 & \cdots & 0 & \cdots & 0 & 0 & 0 & \cdots & S_{mat,\mathrm{f}} & \cdots & 0 & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cdots & \cdots & S_{max-1,\mathrm{f}} & 0 \end{pmatrix}.$$

where N_t is the vector of population number by each age in time t and $\mathbf{A}$ is projection matrix. The projection matrix consists of the term of survival rate S and reproduction F defined below.

$$S_{a,s} = e^{-M_{a,s}}$$

$$S_0 = 0.5(e^{-M_{0,\mathrm{m}}} + e^{-M_{0,\mathrm{f}}})$$

$$F_{a,s} = \begin{cases} \dfrac{kn_f}{n_f + n_m} S_{a,s} & \text{(Male)} \\ \dfrac{kn_m}{n_f + n_m} S_{a,s} & \text{(Female)} \end{cases}$$

M represents a mortaliry at age by each sex. Subscript a and s means age and sex, respectively. The survival rate of neonates is different from other age. Neonates (i.e. age = 0) includes both sexes. Thus, the survival rate in neonates is equal in males and females (sex ratio at birth set to 0.5). F represents the contribution of male and female to reproduction. k is litter size. n is total population number of participate in mating after maturation by each sex (m: male, f: female). If the reproduction cycle is two years, n is half of one year (male fixed one year). The mating system assumes a monogamy or promiscuity. Stable age distribution (N_0) was used (i.e. age distribution reaches equilibrium state). The stable age distribution was made using a value from the transition of 3000 times.

Analysis was carried out using the parameters and methods shown in the table 2. As a result, the intrinsic rate of natural increase was 0.221. An alternative value for the reproduction cycle of 2 years was 0.187.

References

Caswell, H. (2001). Matrix population models, 2nd Edition. Sinauer Associates, Sunderland, Massachusetts, USA.

Fujinami, Y., Semba, Y., Okamoto, H., Ohshimo, S., and Tanaka, S. (In press). Reproductive biology of the blue shark (*Prionace glauca*) in the western North Pacific Ocean. Mar. Freshwater. Res.

Okamura, H., and Semba, Y. (2009). A novel statistical method for validating the periodicity of vertebral growth band formation in elasmobranch fishes. Can. J. Fish. Aquat. Sci. 66: 771–780.

Semba, Y., and Yokoi, H. (2016) Update of age and sex specific natural mortality of the blue shark (*Prionace glauca*) in the North Pacific Ocean. ISC/16/SHARKWG-1/06

Taylor, C. C. (1958). Cod growth and temperature. J. Cons. Int. Explor. Mer. 23: 366–370.

Tsai, W. P., Sun, C. L., Punt, A. E., and Liu, K. M. (2014). Demographic analysis of the shortfin mako shark, isurus oxyrinchus, in the northwest pacific using a two-sex stage-based matrix model. ICES J. Mar. Sci. 71, 1604–1618.

Walter, J., Sharma, R., Cass-Calay, S., Ortiz, M., and Brown, C. (2016). Scaling natural mortality rate as a function of length or weight with an application to yellowfin tuna. SCRS/2016/116.

Table 1. Von Bertalanffy growth parameter with 95% credibility intervals (95% CI) for blue shark. WAIC denote Watanabe-Akaike Information Criterion.

Sex	L_∞ (cm)	95% CI	k (year^{-1})	95% CI	t_0	95% CI	WAIC
Males	284.8	273.7; 297.4	0.117	0.107; 0.127	–1.34	–1.51; –1.20	
							9657.1
Female	256.3	248.9; 264.7	0.147	0.136; 0.158	–0.97	–1.11; –0.84	
Sex combined	267.2	261.0; 274.1	0.134	0.126; 0.141	–1.13	–1.23; –1.03	9674.0

Working document submitted to the ISC Shark Working Group Workshop, 17-24 March 2017, NOAA Southwest Fisheries Science Center, La Jolla, California U.S.A.

Table 2. Parameter and method used in this study

Parameters/Specification	Value/Method	Reference
Reproductive cycle	1	Fujinami et al., (In press)
Litter size	35.5	Fujinami et al., (In press)
Age at maturity	male 6; female 5	This study
Longevity (Taylor's function)	male 24; female 19	This study
Growth curve	von Bertranffy growth curve	This study
Mortality estimator	Method II in Walter et al.	Walter et al. 2016; Semba & Yokoi 2016

