ISC/12-2/PBFWG/09

Estimation of effective sample size for PBF caught by Japanese longline with bootstrap resampling method

Akiko N. Mizuno

National Research Institute of Far Seas Fisheries, 5-7-1,Shimizu-orido, Shizuoka 424-8633, JAPAN
Corresponding author: mizunoakiko@fra.affrc.go.jp
May-June. 2012

Working document submitted to the ISC Pacific Bluefin Tuna Working Group, International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), 23 May-6 June 2012, Shimizu-orido, Shizuoka 424-8633, JAPAN. **Document not to be cited without author's permission.**

Introduction

From a sampling-theory perspective, the effective sample size (ESS) is defined as the sample size such that the variability from complex sampling designs would be the same as that based on a simple random sample (Pennington et al., 2002 and Hulton et al 2011). Estimation of effective sample size is one of the most important issues in stock assessment. Effective sample size can be used to show which length composition data sets of each year and quarter within and/or between fleets are most reliable. In addition, weighting parameters for length composition data sets for ss3 can be determined using effective sample size.

Length composition data of all fleets as input data using stock assessment model (ss3) was provided in the form of catch at size at the Data Preparatory Meeting (ISC12/PBF1) unlike previous stock assessment (ISC8/PBF). Estimation method of catch at size for all fleets shares an attribute with each other. The attribute of method is simply to raise length data up to catch without statistical model. For this reason, estimation of sample size in catch at size is more difficult unlike with raw sample data which were used in previous stock assessment as input length composition data for ss3 (ISC8/PBF). Also completely random sampling of length data is considered next to impossible at any fleet. So, it is fundamental to estimate effective sample size of length composition as input data for stock assessment model (ss3).

Currently, there are only two fleets, EPO-PS and Japanese Tuna PS, whose estimated effective sample sizes of length data are available for stock assessment of PBF. These fleets target at small to medium fish of PBF. There is no fleets target at large fish of PBF, for which an estimated effective sample size is available. Length data of fish caught by Japanese longline without estimated effective sample size is one of the most important length input data for ss3 for two reasons. First, the length data have the second highest number of data set in terms of number of period which data is available. It is 83 set (12.5%) for JLL out of 663 sets for all fleets in the base case (where, 1 data set corresponds to each year and each quarter). There are only two fisheries that target at large fish of PBF, i.e. JLL and TWLL. The latter only have 20 length data sets.

In this working paper, I estimated effective sample size of length data caught by Japanese longline as to how much equivalent sample size can be assumed to random sampling using resampling data through bootstrap method. Effective sample size is estimated using ratio of coefficient of variation between frequency of bootstrap and observation.

Data

Length data using stock assessment of PBF (ISC12/PBF2) is divided into two periods, 1952-1968 and 1994-2010 (see ISC12/PBF1/01 for more information). Between these two periods sampling procedures were different (ISC07/PBF01/11).

Methods

Bootstrap

Length data were pooled for each year and month, and resampling was taken from the pooled length data with the same number of fish tin the pooled data. 500 sets of resampled data were made from bootstrap. I adopt month for the minimum scale (stratum) of pooling and resampling. The reasons are that variance of length is best accounted by month within year, month, latitude and longitude and length data of JLL were pooled on the same month and year scale as estimating catch at size. (See ISC12/PBF01/01 for more information).

