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EFFECTS OF SUBSTITUTION OF LENGTH FREQUENCY SAMPLES BETWEEN SAMPLED AND UNSAMPLED STRATA

by

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INTRODUCTION

Age-based status of stocks analyses for tuna, in various Ocean areas, have been conducted for many years. Some examples are yellowfin tuna in the eastern Pacific (IATTC 1991) and albacore, skipjack, yellowfin, bigeye and bluefin tunas in the Atlantic Ocean (ICCAT 1990). In all of these analyses, a length-frequency data base was created for all fisheries exploiting the stock. In the process of creating many of these data bases, length-frequency data were often substituted between fishing fleets for missing data. Even for fishing fleets that had been sampled, many times some months and areas were unsampled and length-frequency data from adjacent areas or months had to be substituted. Usually, the substitutions were assumed correct, and no attempt was made to verify any bias in the substitutions.

At the second meeting of the Western Pacific Yellowfin Tuna Research Group (WPYRG 1993), concern was expressed at the amount of substitution that was needed to compile a length-frequency data base for yellowfin tuna. The group asked that an assessment of the appropriateness of the substitutions be made. The objective of this study is to statistically assess the validity of substitutions of age-frequency or length-frequency data between months, areas or fishing fleets. The U.S. purse seine, southwestern Pacific fishery, yellowfin tuna length-frequency data are used to assess the effects of substitutions between areas and months and the Japanese and U.S. purse seine, southwestern Pacific, yellowfin tuna length-frequency data are used to assess the effects of substitutions between fishing fleets. Some of the length-frequency data was also aged to assess the effects of substituting age frequencies instead of length frequencies.

DATA

Length-frequency samples, taken from U.S. purse seiners as they unloaded their catches in Pago Pago, American Samoa in 1989 and 1990, were combined by Western Pacific Yellowfin (WPYF) area (Figure 1) and month strata. Samples were taken from purse seine wells that could be identified to a single month, sampling area and type of set, i.e. those associated with floating objects (log sets) and those unassociated, free-swimming schools (school sets). Sample sizes usually varied between 50 to 100 fish per sample. However, smaller sample sizes were sometimes taken when of the amount of fish landed was small. Over 27,000 yellowfin tuna from school and log sets were measured for fork length in 1989 and 1990 (Table 1). Most of the samples came from area 4, in both 1989 and 1990. In 1990, a substantial number of samples also came from area 5. Sample sizes for length frequencies combined by month and WPYF area strata varied between 17 and 4,329 fish. Although samples were also taken from wells that could not be identified by type of set or that contained a mixture of both log and school sets, only log and school set samples were used in this analysis.

Length-frequency data for Japanese purse seine yellowfin tuna catches in 1989 and 1990, were supplied at the second meeting of the WPYRG. The data were already summarized by WPYF area, type of set and quarter. The total number of fish sampled from school and log sets in 1989 was 13,562, and in 1990, 20,325. The sample size in each quarter and WPYF area strata is unknown and the amount of substitution between strata is unknown. All of the samples were from WPYF area 4, and all quarters had length-frequency data for both 1989 and 1990. As with the U.S. data, samples were also taken from other types of sets, but only data from log and school sets are used in this analysis.

METHODS

Yellowfin tuna length and age-frequency data from catches of U.S. purse seiners fishing in the southwestern Pacific were used to compare substitutions between months and WPYF areas. Length frequency data substitutions were compared for log and school sets in all areas and months fished in 1989 and 1990. However, monthly comparisons were made for log and school set age frequencies in 1989, area 4, only, and area comparisons from 1990, school set age frequencies in areas 4 and 5, only.

In general, area-time strata where length or age-frequency samples existed were assumed to be unsampled and two types of monthly substitutions were made; one which substituted data from a single month that followed the missing month, and one which substituted data from the adjacent two months, before and after the missing month. For example, the U.S. length or age-frequency data in area 4, month 1, was assumed missing and length or age frequencies in area 4, month 2, were substituted, or length or age frequencies in area 4, month 2, was assumed missing and length or age frequencies from month 1 and 3, area 4, were substituted. Monthly substitutions were made only between months in the same WPYF area and set type.

Area comparisons were made by substituting yellowfin tuna length or age frequencies from area 4, for length or age frequencies of catches in areas 3, 5 or 6, in the same month. All Comparisons were made between log and school sets separately.

Comparisons between fishing fleets were made by substituting yellowfin tuna length or age-frequency data from catches of Japanese purse seiners for U.S. purse seine yellowfin catch length frequencies in the same quarter and WPYF area 4. Since the Japanese data were by quarter, U.S. monthly frequencies were combined to quarter (January-March, April-June, etc.). Log and school sets were again treated separately.

Comparisons between the substituted area, time, or fleet length or age frequencies and those that were actually taken were made with the Kolmogorov-Smirnov nonparametric test of distributions (Zar 1974). The test compares the relative maximum distances (D values) between the two cumulative distributions (substituted and actual) and compares this value to a critical D value. Because of the large sample sizes, many critical D values could not be found in statistical tables and had to be calculated using,

$$D \text{ critical} = \ln(1/.05)/n$$

where n is the sample size. All comparisons were made at the 95% confidence level. The null hypothesis in each case was that the substituted and actual length or age frequencies were the same.

Yellowfin tuna age-frequency data were generated from length-frequency data using a computer program, MULTIFAN (Otter Research 1990). MULTIFAN determined the best fit, in all cases aged, to be the model with von Bertalanffy growth parameter K of 0.3, and 7 age classes.

RESULTS

Comparisons Using Following Month's Data

Comparisons of monthly yellowfin tuna length-frequency distributions, when the following month's data were substituted, led to the rejection of the null hypothesis in every comparison (Figure 2). D values were consistently above the critical D values. The most statistically significant difference in D values for log sets occurred in 1990, when month 6 length frequencies, were substituted for month 5 (>0.4 units) and the least significant difference also occurred in 1990, when month 7 data, were substituted for month 6 (0.01 units).

