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On accuracy of the estimated fish school weights by sonar specialists

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Contents:

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1. Introduction

In the SBT acoustic survey off Esperance in WA, sonar specialists estimate weights of the fish schools detected by the sonar CRT, which are used to estimate the SBT population during the survey period in the survey area. Therefore, estimated SBT population are critically influenced by their judgments (estimations) of the individual SBT school weights. In this paper, accuracy of the sonar specialists' estimation of the fish school weights are examined through simple experiments conducted in the purse seine boats operating in the Pacific Ocean.

2. Experiments

The only approach to check accuracy of the estimated fish school weights by the sonar specialists in the SBT acoustic survey, is to measure the weights directly by catching the whole school observed in the sonar CRT on site. However, it is technically and also financially difficult to catch the whole school at the current budget level. Instead of conducting such direct verification, this paper attempts to evaluate accuracy of the fish school weight estimation by taking advantage of the purse seine operations conducted in the Pacific Ocean, i.e., two types of data (real catch and fish school weights estimated by the sonar specialists) are collected, which are statistically examined.

The sonar specialists participating in the SBT acoustic survey, used to work in these purse seine fisheries in the Pacific for long periods. Therefore, this comparison will be a reliable and practical reference to evaluate accuracy of their estimations in the SBT acoustic survey, although it is the indirect approach.

Two purse seine vessels (A & B) belonging to Taikei Fisheries Inc., and one boat (C) to Kyokuyo (fishing) Inc., participated in this investigation from November, 1996 to August, 1997. There are five sonar specialists in this experiment. Table 1 summarizes the areas and the periods of the fishing operations (experiments) by boat. The sonar specialists took both records (in MT) of the real catch and the estimated fish school weights in the net observed in the sonar CRT.

In each boat, there are one or two specialist/s (usually captain and/or radio operator). In some boat, one specialist engages in searching and estimating the fish schools and another (captain) operates the boat to approach the fish school for setting the net and estimate the school weights in the net by looking at the sonar CRT. In some boats, only one specialist conducts these practices by one person. Table 2 lists years of experiences of sonar specialists for the omni scan sonar, who made estimations of the fish school weights <u>in the net</u> (not for the specialists to search the fish schools and estimate the weights of these schools).

Major fish species caught by these purse seine boats are skipjack, yellowfin and bigeye and skipjack is the most dominate species. It is coincident that sizes (fork length) of SBT in the acoustic survey area and skipjack in this experiment are almost same classes ranging from 40-60cm.

Table 1 Area and periods of the purse seine boats which conducted the experiments.

Year/Mo vessel→	Ａ	Ｂ	Ｃ
1996/11		western Pacific	
1996/12		↓	western Pacific
1997/01		↓	↓
19970/2	western Pacific		↓
1997/03	↓		↓
1997/04	↓	western Pacific	↓
1997/05		↓	↓
1997/06		↓	
1997/07		off northern Japan	
1997/08		↓	

Table 2 Information on the sonar specialists

Vessel	Names of sonar specialists (initials)	number of the experiments (operations) (*)	Years of experiments of the omni scan sonar	Age
Ａ	ＡＢ	６６	１０	？
Ｂ	ＸＸ	４６	７	４７
Ｃ	ＹＨ	５１	１５	４９
	ＨＳ	２４	１５	４６
	ＫＯ	１８	５	４１

(*) Those experiments (operations) when fish escape from the nets are not included.

3. Analyses and Results

The raw data are plotted in Fig. 1. In Fig.1 (and also for Figs.2-3), 'XX', 'AB' -------, represent initials of five sonar specialists, while 'n' and 'years' represent sample size and years of experiences of the omni scan sonar, respectively.