Estimation of effective sample size

Bootstrap resampled data taken each year and month were pooled for each year and quarter, and then effective sample size was estimated based on Kanaiwa et al (ISC08/PBF/01/06). After this, I described a length data each year and quarter. i_{max} is the number of bins and i is a bin number ($i = 1 \cdots i_{max}$). Here, total sample size of a year and a quarter is $N_{obs} = \sum_{i=1}^{i_{max}} n_{obs,i} = N_b$. And, $n_{obs,i}$ is the number of length data included in bin i in a year and a quarter. Sample size of data in a year and a quarter obtained by a bootstrap resampling is equal to sample size of observation data in the year and the quarter ($N_{obs} = N_b$). Coefficient of variation (CV) of frequency of length data expressed variability of each bin and each year and quarter. When it is assumed that average of CV of resampling data with bootstrap is equal to CV of population which is length composition of PBF caught by Japanese longline, then I can assume that

$$E(CV_b): CV_{obs} = N_{effn}: N_{obs}$$

$$N_{effn} = N_{obs} \frac{E(CV_b)}{CV_{obs}}$$

Here, $CV_b = \sqrt{V(n_{b,i})}/E(n_{b,i})$.

Results

Fig. 1 shows effective sample size (ESS) and sample size of observation each year and quarter. It is indicated ESS lower than sample size (average of sample size is 996.2 and average of ESS is 258.68). Difference in ESS between data before 1968 and after 1994 was not significant (table 1). As mentioned earlier, the sampling procedures were different between these two periods. Fig 2 shows rate of estimated ESS to sample size. This rate is called sampling efficiency in this document Calculated total average is 15.8%. Estimated ESS of before 1968 and after 1993 have no difference, despite the difference in sampling procedures (Table 1). The average of estimated ESS before 1968 is 15.3% and that of after 1994 is 16.3%.

Estimated ESS was plotted to sample size in Fig. 3. Estimated ESS has a strong correlation with sample size (Table 1) and this correlation has little difference between before 1968 and after 1994. Also there was very little difference in sampling efficiency between before 1968 and after 1994 (Table 2). Sampling efficiency was plotted to sample size in Fig. 4. Curve regression was calculated for the relation of sampling efficiency and sample size for each period using non-linear least-square method with R. For each period, model selection of four functions was made using AIC. As a result, saturation function was selected for data before 1968 and decreasing after saturation was selected for data after 1994 (Table 3). These results were almost identical even if the month and year are pooled.

Discussion

It is revealed that estimated ESS tends to increase as sample size increases. Because this correlation was not saturated, increase of ESS needs larger sample size. Average of ESS is around 20% and there is little difference between average of ESS before 1968 and after 1994. In contrast, relationship of sampling efficiency and sample size is differed between two periods. Increasing sample size saturated sampling efficiency before 1968, but decreasing that after 1994 having exceeded the threshold level.

After 1994, length of PBF landed in Japan has been measured in an organized way and coverage rate (sample size divided by catch in number) increased (covering rate of data before 1968 is 14.5% and that after 1994 is 29.5%). However, there was no sign of larger ESS and sampling efficiency after 1994, as expected from a larger coverage rate.

This is probably due to that some data were of extremely low sample size. If the data include a stratum (year and month) with low sample size, the difference between two periods may have been clarified. We attempted to analyze, excluding small samples for each year and quarter stratum that is the sample size being less than 118 fish (The number corresponds to the case that each bin has 5 samples on am average. Observation of data has 23.6 bins included sample. 23.6*5=118). Then, average of sampling efficiency was different between before 1968 and after 1994 8 (before 1968 is 21.3% and after 1994 is 29.5%).

Second reason of similar values of sampling specifications between two periods could be the distribution shape of length composition. If sampling efficiency varies with different complexity of shapes of distributions, for example unimodal or bimodal, then average of sampling efficiency may depend on the length composition of PBF for each year and quarter rather than sample size. In future, analyses using indicator of shapes of length composition would be made.

I pooled length data and resampled bootstrap with replication because average of length was most explained by month. But accuracy of sampling may not be directly associated with less residual of length average. In a future analyses, it should be attempted to pool various scales, i.e. landing port, latitude and longitude, quarter and year, and resample. That would help to understand construction of errors.