D values in school sets, for substitutions between months where the following month's data were used, differed more significantly than D values in log sets. The most significant difference occurred in 1990, when month 2 length frequencies, were substituted for month 1 (0.8 units), while the least significant difference occurred in 1989, when month 7 was substituted for month 6 (0.1 units).

The use of yellowfin tuna age frequencies instead of length frequencies in substitutions between months, where the following month's data were used, again led to the rejection of the null hypothesis in each comparison (Figure 3). While some of the D values obtained using age frequencies were closer to the critical D value, than when using length frequency data, others were even more significantly different. For log sets in 1989, only 4 out of 9 comparisons showed an improvement and for school sets, only 4 of 11.

Comparisons Using Two Adjacent Month's Data

Comparisons of monthly length-frequency distributions, when the two adjacent month's length-frequency data were substituted, led to a rejection of the null hypothesis in each comparison (Figure 4). For log sets, the most statistically significant difference occurred in 1990, when months 9 and 11 length-frequencies were substituted for month 10 (0.4 units) and the least in 1989, when months 5 and 7 data, were substituted for month 6 (0.03 units).

Again as when single months were substituted, substitutions of school sets length-frequencies were more significantly different than those substitutions made in log sets. The most significant difference in D values for school sets occurred in 1990, when months 1 and 3 length frequencies, were substituted for month 2 (0.6 units) and the least significant difference occurred in 1990, when months 5 and 7 data were substituted for month 6 (0.08 units).

The use of age frequencies instead of length frequencies in substitutions between months, where the two adjacent month's data were used, led to the rejection of the null hypothesis in all but one comparison (Figure 5). Substitution of age frequencies in months 6 and 8 for month 7 age frequencies, in 1989, led to the acceptance of the null hypothesis. For the rest of the substitutions, some of the D values, obtained using age frequencies, were closer to the critical D value, than when using length frequency data, others were even more significantly different. For log sets, only 3 out of 7 comparisons showed an improvement and for school sets, only 2 of 10.

Comparisons Between Areas

Area comparisons were very limited, since U.S. purse seiners tended to fish mainly in area 4. However, two log set comparisons (areas 3, 4 and 5) and six school set comparisons (areas 3, 4, 5, and 6) of length-frequency substitutions led to the rejection of the null hypothesis in every case (Figure 6). The least significant difference was obtained when school set length frequencies in area 4, were substituted for area 5 length frequencies, in month 8 (0.07 units). The most significant difference was obtained when area 4, school set length frequencies were substituted for area 6, in month 12 (0.8 units).

Comparisons between areas, using age frequencies instead of length frequencies, led to the rejection of the null hypothesis in every case (Figure 7). Only two out of the six age-frequency comparisons showed improved D values over length-frequency comparisons.

Between Fleet Comparisons

Substitution of Japanese fleet, yellowfin tuna length frequencies for U.S. catches in area 4, led to the rejection of the null hypothesis for all comparisons (Figure 8). The most significant difference in D values, for log set substitutions, occurred in 1990, quarter 4 (0.4 units) and the least significant difference in 1990, quarter 3 (0.2 units). Substitution of school set length frequencies produced more significant differences than with substitutions using log sets. The most significant difference in D values for school sets occurred in 1989, quarter 3 (0.7 units) and the least significant difference in 1990, quarter 2 (0.3 units).

Substitutions of age frequencies instead of length frequencies in between fleet comparisons, still led to the rejection of the null hypothesis in all cases (Figure 9). Improvements in the calculated D values were made for all school set comparisons and 1 of 4 log set comparisons.

CONCLUSIONS

Results indicate that any type of area or month substitution of length or age frequencies would probably lead to statistically significant differences between the substituted and the actual length frequencies. Differences were slightly less significant for monthly length or age-frequency substitutions than area length or age frequency substitutions, indicating that a greater difference in sizes of fish probably exist between areas than between some months. Differences between substitutions of log set length or age-frequency data were also slightly less significant than in school set substitutions, probably caused by the greater ranges of fish sizes in school fish samples. Therefore, if substitutions must be made monthly substitutions are preferred. There was no clear advantage over using age frequencies instead of length frequencies in substitutions.

Substitution of Japanese length-frequency samples for U.S catches would also lead to statistically significant differences between the actual and substituted samples. Again, log set differences were slightly less significant than school set differences. Differences noted in between fleet substitutions were probably caused by differences in operations of the two fisheries or in sampling of their catches. Therefore, an assessment of the operating characteristics of each fleet and the sampling procedures need to be made before substitutions can be made.

It should be noted that some of the differences noted here were very small in some cases, and that the Kolmogorov-Smirnov critical D values are directly related to sample size. The higher the sample sizes the narrower the constraint on the D values. The high sample sizes in most area-time strata for the U.S. and Japanese fisheries forced a very narrow constraint on the D values and a resulting rejection of the null hypothesis, in some comparisons, even though the length frequencies looked very similar (Figure 10). If strata sample sizes were 100 fish, the null hypothesis would have been accepted in 14 of the 79 monthly comparisons of length-frequency substitutions. This would again lead to support of monthly substitutions over area substitutions.

In any case, substitutions seem to lead to a high probably of making a mistake in the actual length frequencies of substituted months, areas or fleets. One solution may be to develop an analytical model that would make use of only the actual data with no substitutions. Another solution is to sample as many fleets as possible and as many areas and months fished by each fleet.

LITERATURE CITED

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Otter Research 1990. MULTIFAN 3. User's guide and reference manual. Otter Research Ltd., Canada.

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Table 1: Western Pacific yellowfin (WPYF) areas sampled and number of samples in each month and WPYF area sampled for fork length of yellowfin tuna caught by U.S. purse seiners fishing in the southwestern Pacific in 1989 and 1990.