The following simple linear regression model without y-intercept, (1), is used to examine accuracy of the estimates. It is assumed that when estimated weight (D) is 0, the real weight (R) is 0. Error terms are assumed to follow the log normal.

$$\mathrm{In}(D_i) = b\ \mathrm{In}(R_i) + \varepsilon_i \qquad (i = 1, \cdots, n) \tag{1}$$

, where In : Natural logarithm

D : Decision made by sonar specialist (estimated school weights in MT)

R : Real value (catch in MT)

b : Slope

ε_i : Error term is assumed to follow $N(0, \sigma^2)$

In the SBT acoustic survey, SBT school weights are less than 100 MT, thus no data more than 100 MT (for both D and R) are used for the analyses, which are plotted in Fig. 2 in log scale. The point (0,0) is not concerned in the analyses due to the log scale. The points with R=0 are also excluded, i.e., cases when fish are escaped from the net. In Fig. 2, 45 degrees line (slope = 1) represents exact (correct) estimation of the real catch. 'b' (slopes) are initially estimated and statistically examined if they are equivalent to 1, i.e., Ho : b=1 Ha: b $\neq$ 1 . The test statistics (T) is represented as below:

$$T := \frac{(\hat{b} - b)\sqrt{\sum_{i=1}^{n}\{\mathrm{In}(R_i)\}^2}}{s} \qquad \left(s^2 := \frac{1}{n-1}\sum_{i=1}^{n}\varepsilon_i^2 、 E\left[s^2\right] = \sigma^2 \right) \tag{2}$$

T follows t distribution with (n-1) degree of freedom. Two tails statistical test with 5% of α (significance level) are used. Table 3 shows the results. The residuals are plotted against R (real catch) in Fig. 3.

Fitness of the data to the model (1), is examined by mean square error (MSE) which is defined by (3):

$$\mathrm{MSE}(R, D) := \frac{1}{n}\sum_{i=1}^{n}\left[\,\mathrm{In}(R_i) - \mathrm{In}(D_i)\,\right]^2 = \frac{1}{n}\sum_{i=1}^{n}\left\{\mathrm{In}\left(\frac{R_i}{D_i}\right)\right\}^2 \tag{3}$$

Then, accuracy of the estimations among five sonar specialists are compared by relative mean squared error (RMSE), which are defined by the equation (4). This is not a general concept, but derived particularly for this case (per. comm. with Dr. H. Kishino).

$$\mathrm{RMSE}(R, D) := \frac{1}{n}\sum_{i=1}^{n}\left(\frac{R_i - D_i}{R_i}\right)^2 = \frac{1}{n}\sum_{i=1}^{n}\left(1 - \frac{D_i}{R_i}\right)^2 \tag{4}$$

Results of (3) and (4) are summarized in Table 3.

Table 3 Results of the regression analyses, statistical tests, fitness to the model and degrees of accuracy

Initials of sonar specialist	years of experience	b (estimated slope) ( ) bias from 1	T (test statistics)	t(n-1,α /2) critical value at α =5%	Decision of H o (b=1)	MSE (fitness to the model (rank) best to worst	RMSE (accuracy of estimates) (rank) best to worst
AB	10	0.993(-0.007)	0.676	2.000	accepted	0.070 (1)	0.000994 (1)
XX	7	0.948(-0.052)	1.019	2.014	accepted	1.101 (5)	0.006965 (4)
YH	15	1.024(+0.024)	0.742	2.010	accepted	0.491 (4)	0.003059 (3)
HS	15	1.020(+0.020)	0.541	2.074	accepted	0.256 (3)	0.001782 (2)
KO	5	1.059(+0.059)	1.589	2.120	accepted	0.180 (2)	0.008953 (5)

