Stock analysis of Mako Shark in the North Pacific Ocean by virtual population analysis.

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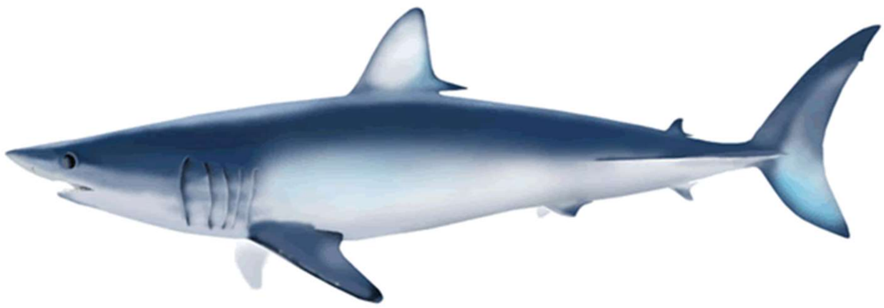

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[1]Working document submitted to the ISC Shark Working Group Workshop, 9 Apr. - 16 Apr. 2018, La Jolla, USA **Document not to be cited without author's permission.**

Abstract

In this paper, estimation of stock abundance in each year and age for female of mako-shark in North Pacific Ocean was provided by using virtual population analysis.

Introduction

One of major methods of stock abundance estimation is the virtual population analysis (VPA), which is based on an abundance estimation by backward calculation from the catch at age data (Hilborn and Walters, 1992). The required data for VPA are catch abundance at age and natural mortality at age in each year. VPA can address the initial condition of stock without an assumption of historical catch before the terms of stock analysis, historical trend of selectivity of catch for each age and the trend of recruitment. The historical fishery data of mako-shark in North Pacific Ocean was poorer than other main targeted fishes because there is lack of data, even catch data, before 1994. It makes difficult to estimate initial condition for stock assessment before 1994. In this paper, we estimated stock abundance for mako-shark by using VPA and provide some informations, e.g. initial condition and historical change of catch, to check the assumption of stock assessment by Stock synthesis (SS; Methot and Wetzel, 2013).

Material and method

data sets

We conducted two VPA, one is classic VPA (Pope 1972) and another is ridge VPA (Okamura et al. 2017). We used only female data not male, because of simplification. Catch at age data between 1975 and 2016 was used the output of preliminally run by SS. Natural mortality was assumed 0.128 which is same value with the input of SS. All biological parameters used were those assigned in the Data Preparatory Meeting in November 2017. Age-specific weight by sex was estimated by applying the growth curve by Takahashi et al. (2017) and length-weight relationships by Su et al. (2017), which were agreed to be used in the stock assessment. Von Bertalanffy growth curve was estimated with birth size fixed as follows;

$$L_t = L_0 + (L_\infty - L_0)\{1 - exp(-Kt)\}$$

, where L_t L_0, L_∞, and K denote length at age (t), length at birth of 60 cm precaudal length (PCL), asymptotic length and Brody growth rate parameters, respectively. Estimated L_∞, and K were 232.0 cm PCL and 0.174 for males and those for female were 293.1 cm PCL and 0.128, respectively. Regarding body length (PCL; cm) and whole weight (kg) relationship, intermediate size within the size range in each age was calculated for each sex (e.g., 73.95 cm in case of 0-1 years old male with size range of 60-87.9 cm) until sex-specific longevity (24 for males and 31 for females;) based on the sex-specific growth curve and then substituted into the following equations;

$\text{Weight} = 4.62 \times 10^{-5} \times PCL^{2.77}$ for males and $\text{Weight} = 3.4 \times 10^{-5} \times PCL^{2.84}$ for females.

Age-specific maturity rate was estimated by combining the length at age based on the growth curve above and maturity ogive estimated by Semba et al. (2017). and then the intermediate size described above was substituted into the following maturity ogives to derive age-specific maturity rate;

$$\text{Male: Maturity rate} = \frac{1}{1 + \exp(25.06499 - 0.01373 \times PCL)}$$

$$\text{Female: Maturity rate} = \frac{1}{1 + \exp(34.23496 - 0.14652 \times PCL)}$$

Age specific maturity and weight were used to calculate spawning stock biomass. Older than 17 years old were aggregated as plus group because the length at 17 reach to 90% of Linf and the maturity rate at 17 of female is almost 1. As the tuning factor, we used standardized CPUE by Japanese shallowset longliner between 1994 and 2016 (Kai 2017)

Ridge VPA

For the classic VPA, the assumption of terminal F was sensitive on the estimation of stock abundance. Ridge VPA is the method to estimate terminal F with penalty parameter to reduce the amount of retrospective bias. The detail information should be reffered from Okamura et al. (2017).