MONTH	1989 SAMPLING COVERAGE					1990 SAMPLING COVERAGE			
	LOG SETS		SCHOOL SETS			LOG SETS		SCHOOL SETS	
	AREA 3	AREA 4	AREA 3	AREA 4	AREA 6	AREA 4	AREA 5	AREA 4	AREA 5
1	-	365	-	1,482	-	1,519	-	568	-
2	-	1,167	-	146	-	1,204	-	806	-
3	-	1,607	-	634	-	3,233	-	877	17
4	-	1,464	-	127	-	4,329	-	339	-
5	-	1,920	-	403	-	347	-	1,290	-
6	100	4,028	-	910	-	139	-	700	734
7	-	645	-	724	-	713	-	733	297
8	-	1,081	-	1,442	-	240	-	204	1,794
9	-	-	200	3,103	-	380	90	-	2,346
10	-	86	-	1,713	-	-	292	712	202
11	-	418	-	1,714	-	135	-	1,179	300
12	-	1,709	-	690	75	853	-	695	-
TOTAL	100	14,490	200	13,088	75	13,092	382	8,103	5,690

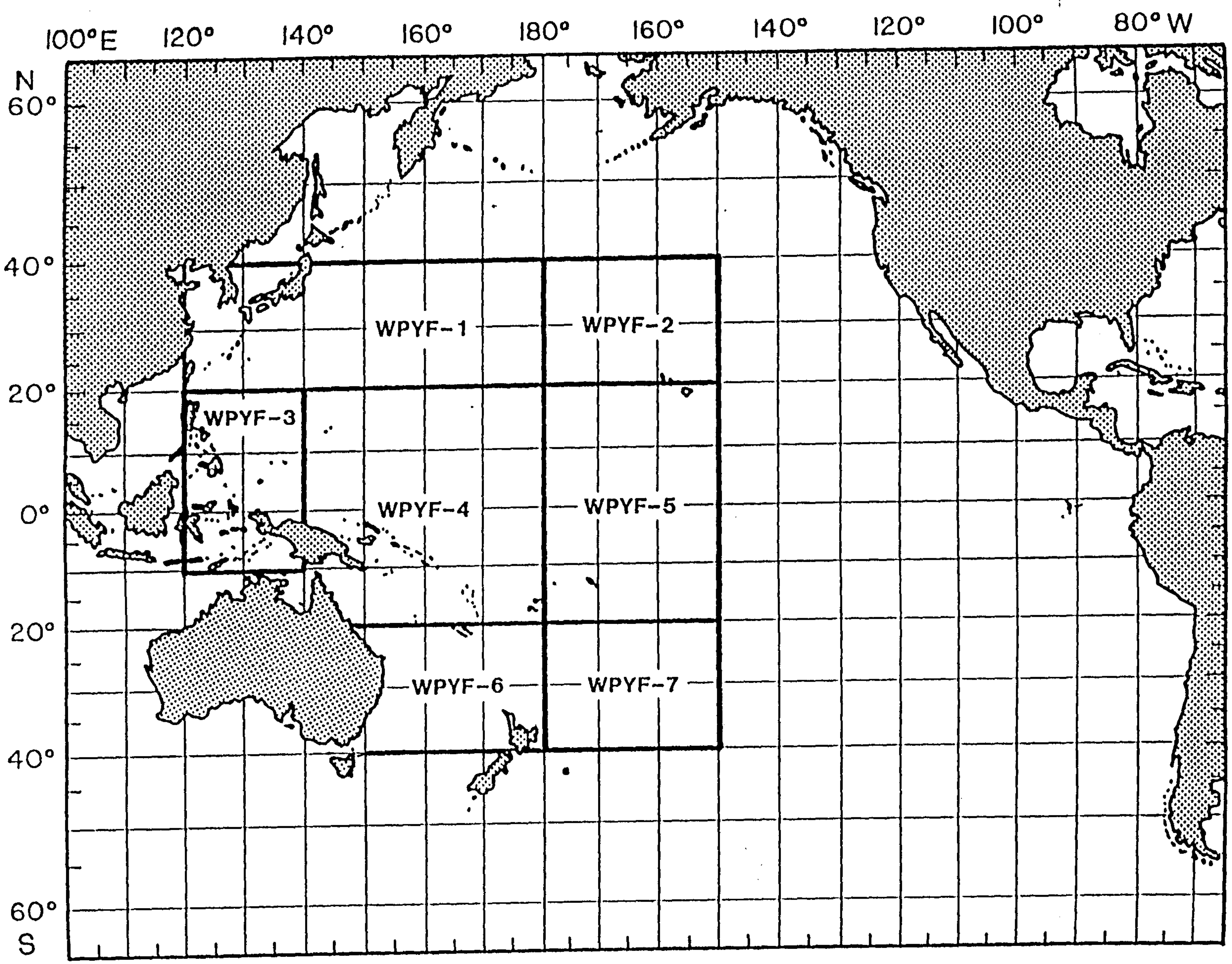


Figure 1: Western Pacific yellowfin tuna area strata used to summarize length and age frequency data.