Estimated ESS is about 80 on an average. This value is close to ESS of Japanese parse seine (71.6) and considerably larger than that of EPO parse seine (15.6). By using estimated ESS of JLL, it is possible to give more weight to the length compositions of that fishery in stock assessment model (ss3). See document ISC12/PBF02-10for more information on the effect of estimated effective sample size of JLL.

Reference

Ichinokawa, M., (2007), Length frequency of Pacific bluefin tuna caught by Japanese longliners, ISC07/PBF1-11

Kanaiwa, M., Shibano, A., Shimura, T., Uji, R., and Takeuchi, Y., (2008), Estimation of effective sample size for landing data of Japanese purse seine in Sakai-Minato, ISC08/PBF01-06

Mizuno, A., Oshima, K., and Takeuchi, Y., (2012), Estimation of length compositions on Pacific Bluefin Tuna caught by Japanese longline fishery, ISC12/PBF01-01

Hulson, P.-J. F., Hanselman, D. H.,Quinn, T. J., (2011), Effects of process and observation errors on effective sample size of fishery and survey age and length composition using variance ratio and likelihood methods., ICES J.Mar. Science, 68(7), 1548-1557

Pennington, M., Burmeister, L.-M., Hjellvik, V., (2002), Assessing the precision of frequency distributions estimated from trawl-survey samples, Fish. Bull., 100, 74-80