Results and Discussions

From the retrospective analysis we choose the lambda is 0.05 for this analysis. Mohn's rho (Mohn, 1999) for the number of stock (N), biomass of stock (B), spawning stock biomass (SSB), recruitment and F were estimated as Table. 1.

Table. 1 Mohn,s rho

classic VPA

N	B	SSB	R	F
1.7	2.5	4.4	-0.8	2115.1

ridge VPA

N	B	SSB	R	F
38081.5	55365.9	93573.5	1106.5	-0.6192806

Therefore, all estimated value except R were overestimated and R was underestimated by classic VPA. and all estimated value except F were overestimated and F was underestimated by ridge VPA.

The estimated SSB by classic VPA had flat trend and the one by ridge VPA had upper trend in recent years (Fig. 1). The initial SSBs (i.e. SSB in 1975) were 529,578.3 MT by classic VPA and 604,291.2 MT by ridge VPA.

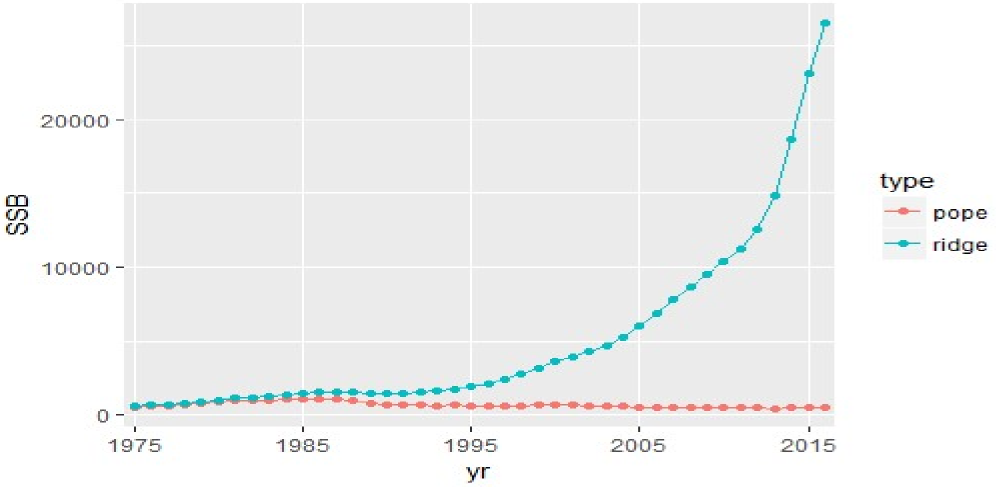

Figure 1. Estimated spawning stock biomass.

The estimated N at ages and the proportions by classic VPA and ridge VPA were shown on Fig. 2 and 3.

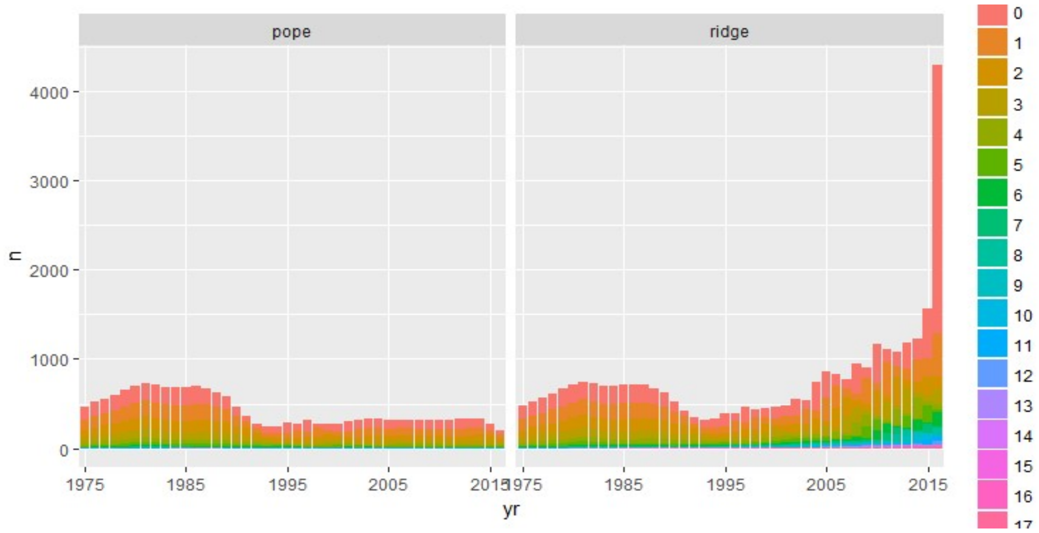

Figure. 2 Estimated N at ages.

