Effect of Ocean Mortality and Growth on Ocean Life History of Pacific Salmon

Masa-aki Fukuwaka
Hokkaido National Fisheries Research Institute, Fisheries Research Agency
116 Katsurakoi, Kushiro 085-0802, Japan

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The objective of this study is to evaluate the effects of ocean mortality and growth on life history variability of Pacific salmon. Ocean mortality of Pacific salmon may be size-selective (Ricker 1976), and size-selective mortality may be caused by predation or gillnet fisheries. In general, Pacific salmon with high growth rate mature at younger ages within a year class. But body size of younger fish is smaller than of older fish. Healey (1987) found that the optimum life history model cannot explain such a life history variation within a sockeye salmon population. From the 1970s to the 1990s ocean growth rate was lower, and age at maturity of Pacific salmon increased and mean size at age decreased simultaneously. Pacific salmon life histories are characterized by "big-bang" reproduction and a multi-year life span, in which a fish lives two or more years, reproduces only one time, and dies after the reproduction. General life history models merely treat such a specific condition. Recently, the dynamic state variable approach was used to model salmon life history, and was used elsewhere to model life history of a plant that has "big-bang" reproduction and a multi-year life span similar to Pacific salmon (Mangel 1994; Rees et al. 1999). I examined whether this life history model could explain the within-population variability and temporal changes in age and size at maturity of Pacific salmon.

I used life history models with the "1-year look-ahead criterion" (Rees et al. 1999). The "1-year look-ahead criterion" is a criterion which a fish uses to decide whether to mature now or next year by comparing two expected fitnesses. In contrast, the regular optimal life history model compares fitness overlooking the possible future life span to treat a problem of when an individual organism matures in its life history. The "1-year look-ahead criterion" is convenient to simulate a life history in which individual body size or condition is variable and not predictable. Rees et al. (1999) indicated that the difference or bias was small in the results of simulations between with "1-year look-ahead criterion" or "life span overlooking criterion" for size and age at maturity.

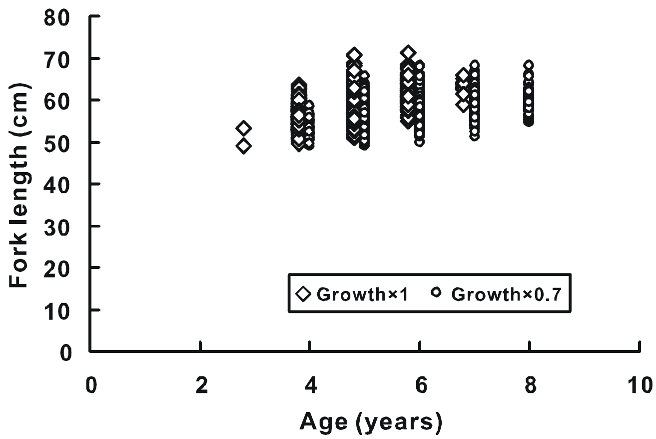
First I considered the condition that a fish "knows" its mean future growth rate. I used life history models assuming a constant, size-selective, or age-selective ocean mortality. The condition is interpreted that a life history of fish is evolved to adapt a mean ocean growth. Models assuming a constant or size-selective mortality predicted a constant size at maturity regardless of age, while models assuming age-selective mortality predicted plasticity both in age at maturity and size at maturity within a year class (Table 1). Second, I considered the condition that a fish "knows" the mean and variance of its future growth. In this case, the predicted size at maturity was slightly larger than in the case that a fish knew only its mean growth rate. Finally, I considered the condition that individual fish expect different growth rates within a population. In this case, models predicted that size at maturity was positively correlated with age at maturity in a Monte Carlo simulation (Table 1, Fig. 1, rectangular plots). And in the similar condition but with mean growth rate decreased to 70%, age at maturity increased and mean size at age decreased (Table 1, Fig. 1, circle plots).

Table 1. The relationship between size at maturity and age at maturity, and changes in age at maturity and size at age at maturity under a condition that ocean growth is decreased to 70% in results of Monte Carlo simulations of life history models for Pacific salmon.

Expected growth	Ocean survival	Relation between size and age at maturity	Changes at decreased growth	
			Age at maturity	Size at age
Mean	Constant	Size is constant	Increase	No change
	Size-selective	Size is constant	Increase	No change
	Age-selective	Positive	Increase	No change
Mean and variance	Constant	Size is constant	Increase	No change
	Size-selective	Size is constant	Increase	No change
	Age-selective	Positive	Increase	No change
Individually different	Constant	Positive	Increase	Decreased
	Size-selective	Positive	Increase	Decreased
	Age-selective	Positive	Increase	Decreased

All correspondence should be addressed to M. Fukuwaka.
e-mail: Fukuwaka@fra.affrc.go.jp

Fig 1. Predicted age and size at maturity for female chum salmon using Monte Carlo simulations assuming that individual fish has a variability in growth and a variability in growth expectation with a constant ocean survival rate.



These analyses indicate that a simpler salmon life history model with the "1-year look-ahead criterion" can explain variability within a population and temporal changes in ocean life history of Pacific salmon than the ordinary optimum life history model (Healey 1987). Ocean survival of Pacific salmon may be size-selective (Ricker 1976). Individual variability in the expectation for ocean growth rate and size-selective mortality may produce the observed age and size variability of Pacific salmon which has ocean age variability, such as chum, sockeye, chinook salmon.

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