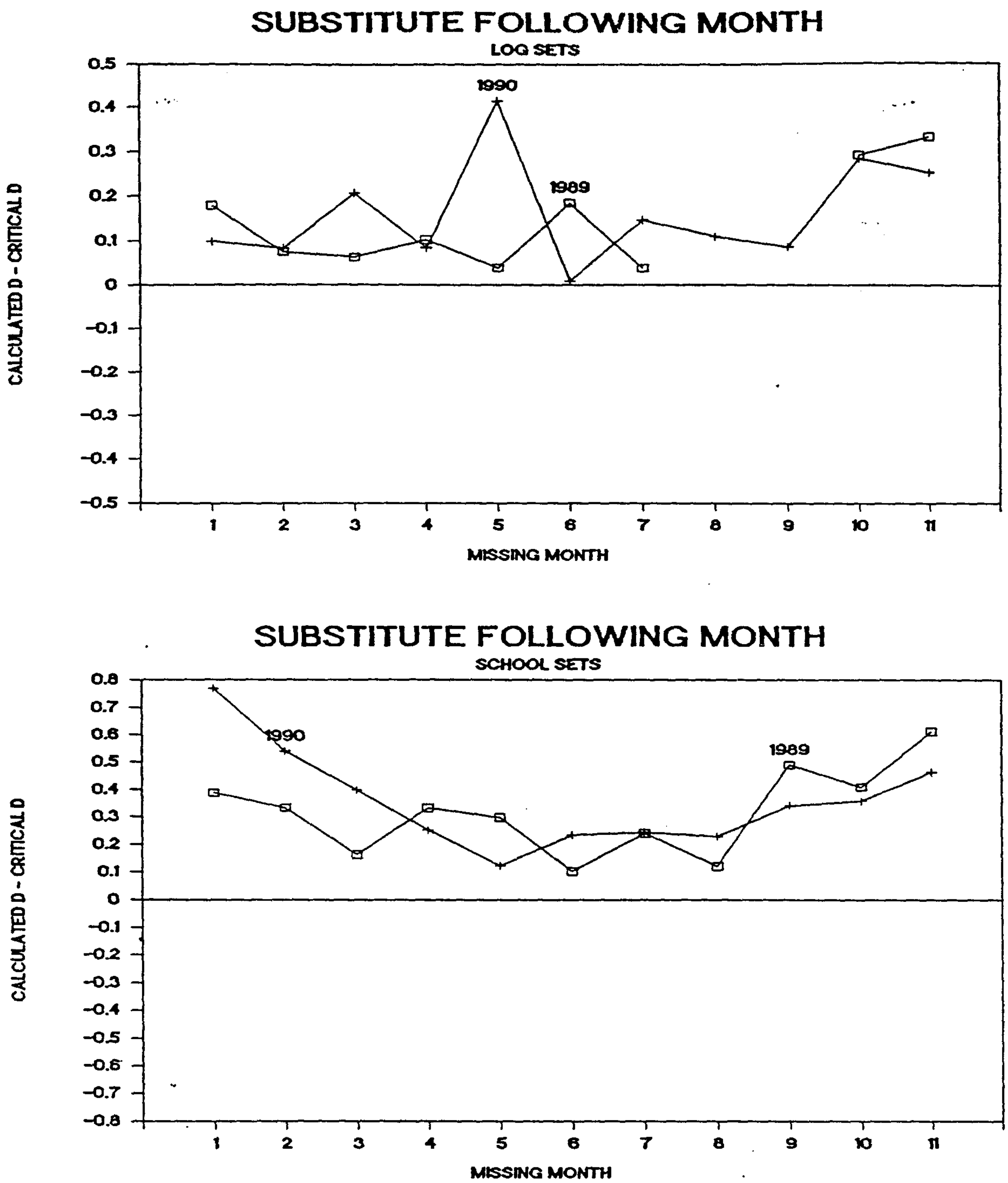
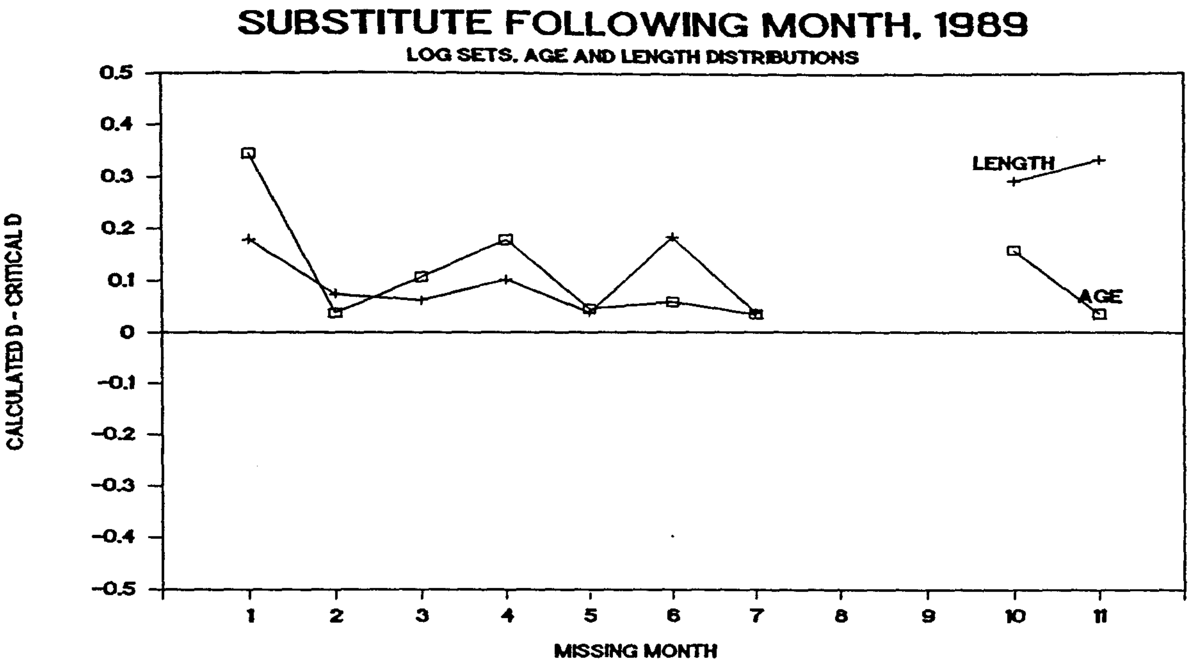


Figure 2: Comparisons of Kolomogorov-Smirnov D values (calculated D and critical D) obtained from substitutions of following month's length-frequency samples by year and type of set, log (top) and school (bottom). Values above the zero line would indicate a rejection of the null hypothesis and values below or on the line, an acceptance.