Figs and Tables

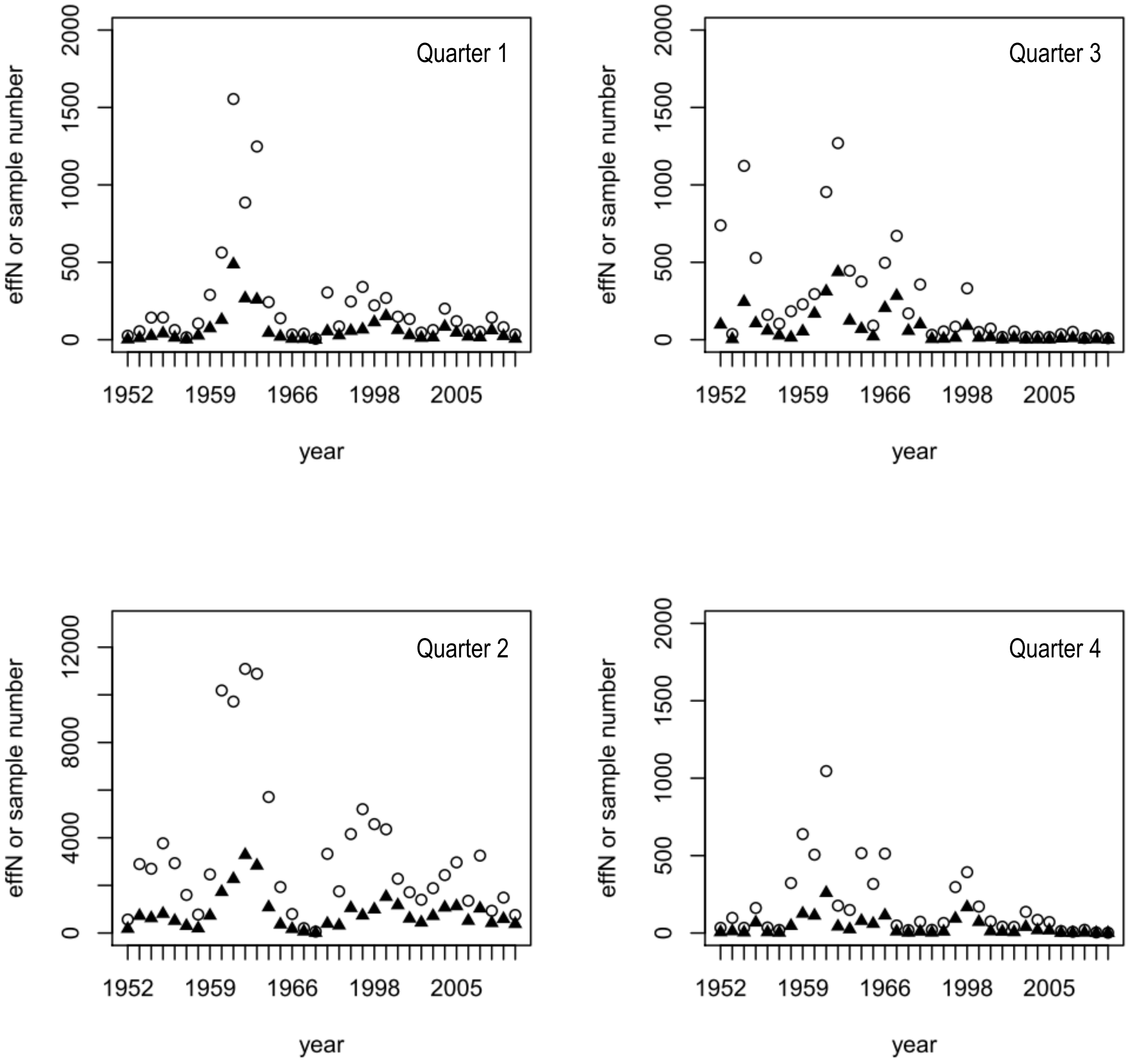


Fig.1 Estimated effective sample size (black triangle) and sample size (open circle) each year and quarter.