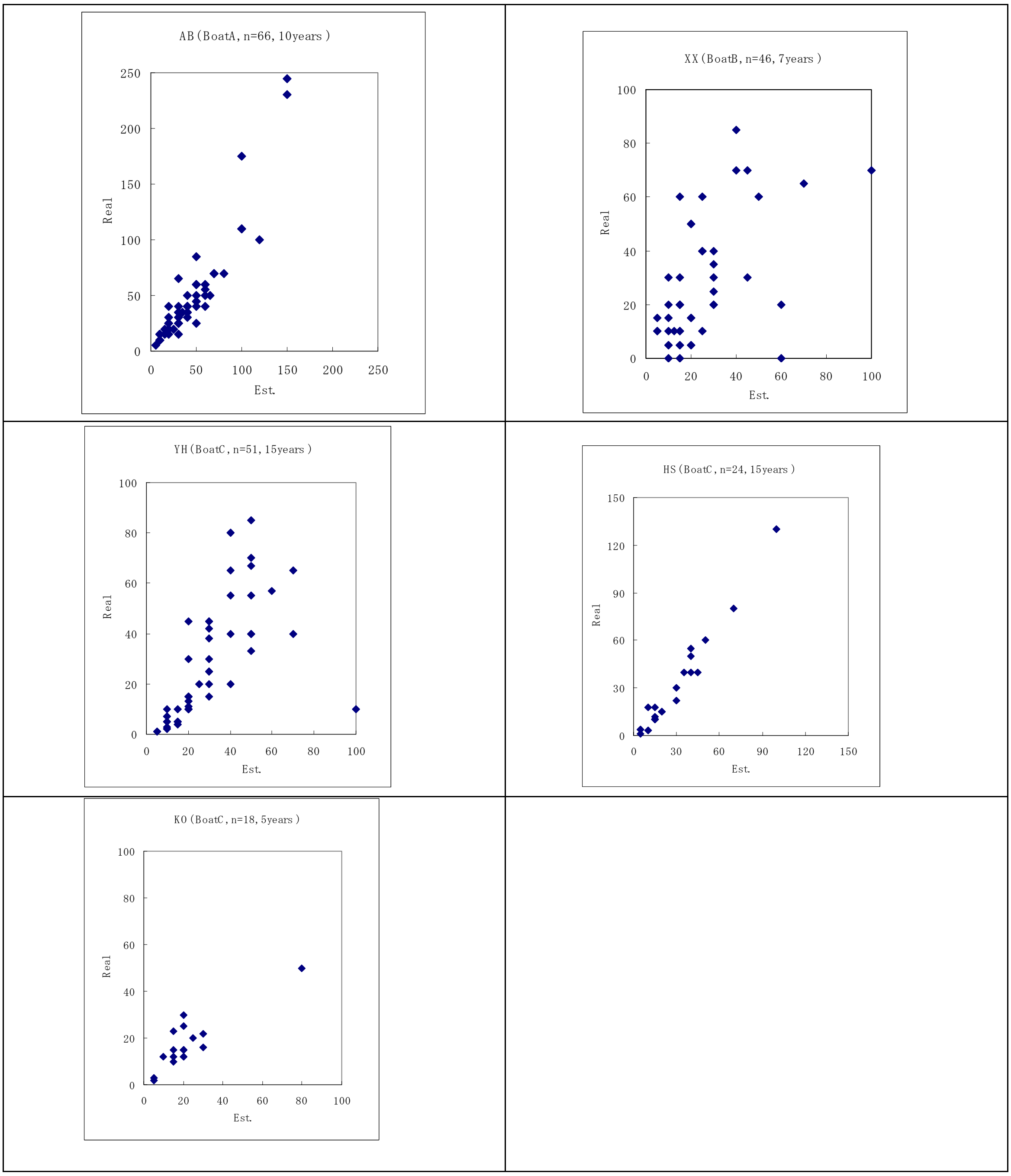


Fig. 1 Scatterplots of Decision (estimation) of the weights (MT) by five sonar specialists vs. Real weights (MT) of the catch (raw data). ‘AB’, ‘XX’,--- indicate initials of names of the sonar specialists. ‘Years’ means the period of the experience of the omni scan sonar by each specialist.