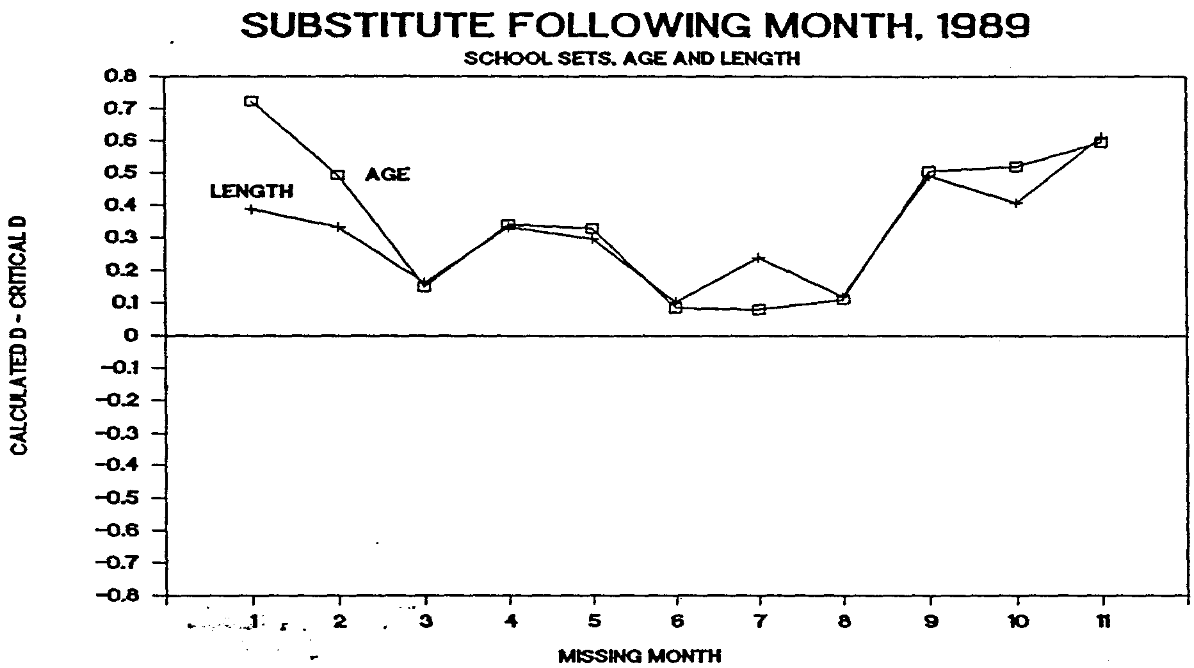
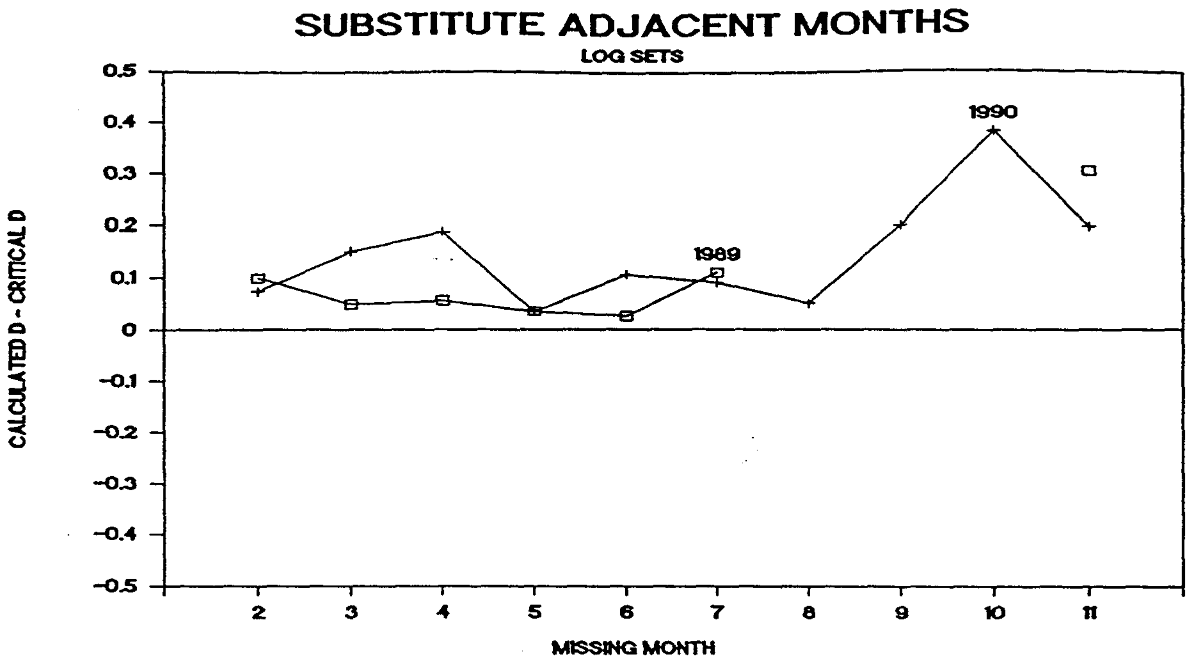


Figure 3: Comparisons of Kolomogorov-Smirnov D values (calculated D and critical D) obtained from substitutions of following month's age-frequency or length-frequency samples in 1989, by type of set, log (top) and school (bottom). Values above the zero line would indicate a rejection of the null hypothesis and values below or on the line, an acceptance.