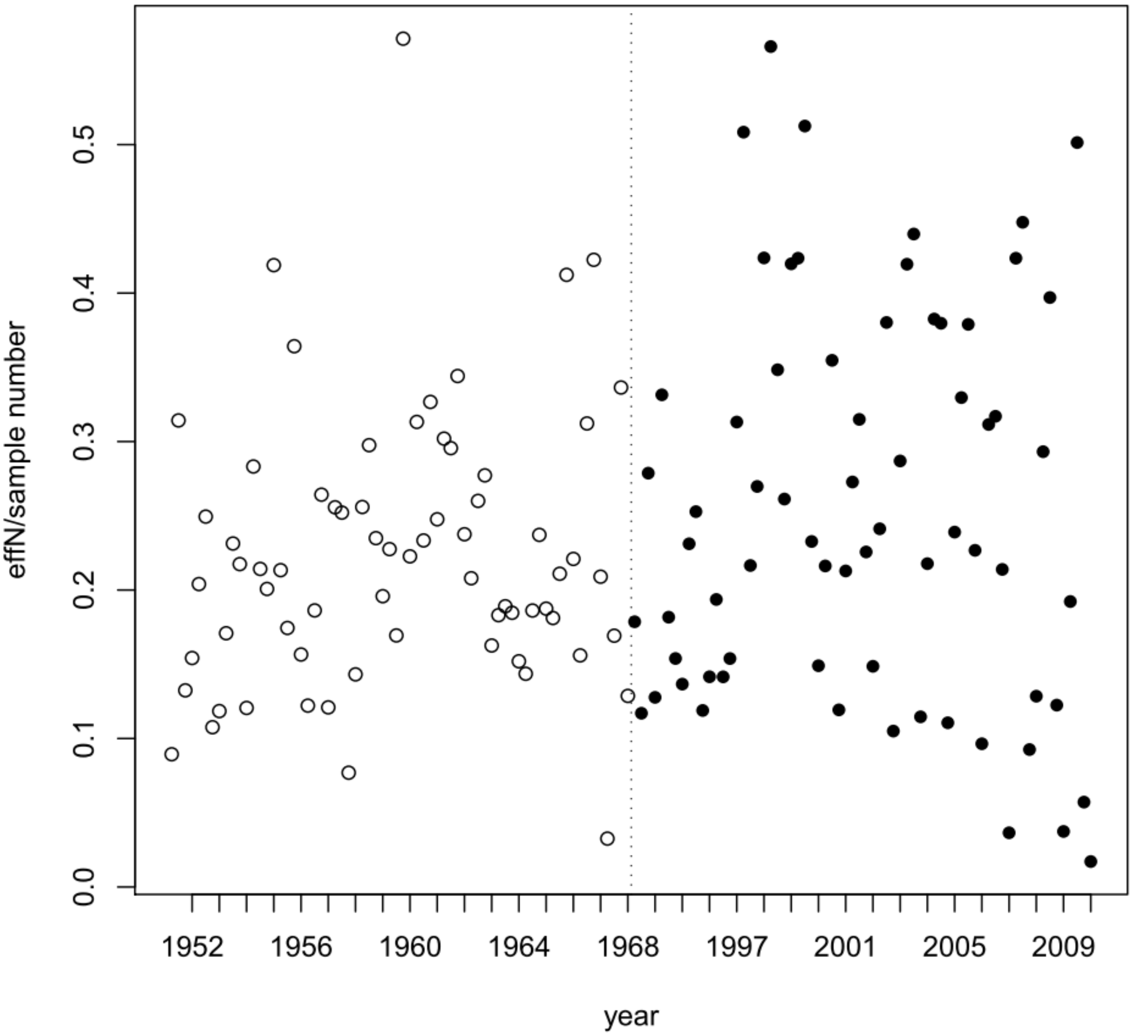


Fig. 2 Sampling efficiency each year and quarter. Open circle is data before 1968 and black circle is after 1994.

