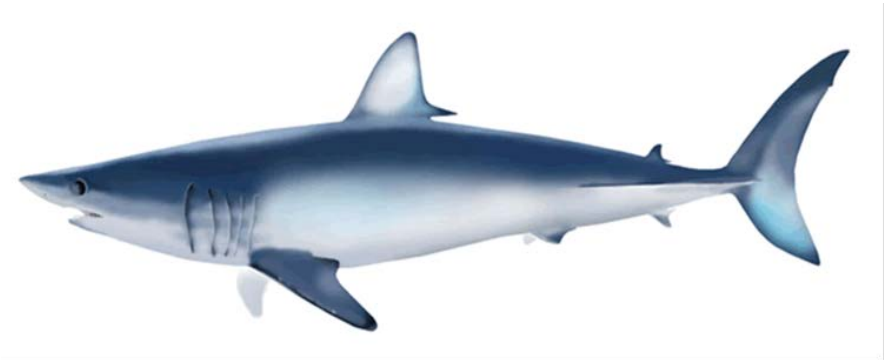
ISC/13/SHARKWG-2/04

Estimate of the intrinsic rate of population increase for the blue shark in the North Pacific[1]

Chien-Pang Chin[2] and Kwang-Ming Liu[3,4]

2. Institute of Oceanography, National Taiwan University
3. Institute of Marine Affairs and Resource Management, National Taiwan Ocean University
4. George Chen Shark Research Center, National Taiwan Ocean University



[1]Working document submitted to the ISC Shark Working Group Workshop, 16-24 April, National Research Institute of Far Seas Fisheries, Shizuoka, Japan.

Abstract

The intrinsic rate of increase (*r*) is an important and crucial parameter in fish stock assessment especially using the production model. In this study, the *r* of the blue shark in the North Pacific Ocean was estimated using a demography approach. The input parameters, collected from 3 studies, include the growth coefficient, longevity, fecundity, age at maturity, reproduction cycle, and natural mortality. The results of demographic analysis indicated that the *r* of blue shark ranges from 0.270 to 0.356 with standard error from 0.038 to 0.103. The results derived from this study can be used as the prior of Bayesian surplus production model of blue shark in the North Pacific Ocean.

Introduction

Shark conservation and management attracted great concern in recent years. Many countries and regional fisheries management organizations (RFMO's) have made their management measures on sharks for example, USA, Australia, and Maldives have the regulations of total allowable catch (TAC) and limited fishing grounds. The International Science Committee (ISC) Shark Working Group plans to conduct the North Pacific blue shark stock assessment in 2013. However, some of the input parameters are still lacking due to the data limitation. McAllister et al. (2001) used the demographic analysis to construct Bayesian priors for the intrinsic rate of population increase (r) in the Schaefer model for sandbar shark and blacktip shark. The objective of this study is to estimate the intrinsic rate of increase for the blue shark in the North Pacific Ocean.

Materials and Methods

The Euler–Lotka method (Lotka, 1907) was used to estimate the *r* of blue shark in the North Pacific Ocean. This method assumes the population is in an equilibrium condition:

$\sum m_x \times l_x \times e^{-rx}=1$, where m_x is fecundity at age *x*, l_x is survival rate until age *x*. The *r* was estimated by iteration using the statistical package R with nlm procedure. Generation time in year (G) can be estimated as:

$G = \sum x l_x \times m_x / l_x \times m_x.$

The input parameters for this method include:

1. k: The growth rate in the von Bertalanffy growth equation,
2. Maximum age (longevity) (T_{max}): T_{max} of the blue shark was estimated from Taylor's

（1958）equation as following: $T_{max} = t_0 - \frac{\ln(0.05)}{k}$, where t_0 is the theoretical age at zero length.

3. Fecundity (f): the mean litter size of pregnant females, or the mean of the maximum and minimum of littler sizes. The sex ratio of pups is assumed to be 1:1.

4. Age at maturity (T_m): the age at 50% maturity. T_m was estimated by substituting the size at 50% maturity into the von Bertalanffy growth equation.

5. Reproduction cycle (R_c): including gestation and resting periods. Reproduction cycle was assumed to be 2 years (Hsu et al. 2011). For comparison, the 1-year reproductive cycle was also used in our estimation.

6. Natural mortality: Hoenig's (1983) equation was used to estimate natural mortality (M): $\ln(M) = \ln(Z) = 0.941\text{-}0.873\ln(t_{max})$.

The life history information of North Pacific blue shark was collected from Cailliet and Bedford (1983), Nakano and Seki (2002), and Hsu et al. (2011). The input parameters of cases 1, 2, and 3 were based on Hsu et al. (2011), Cailliet and Bedford (1983) and Carrera-Fernandez et al. (2010), and Nakano and Seki (2002), respectively (Table 1).

Results and Discussion

Longevity and natural mortality estimation

The longevity and natural mortality of blue shark varied depending on the life history parameter. The longevity and natural mortality of blue shark were 16.29 year and 0.224 yr^{-1} (based on the Hsu et al., 2011), and 19.96 year and 0.188 yr^{-1} (based on the Nakano and Seki, 2002 and and Carrera-Fernandez et al., 2010), respectively. However, Cailliet and

Bedford (1984) documented the longevity and natural mortality of blue shark being 12.63 year and 0.28 yr^{-1} (Table 2).