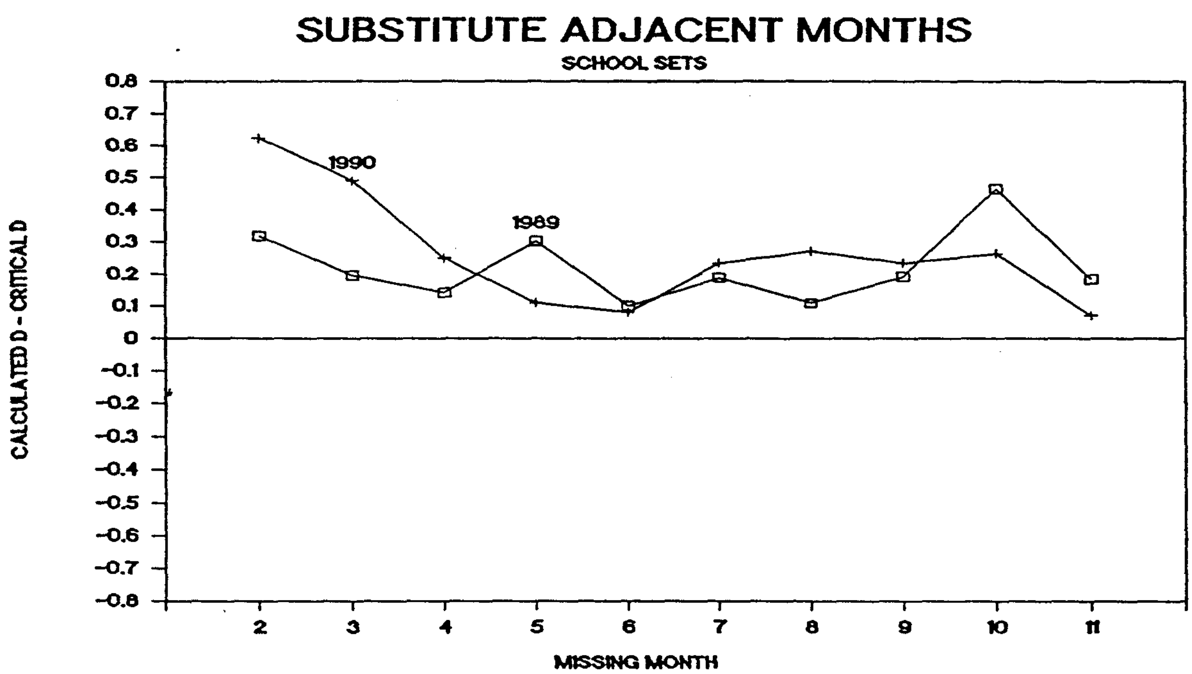
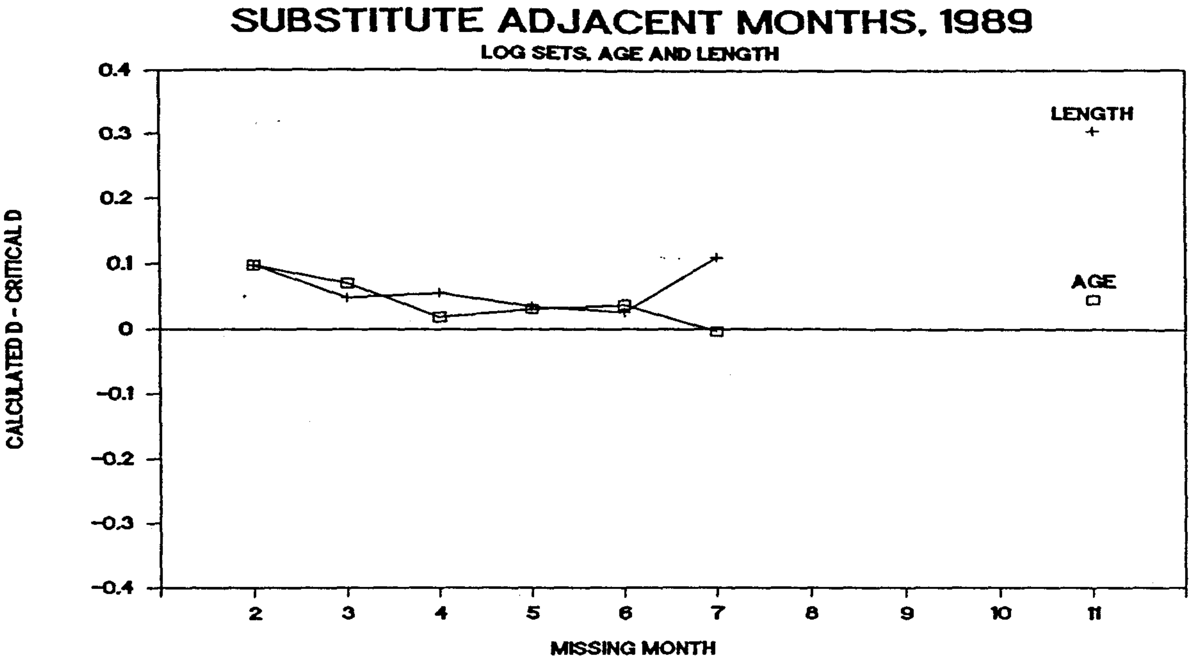


Figure 4: Comparisons of Kolomogorov-Smirnov D values (calculated D and critical D) obtained from substitutions of the adjacent two month's length-frequency samples by year and type of set, log (top) and school (bottom). Values above the zero line would indicate a rejection of the null hypothesis and values below or on the line, an acceptance.