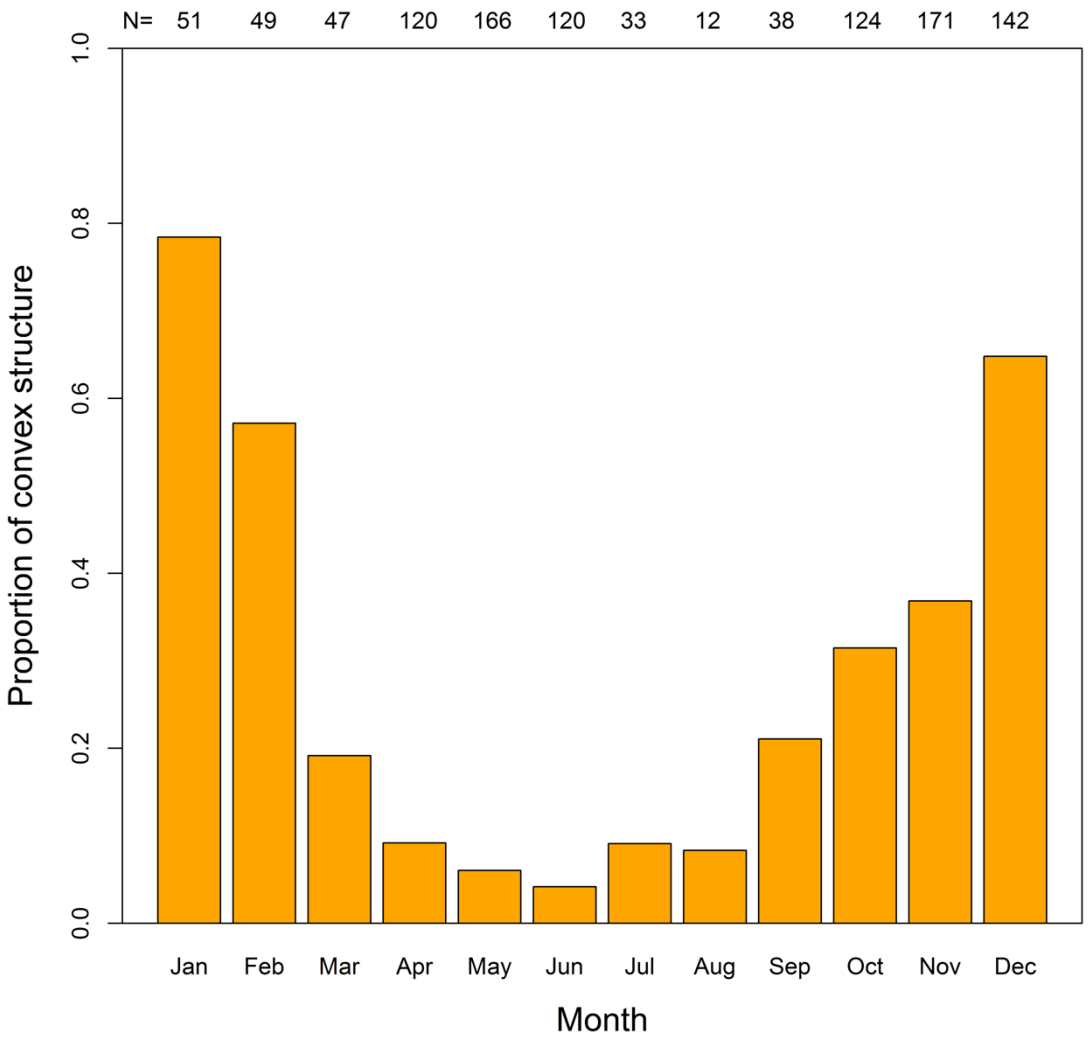

Figure. 1. Monthly proportion of convex structure on centrum edge for blue sharks smaller than 200 cm PCL. The numbers above denote sample size per month.