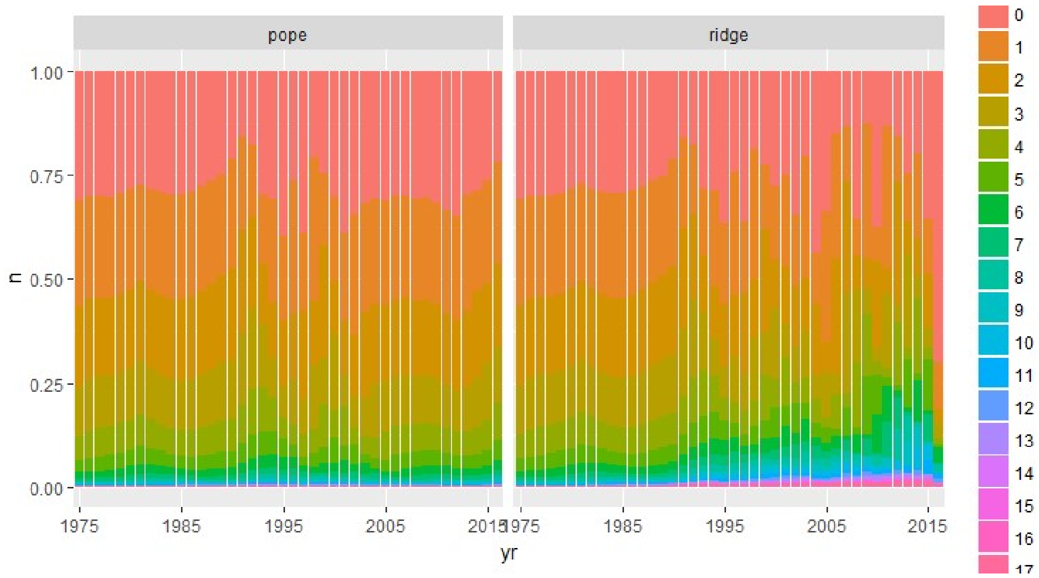

Figure. 3 Estimated poportion of N at age

The recent trend and proportion were different between classic VPA and ridge VPA but the initial conditions by both VPA were similar.

The estimated N at ages and the proportions by classic VPA and ridge VPA were shown on Fig. 4 and 5.