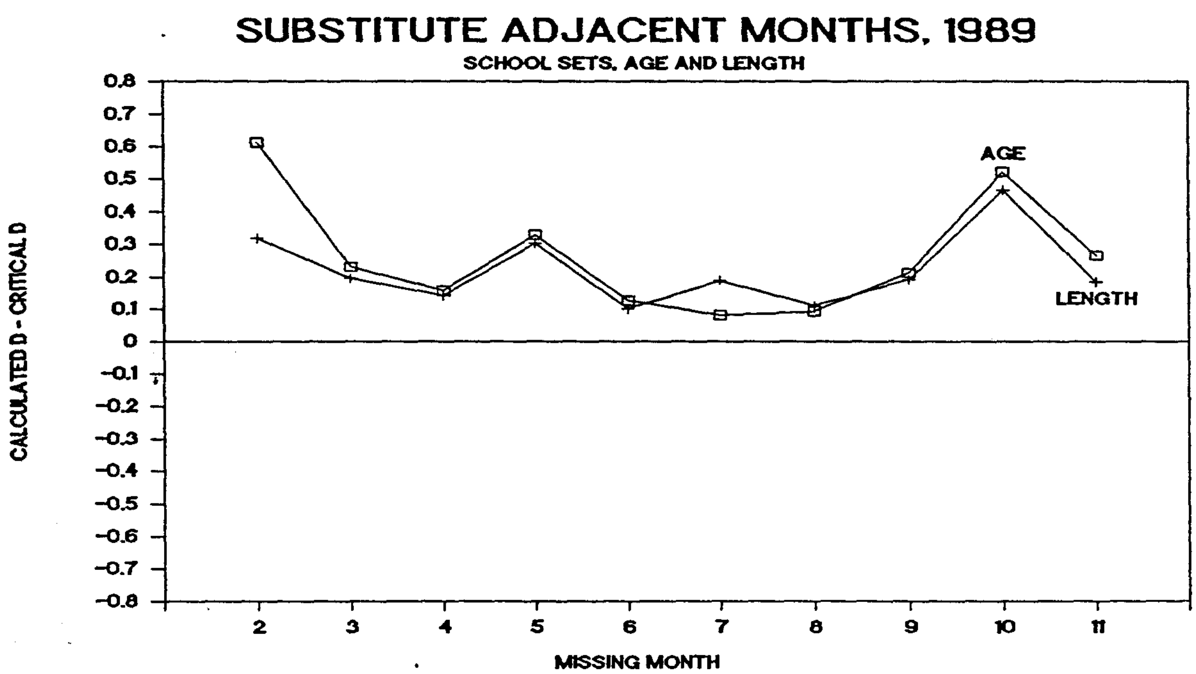


Figure 5: Comparisons of Kolomogorov-Smirnov D values (calculated D and critical D) obtained from substitutions of the adjacent two month's age-frequency or length-frequency samples in 1989, by type of set, log (top) and school (bottom). Values above the zero line would indicate a rejection of the null hypothesis and values below or on the line, an acceptance.

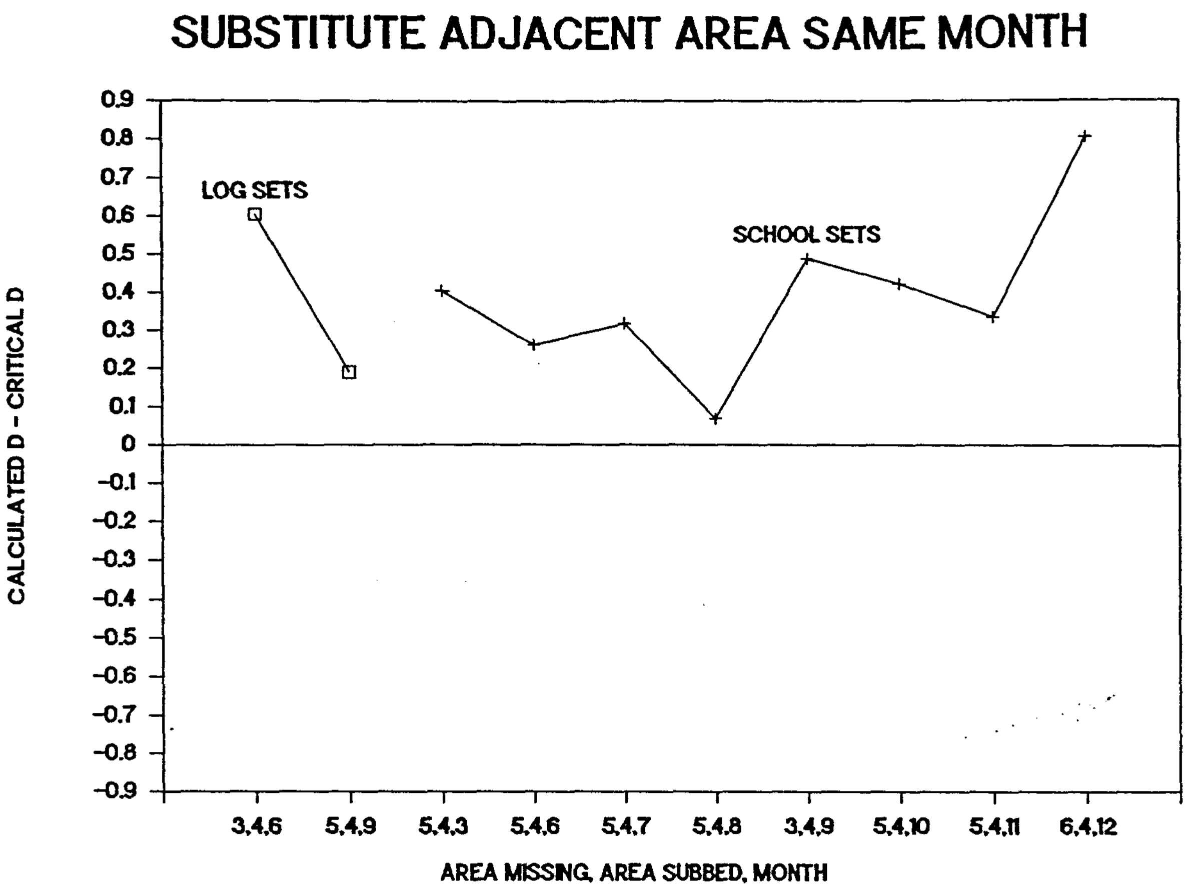


Figure 6: Comparisons of Kolomogorov-Smirnov D values (calculated D and critical D) obtained from substitutions of the adjacent area, same month's length-frequency samples by type of set, log and school. Values above the zero line would indicate a rejection of the null hypothesis and values below or on the line, an acceptance.

