An examination of natural reproduction in Japanese chum salmon using long-term catch and release data

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Introduction

The number of released Japanese chum salmon juveniles increased in the 1970s with a subsequent increase in coastal catch. A steep increase has been observed in the number of released juveniles, and a slower increase has been observed in the coastal catch (Fig.1). This phenomenon has been explained by variations in survival rates under the assumption that natural Japanese chum salmon reproduction is negligible. However, recent research has provided some evidence of natural reproduction.
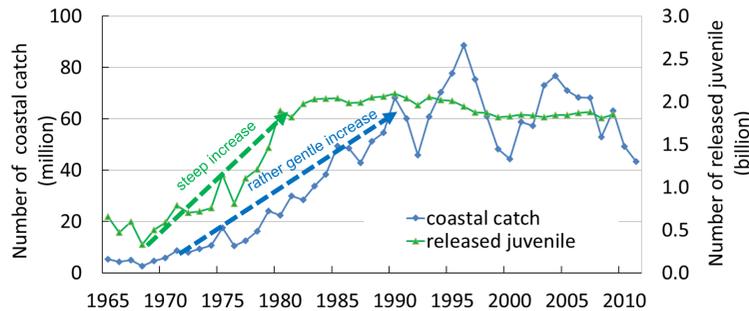

Fig.1 Number of released juveniles and coastal catch of chum salmon in Japan during 1965-2011.

Objective

To estimate the amount of natural reproduction that changes the pattern of increase in released juvenile and coastal catch.

Materials and methods

Data

(1) Number of juveniles released between 1973 and 2011.
(2) Number of > 2-year-old fish caught during the same period.
(3) Age-specific survival rate of > 2-year-old fish calculated by virtual population analysis (VPA).
(4) Age-specific fecundity ratio calculated from fertility and maturation rates (Table 1).

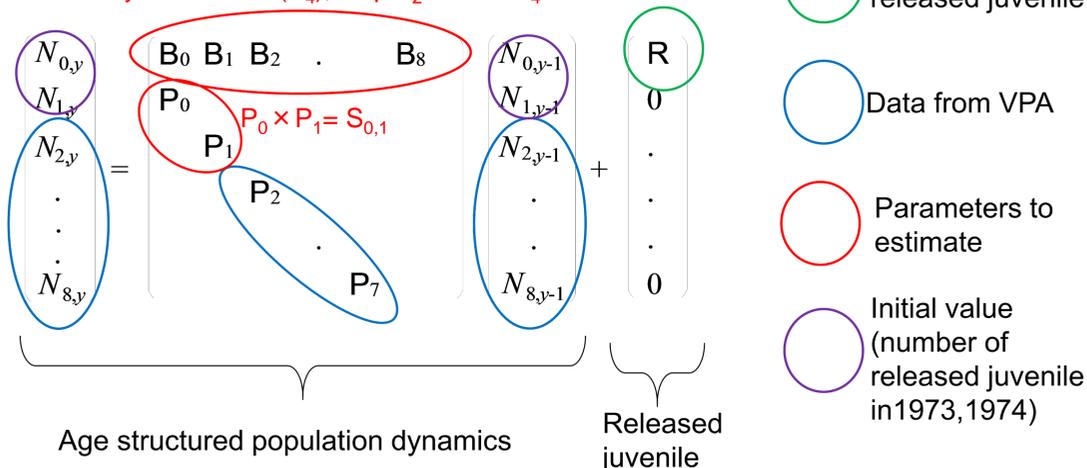Table 1 Age-specific fecundity ratio calculated from fertility and maturation rates

Age	2	3	4	5	6	7	8
fertility	2,503	2,565	2,851	3,017	2,917	2,406	-
Maturation rate (%)	0.3	10.5	62.6	93.8	97.9	98.2	-
Relative fecundity ratio	0.005	0.152	1.000	1.587	1.600	1.325	1.325[*]

- Data not available

* Relative fecundity ratio in 8-year-old fish is assumed to be the same as that of 7-year-old fish