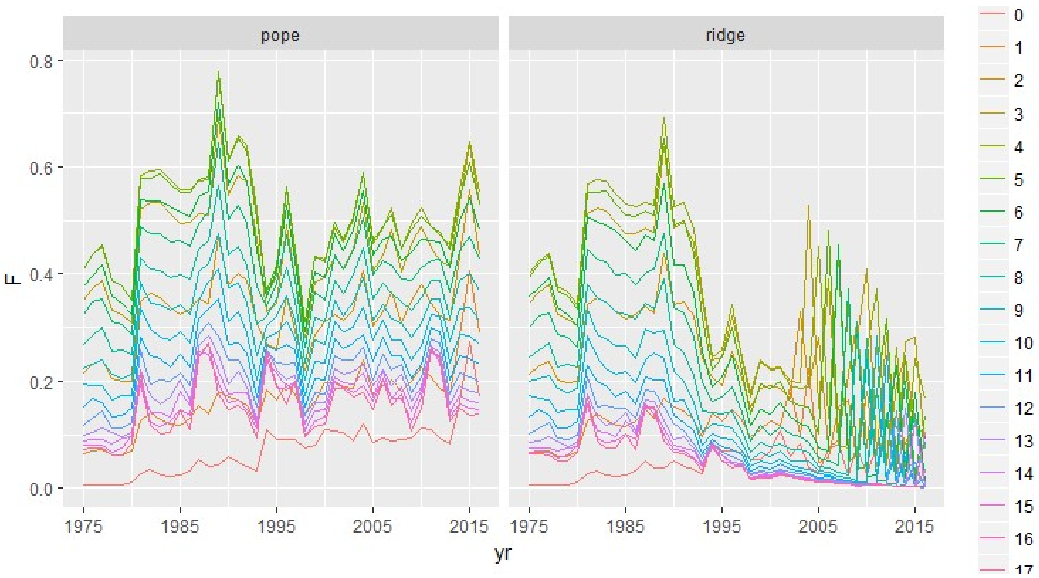

Figure. 4 Estimated F at age

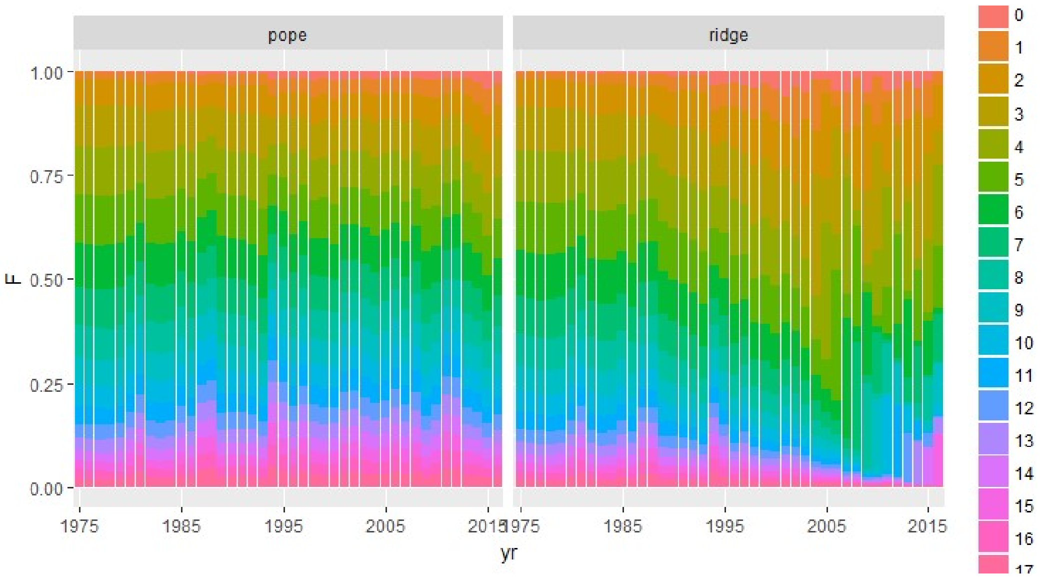

Figure 5. Estimated proportion of F at age.

We also show the scaled F at age by maximum F at age in each year (relative F) on Fig. 6.

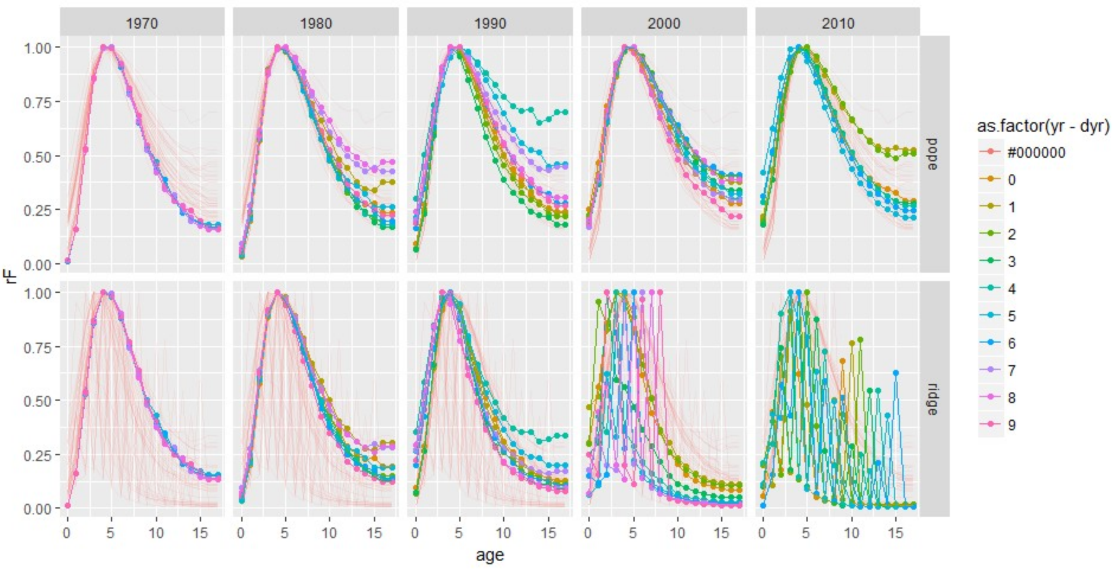

Figure 6. scaled F at age by maximum F at age in each year

The colored lines are relative F for each decade and gray lines are relative F for different decades.

The estimated proportion of F at age and relative F can figure out the change of selectivity at age and it was stable before late 1990s and change after early 2000s. The changing trend was different between the result of classic VPA and ridge VPA. By classic VPA, the Fs on older age increased in recent years but by ridge VPA they decreased in recent years.

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