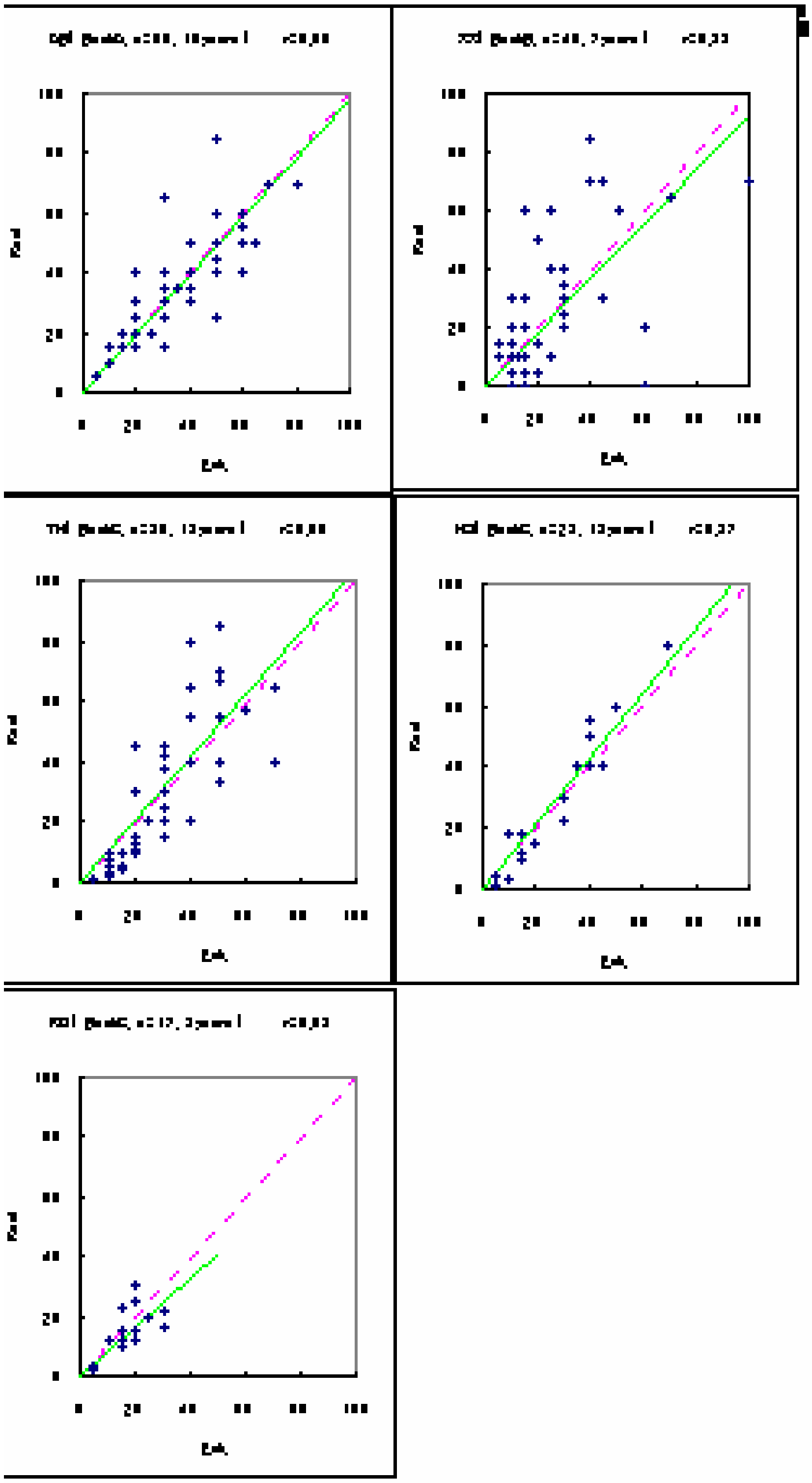


Fig. 2 Scatterplots of Decision (estimation) of the weights (MT) by five sonar specialists vs. Real weights (MT) of the catch (raw data) in log scale within 100 MT. ‘AB’, ‘XX’,--- indicate initials of names of the sonar specialists. ‘Years’ means the period of the experience of the omni scan sonar by each specialist. 45 degrees lines (broken lines) indicates the exact relation (real catch = decided or estimated catch), while the solid lines are the estimated regression lines with the y-intercept=0. Real catch=0 are not included in the analyses.