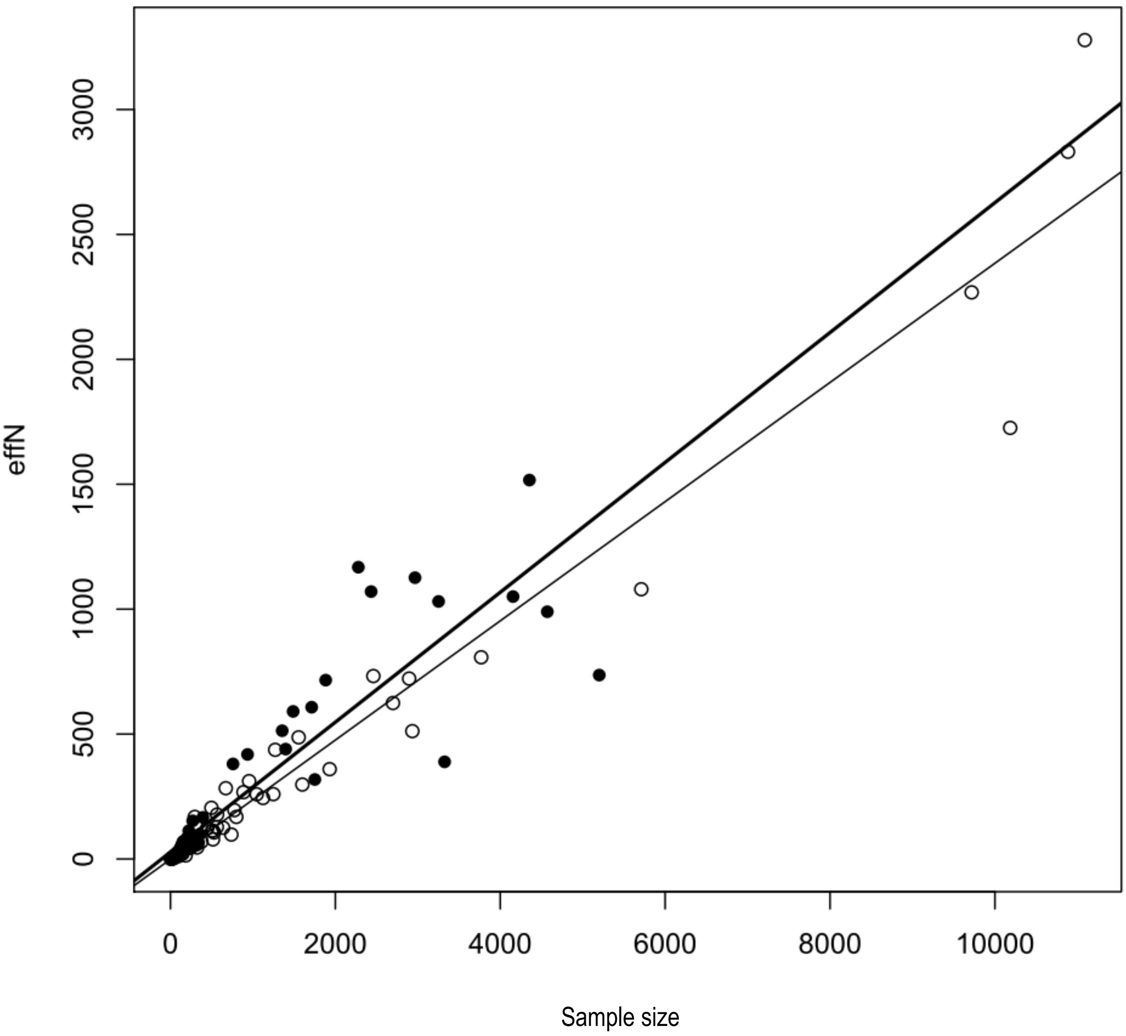
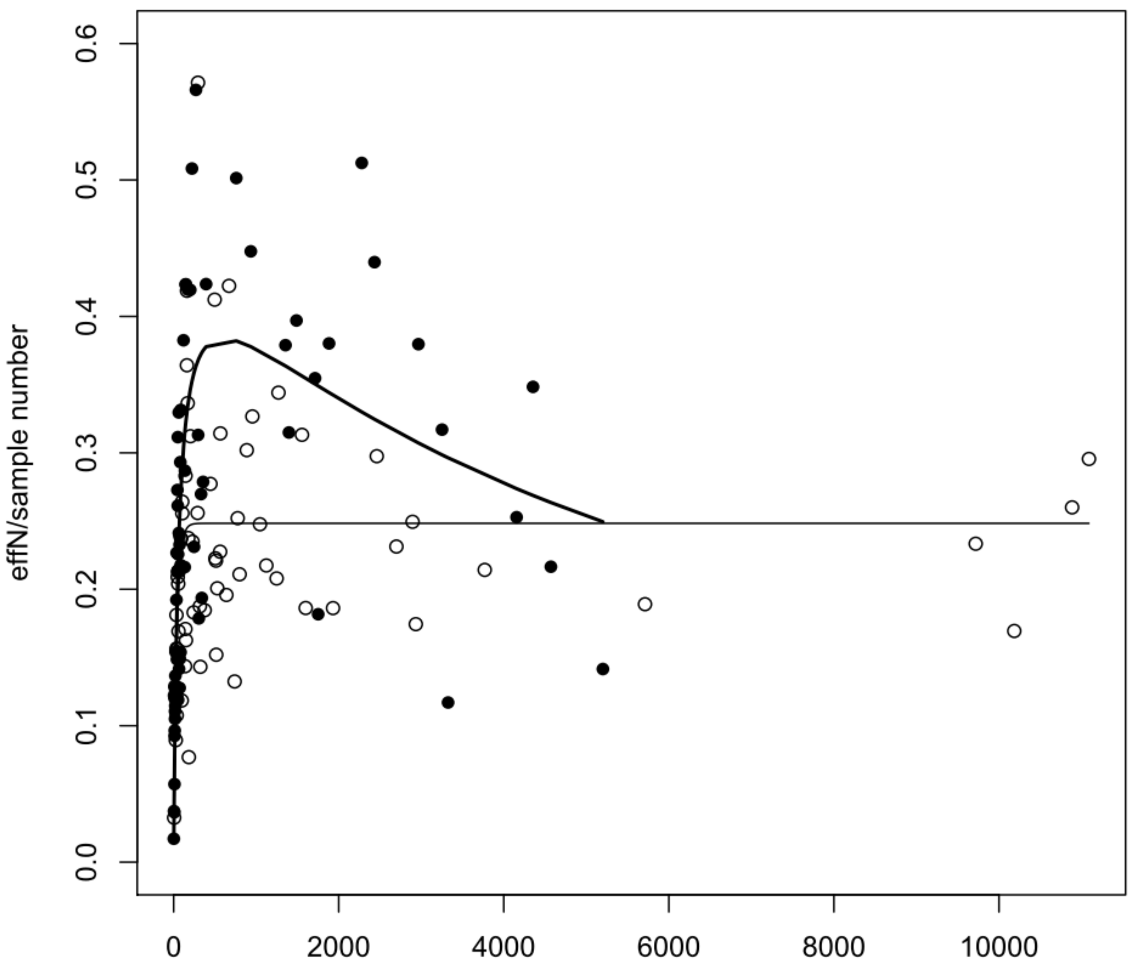


