Stock assessment based on body size information

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KEY WORDS: Pacific cod, SPR, stock assessment, walleye pollock, weight, YPR

INTRODUCTION

The most common methods currently used in fisheries stock assessment rely on catch-at-age data.¹ This is used for virtual population analysis. YPR and SPR are mostly calculated based on age at first capture. Thus the age information of fish is important.

However, maturity, selectivity, price class, etc. depend on length or weight rather than age.

Matsuishi² and Ueda et al.³ developed the size-based virtual population analyses, LPA and WPA, using catch-at-size and size transition matrixes. Using the size transition matrix, we can also calculate the size-based YPR and SPR. Generally, catch-at-size (specially -weight) is easily obtained and this is one of merits of using size-based methods.

In this presentation we introduce the weight-based yield per recruit (YPR/W) and spawning biomass per recruit (SPR/W) analyses, and applied these to Pacific cod and walleye pollock off the Pacific coast of southern Hokkaido (PCSH), Japan.

MATERIALS AND METHODS

To compose the "forward" weight transition matrix ($\mathbf{P}_f$), we assume that the weight of fishes at year j W_j is normally distributed at year $j+1$ with average weight w_{j+1} and standard deviation σ_w . Components (k, i) of $\mathbf{P}_f$, $p_{k,i}$ represent the probability that a fish in a weight class k at year j belongs to a weight class i at year $j+1$.

To calculate the YPR/W and SPR/W, we put the population number recruited in the first year in the smallest weight class, as 1. For this recruited year class, we calculate the population number after the second year in weight class i using Eq. (1):

$$N_{i,j+1} = e^{-(f s_i + M)} \sum_{k=1}^K (p_{k,i} N_{k,j}) \quad (1)$$

where f is fishing mortality, s_i is selectivity in weight class i , and M is natural mortality.

For example, the population number derived using Eq. (1) is shown in Table 1.

Table 1 An example of the transition of population number.

Weight class i (kg)	Year j									
	1	2	3	4	5	6	7	8	9	10
0-1	1.00	0	0	0	0	0	0	0	0	0
1-2	0	0.82	0.01	0	0	0	0	0	0	0
2-3	0	0	0.63	0.04	0	0	0	0	0	0
3-4	0	0	0.03	0.43	0.05	0.01	0	0	0	0
4-5	0	0	0	0.07	0.17	0.04	0.01	0	0	0
5-6	0	0	0	0	0.05	0.07	0.02	0.01	0	0
6-7	0	0	0	0	0.01	0.03	0.03	0.01	0.01	0
7-8	0	0	0	0	0	0	0.01	0.01	0.01	0.01

This example is calculated using $f=0.5$, $s_i=0$ (from 0-1kg to 2-3kg weight classes), $s_i=1$ (from 3-4kg to 7-8kg weight classes) and $M=0.2$.

YPR/W is calculated as Eq. (2):

$$\text{YPR/W} = \sum_{j=1}^J \sum_{i=1}^I \left\{ w_i \hat{N}_{i,j} (1 - e^{-(f s_i + M)}) \frac{f s_i}{(f s_i + M)} \right\} \quad (2)$$

where w_i is the midpoint of weight class i .

SPR/W is calculated as Eq. (3):

$$\text{SPR/W} = \sum_{j=1}^J \sum_{i=1}^I w_i N_{i,j} m_i \quad (3)$$

where m_i is the maturity rate of weight class i .

For both species of Pacific cod and walleye pollock off the PCSH, we calculated YPR/W, %SPR/W, age-based YPR and age-based %SPR. %SPR is expressed as $\text{SPR}_{F=x}$ as a percentage of $\text{SPR}_{F=0}$.⁴ We also compared the value of YPR/W and %SPR/W to age-based YPR and age-based %SPR which are generally used.

For Pacific cod off the PCSH, we used von Bertalanffy's growth parameters to calculate weight transition probabilities from Hattori et al.⁵ The weight-length relationship was derived originally (Ueda, unpubl. data, 1998). Natural mortality was set at 0.2. Weight and age at maturity were set at 3kg and 4yrs. respectively.

For walleye pollock off the PCSH, von Bertalanffy's growth parameters, weight-length relationship, and population number using VPA, were derived from Muroran branch of Hokkaido Hakodate Fisheries Experimental Station.⁶ Natural mortality was set at 0.3. Weight and age at maturity were set at 400g and 3.72yrs. respectively.

RESULTS

Fig. 1 shows the YPR/W and age-based YPR, %SPR/W and age-based %SPR of Pacific cod off the PCSH. The weight at first capture of 1kg corresponds to the age at first capture of 2.1yrs., and so 3kg corresponds to 4.0yrs. The values of YPR/W and age-based YPR were parallel at 1kg and 2.1yrs, or 3kg and 4.0yrs. When weight (age) at first capture are both 1kg and 2.1yrs, YPR was the maximum at $F=0.4$. The values of %SPR/W and age-based %SPR were slightly different. When $F=0.5$, which was nearly $F=0.48$ in 1997 (estimated using WPA), the differences between the values of %SPR were 2.1 points (1kg-2.1yrs.) and 4.5 points (3kg-4.0yrs.).

Fig. 1 YPR/W and age-based YPR (a), and %SPR/W and age-based %SPR (b) of Pacific cod off the PCSH.

Fig. 2 YPR/W and age-based YPR (a), and %SPR/W and age-based %SPR (b) of walleye pollock off the PCSH.

Fig. 2 shows the YPR/W and age-based YPR, and %SPR/W and age-based %SPR of walleye pollock off the PCSH. The weight at first capture of 100g corresponds to the age at first capture of 1.6yrs., and so 300g corresponds to 3.0yrs. The differences between YPR/W and age-based YPR were larger than in the case of Pacific cod, but the values were also parallel for each combination. The values of %SPR/W and age-based %SPR were nearly the

same. When $F=0.5$, which was nearly $F=0.49$ in 1996 (estimated using WPA), the differences between the values of %SPR were only 0.9 points (100g-1.6yrs.) and 4.0 points (300g-3.0yrs.).

DISCUSSION

The value of YPR/W and age-based YPR were parallel for Pacific cod and walleye pollock off the PCSH. This result indicates that YPR/W is also suitable for calculation of F_{max} or $F_{0.1}$, etc. While for Pacific cod, the values of %SPR/W were slightly smaller than age-based %SPR, in the case of walleye pollock %SPR/W and age-based %SPR were nearly the same. This result indicates the potential of the weight-based method for calculating F_{SPR} . We assumed normal distribution of weight in next year. If assume other distribution (log-normal, gamma, etc.) the results of weight-based and age-based methods may different.

There will be some difficulty in determining the variance of weight for constructing P . We examined the sensitivity of this to the result of population estimation, and confirmed that the magnitude of dispersion slightly affects to the estimated population number using WPA. The effect on YPR/W and SPR/W will be potentially small, because YPR/W and SPR/W are calculated from a similar model to WPA.

Using WPA, YPR/W and SPR/W enables to estimate biomass and to assess stock conditions totally based on weight.

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