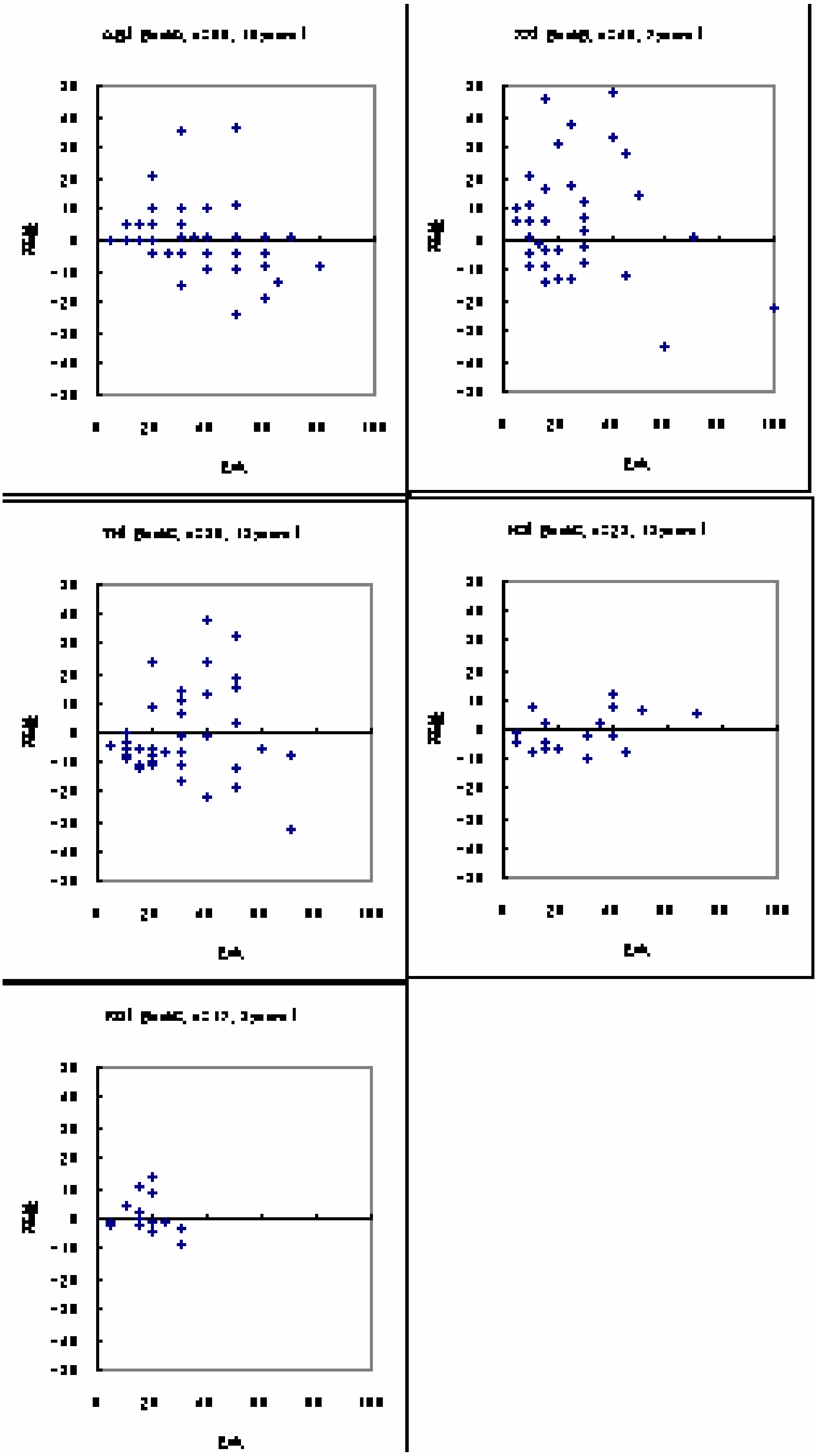
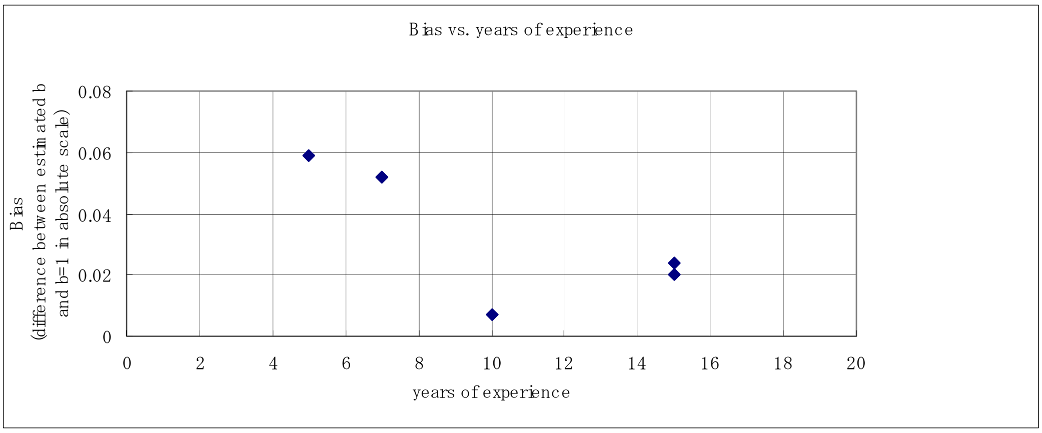