Fig.3 Estimated effective sample size against sample size. Open circle is data before 1968 and black circle is after 1994. Thin line is regression line for data before 1968 and Thick line is that after 1994.



Sample size

Fig. 4 Sampling efficiency against sample size. Open circle is data before 1968 and black circle is after 1994. Thin curve line is regression line for data before 1968 and Thick curve line is that after 1994.

Table 1 statistical results of ANOVA to estimate sample size and effective sample number of length composition each year and quarter. The model includes the effect of era (effective sample size).

Sample number

Null model

	Estimate	DF	Std. error	t value	Pr(>|t|)
Intercept	996.2		172.7	5.77	5.18e-08

ESS

Null model

	Estimate	DF	Std. error	t value	Pr(>|t|)
Intercept	258.68		43.58	5.936	2.34e-08

Anova model

	Estimate	DF	Std. error	t value	Pr(>|t|)
Intercept	301.80		61.64	4.897	2.76e-06 ***
~1968 and 1994~	-86.25		87.17	-0.989	0.324

Table 2 statistical results of linear regression to estimate sampling efficiency from sample size each year and quarter. The model includes the effect of era.

Sampling efficiency

Null model

	Estimate	DF	Std. error	t value	Pr(>|t|)
Intercept	0.238		0.009728	24.48	<2e-16

Anova model

	Estimate	DF	Std. error	t value	Pr(>|t|)
Intercept	0.22348	1	0.01369	16.320	<2e-16 ***
~1968 and 1994~	0.02928	1	0.01936	1.512	0.133

Table 3 statistical results of non-linear least-squares method to sampling efficiency from sample number

Coefficient of model for data before 1968

	a	b	c	residual	DF	AIC
Model 1 saturated function (exponential)	0.24831	-0.02643	-	0.408	3	-148.9060
Model 2 saturated function	0.2198	-7.69e+04	-	0.5522	3	-128.3354
Model 3 saturated function	3.869	80.787	-	0.4181	3	-147.2460
Model 4 attenuation function	8.259e-05	3.695	9.11	0.411	4	-146.4198

Coefficient of model for data after 1994

	a	b	c	residual	DF	AIC
Model 1 saturated function (exponential)	0.33786	-0.01993	-	0.5403	3	-129.81178
Model 2 saturated function	0.2378	-1.151e+04	-	1.107	3	-81.06619
Model 3 saturated function	2.821	87.521	-	0.5688	3	-126.31740
Model 4 attenuation function	3.453e-04	2.188	0.01271	0.4838	4	-135.33069

Function type for Model 1 : y=a*(1-exp(b*x)), Model 2: y~a*(1-x/b), Model 3: y~x/(a*x+b), Model 4: y~x/(a*x^2+b*x+c)