Intrinsic rate of increase

For the 2-year reproductive cycle cases, the r estimated based on Nakano and Seki's (2002) life history data has the highest value of 0.356 (se=0.046) and the longest generation time of 9.0 year. Similar results were obtained based on the life history of Nakano and Seki (2002). The *r* is 0.350 and G is 8.23 year in the case 1. The r and G were estimated to be 0.162 and 8.95 yr, respectively based on the Cailliet and Bedford's (1983) life history parameters (Table 2). The results based on the assumption of 1-year reproductive cycle indicated the both r and G increase (Table 3).

In addition to Hoenig's (1983) method, several empirical equations have been proposed to estimate the natural mortality of fish i.e. Chen and Watanable (1989), Jensen (1996), Pauly et. al. (1983), Peterson and Wroblewski (1984). Although Hoenig's (1983) method is commonly used in elasmobranch, other methods should be tried in the future. Cortes (2002) estimated the intrinsic rate of population increase for 41 shark stocks included Atlantic blue shark using multiple methods in natural mortality estimation. In this study, although only Taylor's (1958) method was applied to estimate natural mortality, our estimations are similar to Cortes (2002), which was 0.337. Several studies have proposed the empirical equations to estimate the longevity of sharks. As the longevity may influence the estimation of natural mortality, these methods should be taken into account in the future.

References

Cailliet, G. M. and D. W. Bedford (1983). The biology of three pelagic sharks from California waters, and their emerging fisheries: a review. Reports of California Cooperative Oceanic Fisheries Investigations 24: 57-69.

Chen, S. and S. Watanabe (1989). Age Dependence of Natural Mortality Coefficient in Fish Population Dynamics, Nippon Suisan Gakkaishi, 55,205-208

Carrera-Fernandez, M., F. Galvan-Magana, P.B. Ceballos-Vazquez (2010). Reproductive biology of the blue shark *Prionace glauca* (Chondrichthyes: Carcharhinidae) off Baja California Sur, Mexico aqua: International Journal of Ichthyology 16: 101-110.

Hoenig, J. M. (1983). Empirical use of longevity data to estimate mortality rates. Fishery Bulletin 82: 898-903.

Hsu, H. H., S. J. Joung, G. T. Lu, K. M. Liu, and C. C. Huang. (2011). Age and growth of the blue shark, *Prionace glauca*, in the northwest Pacific. Ageing Workshop of ISC Shark Working Group Meeting, Dec. 5-6, 2011, La Jolla, CA, USA. ISC/11/SHARKWG-2/12, 18 pp.

Jensen,A.L., 1996. Beverton and Holt life history invariants result from optimal tradeoff of reproduction and survival. Canadian Journal of Fisheries and Aquatic Sciences 53, 820–822.

McAllister, M.K., E.K. Pikitch and E.A. Babcock (2001). Using demographic methods to construct Bayesian priors for the intrinsic rate of increase in the Schaefer model and implications for stock rebuilding. Canadian Journal of Fisheries and Aquatic Sciences 58: 1871-1890.

Nakano, H and M.P. Seki (2002). Synopsis of biological data on the blue shark, *Prionace glauca* Linnaeus. Bulletin of fisheries research agency 6: 18-55.

Pauly, D. (1983). Length-converted catch curves: a powerful tool for fisheries research in the tropics (Part 1). ICLARM Fishbyte 1, 9–13.

Peterson, I. and J.S. Wroblewski (1984). Mortality rates of fishes in pelagic ecosystem. Canadian Journal of Fisheries and Aquatic Sciences Sci. 41, 1117–1120.

Taylor, C. C. (1958). Cod growth and temperature. Journal du Conseil International pour L’exploration de la Mer 23: 366-370.

Table 1. Life history parameters of blue shark in the North Pacific Ocean used in this study.

Case	k (yr^{-1})	t_0	T_{max} (yr)	Natural mortality	T_m	Fecundity	Reference
Case 1	0.172	-1.123	16.29	0.224	4.3	29	Hsu et al. (2011)
Case 2	0.223	-0.8	12.63	0.28	6.5	33	Cailliet and Bedford (1984), Carrera-Fernandez et al. (2010)
Case 3	0.144	-0.849	19.96	0.188	6	25.6	Nakano and Seki (2002)

Table 2. The intrinsic rate of population increase, standard error and generation time of blue shark in the North Pacific Ocean based on a two-year reproductive cycle assumption..

Case	r	se	G
Case 1	0.35	0.103	8.23
Case 2	0.162	0.038	8.95
Case 3	0.356	0.046	9

Table 3. The intrinsic rate of population increase, standard error and generation time of blue shark in the North Pacific Ocean based on an one-year reproductive cycle assumption.

Case	r	se	G
Case 1	0.453	0.083	8.23
Case 2	0.245	0.059	8.95
Case 3	0.468	0.066	9