Fig. 3 Residual plots.

4. Discussion

As a result of the statistical tests, decisions (estimation of school weight) made by all five specialists are statistically not different from the real catch. This means that there are no significant bias in their estimations. Among five specialists, it was resulted that estimation by AB,YH and HS are less biased than in other two (XX and KO).

For the fitness to the model (MSE) and accuracy of the estimations (RMSE), the order from the best to the worst among five specialists is same expect KO. The reason why KO resulted to be the good fitness (MSE) to the model, is as follows: KO did not have the data ranging more than 50 MT like others and points well fit around the line. In this sense, it is likely that RMSE is the better indicator to evaluate accuracy of the judgments of sonar specialists because RMSE takes account of bias and variance into its value. In general, more experienced specialists can provide more accurate estimation (less bias with less variance) as describe in Fig. 4.



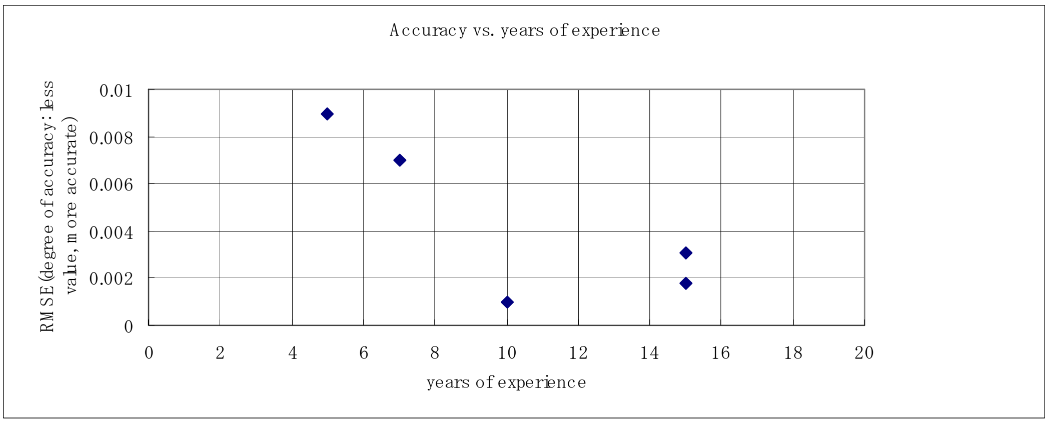


Fig. 4 *(upper)* Bias vs. years experience *(lower)* Accuracy vs. years of experience

In purse seine fishing operations, sonar specialists repeat to compare and evaluate between estimated catch ←→ real catch in many times a year. Thus, they can naturally learn conditions or patterns of images of fish school in the sonar CRT and they can relate these information to the real catch weights. As they accumulate more experiences, they naturally gain and build abilities to make accurate estimations close to the real catch.

In this experiment, sonar specialists looked at the image of fish schools in the net close to the boat with high frequency mode without restrictions of operations of the sonar. On the other hand, in the SBT acoustic survey, sonar specialists watch image of the fish schools in the restricted search range (600m in radius) with fixed tile angle (6^o) and lower frequency mode. Therefore, accuracy of the estimations by specialists in the acoustic survey are considered to be less than in this experiment. However, average year of experiences are longer (10, 13 and 19 years) in the SBT acoustic survey than in this experiment. Thus, it is necessary to consider these two factors to infer real accuracy level of school weights estimated by sonar specialists in the SBT acoustic survey.

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Reference

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