Model

Age-specific fecundity is proportional to that of 4-year-old fish (B_4),   eq. $B_2 = 0.005B_4$

- Number of released juvenile
- Data from VPA
- Parameters to estimate
- Initial value (number of released juvenile in1973,1974)

Age structured population dynamics   Released juvenile

Assumptions

(1) The survival rate from 0 to 2 years old ($S_{0,1}$) is constant
(2) The fecundity of > 2-year-old fish are proportional to that of 4-year-old fish (B4)

Model fitting

Survival rate ($S_{0,1}$) and fecundity (B_4) were estimated to minimize the sum of squares between the difference calculated and the actual catch number (log transformed) during 1973 and 2011. The number of fish caught was calculated as for the VPA. Numerical solutions were obtained using Microsoft Excel Solver.

Results

Catch trend

The estimated survival rate ($S_{0,1}$) and fecundity of 4-year-old fish (B_4) were 0.04 and 7.68, respectively. The calculated catch trend showed a better fit before 1990; however, the large fluctuation after the 1990s made it difficult to evaluate the data.
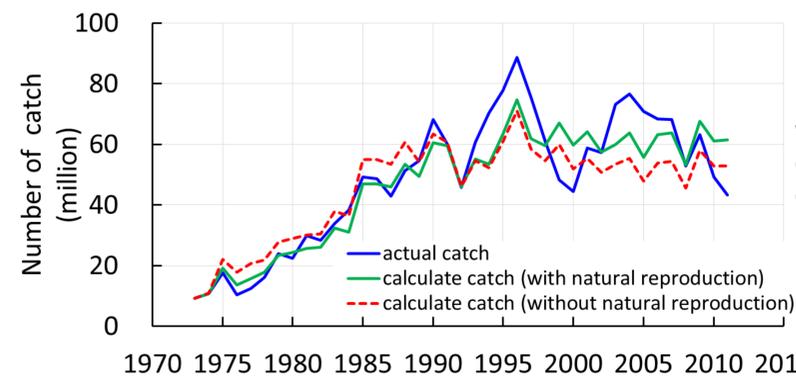

Fig.2   The calculated catch trend with (green) and without (red dotted) natural reproduction. The calculate catch trend without natural reproduction is over estimate before 1990 and under estimate after that.

Contribution from natural reproduction

The contribution from natural reproduction during 1973–1983 when the number of stocked juveniles increased was estimated to be 10–15%. The number of stocked juveniles became rather constant. However, the contribution from natural reproduction has increased ~35% in recent years because of overall population growth.
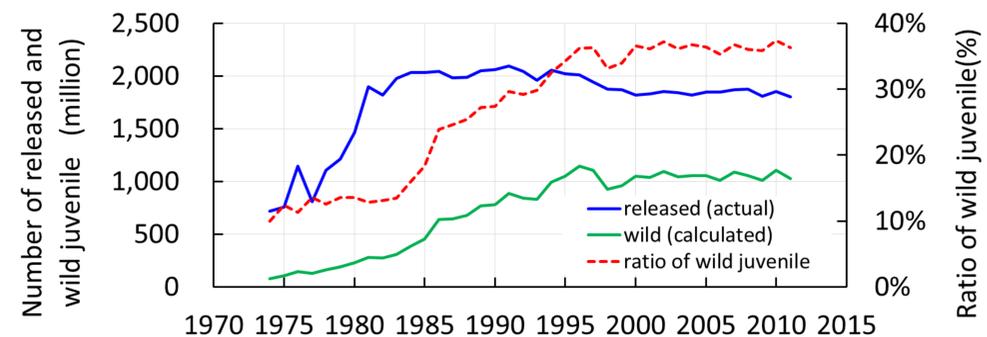

Fig.3 Number of released (blue : actual) and wild (green : calculated) juveniles of chum salmon in Japan. The ratio of wild juvenile has increased because of overall population growth.

Conclusion

The contribution from natural reproduction was estimated to be 10–15% in the late 1970s but has increased ~35% in recent years. However, this value was calculated under the assumption that survival rate of juvenile was constant. Further studies considering variations in survival rates are required.