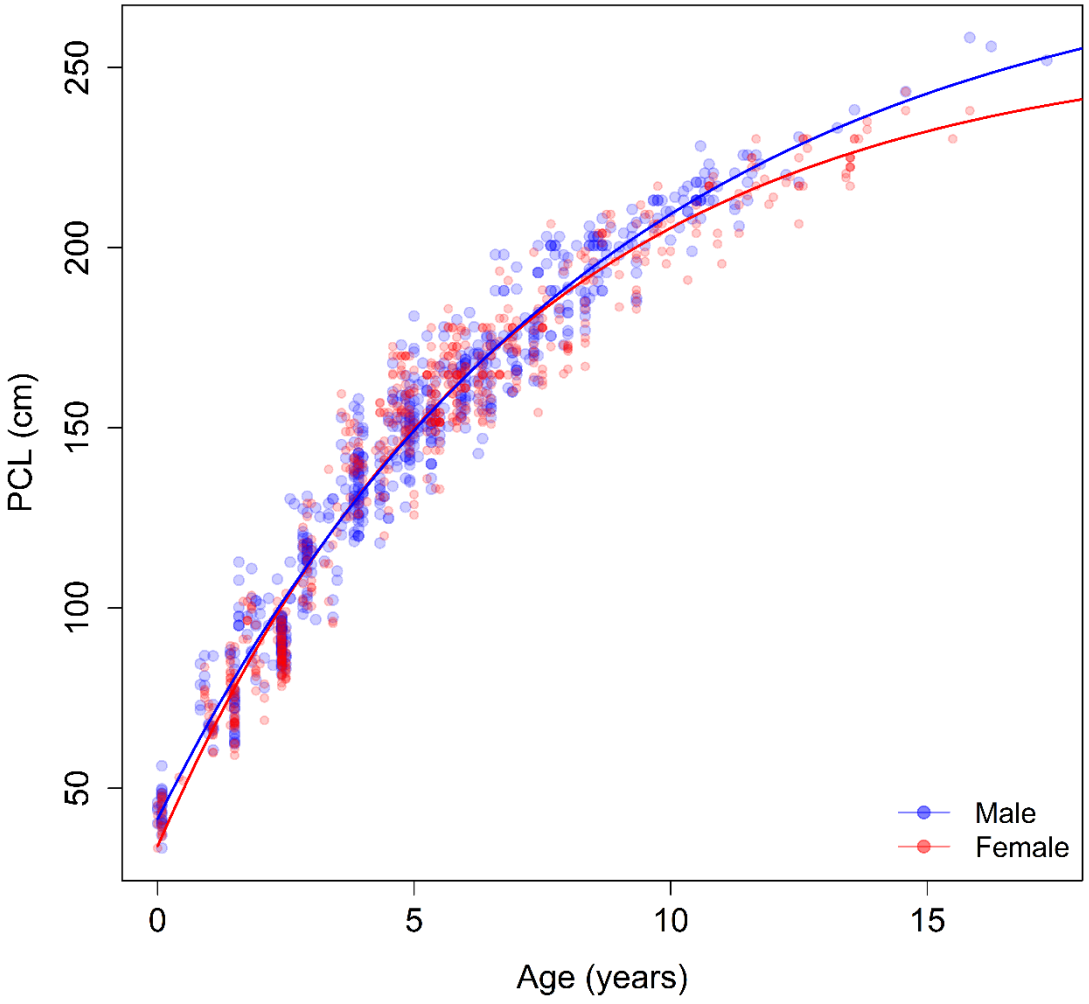

Figure.2. Observed growth data for blue shark (*Prionace glauca*) in the western North Pacific Ocean and fitted Von Bertalanffy growth curves to the data. Blue circles and line represent males, and red circles and line represent females, respectively.

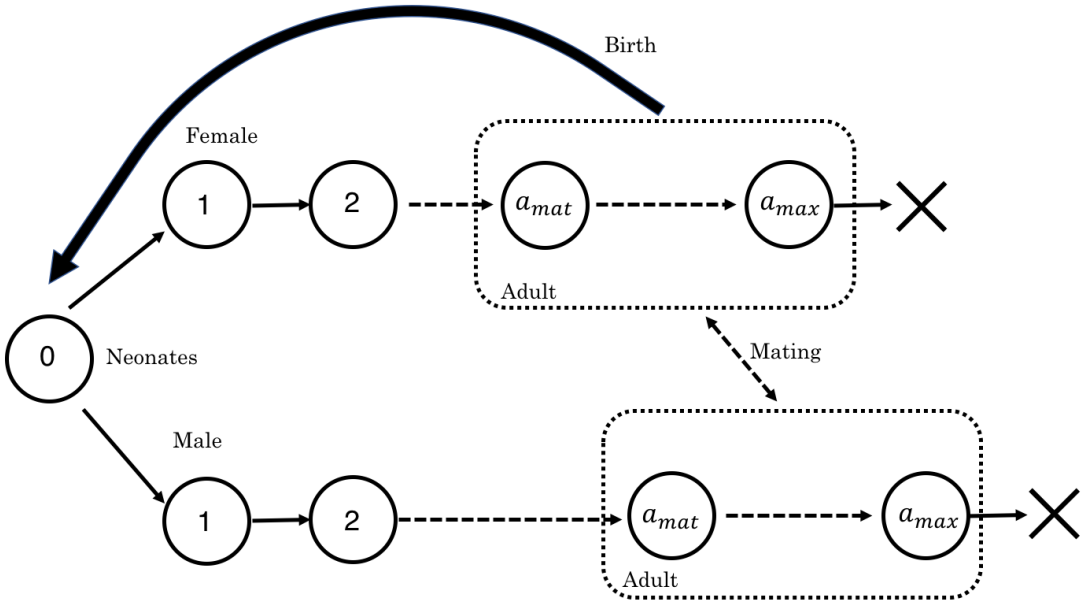

Figure 3. Scheme of two-sex age structured matrix model. The population number at next age will be determined by the survival rate at current age. Maximum age (a_{max}) does not survive next age. After reaching the maturity age (a_{mat}), it becomes adult shark and start mating and reproduce.