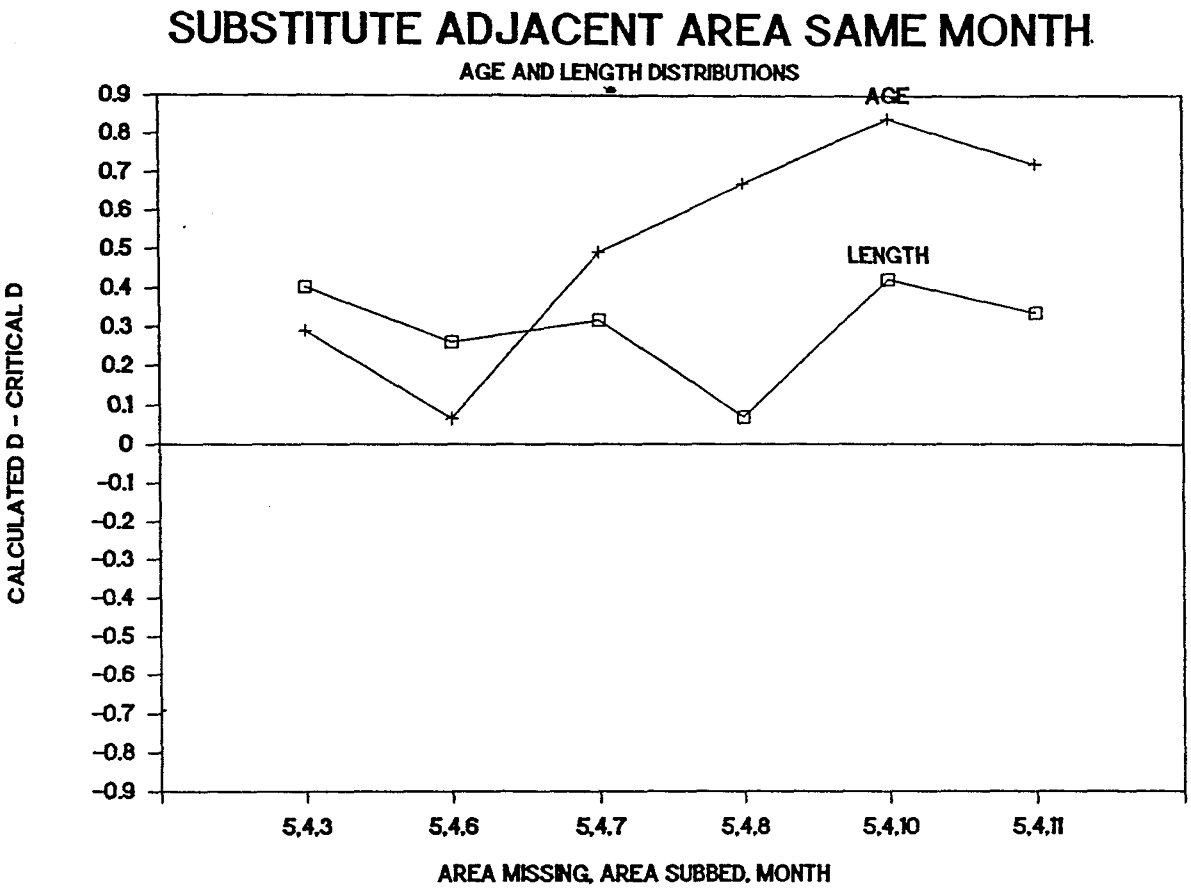
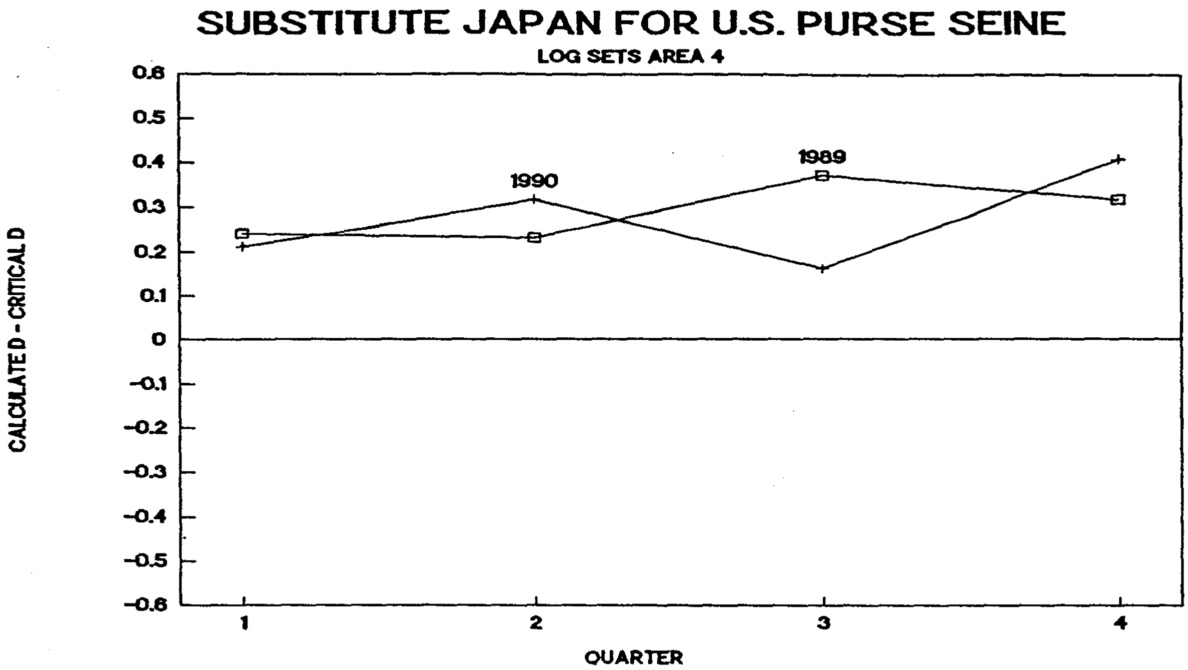


Figure 7: Comparisons of Kolomogorov-Smirnov D values (calculated D and critical D) obtained from substitutions of the adjacent area, same month's length-frequency or age-frequency samples in 1990, school sets. Values above the zero line would indicate a rejection of the null hypothesis and values below or on the line, an acceptance.



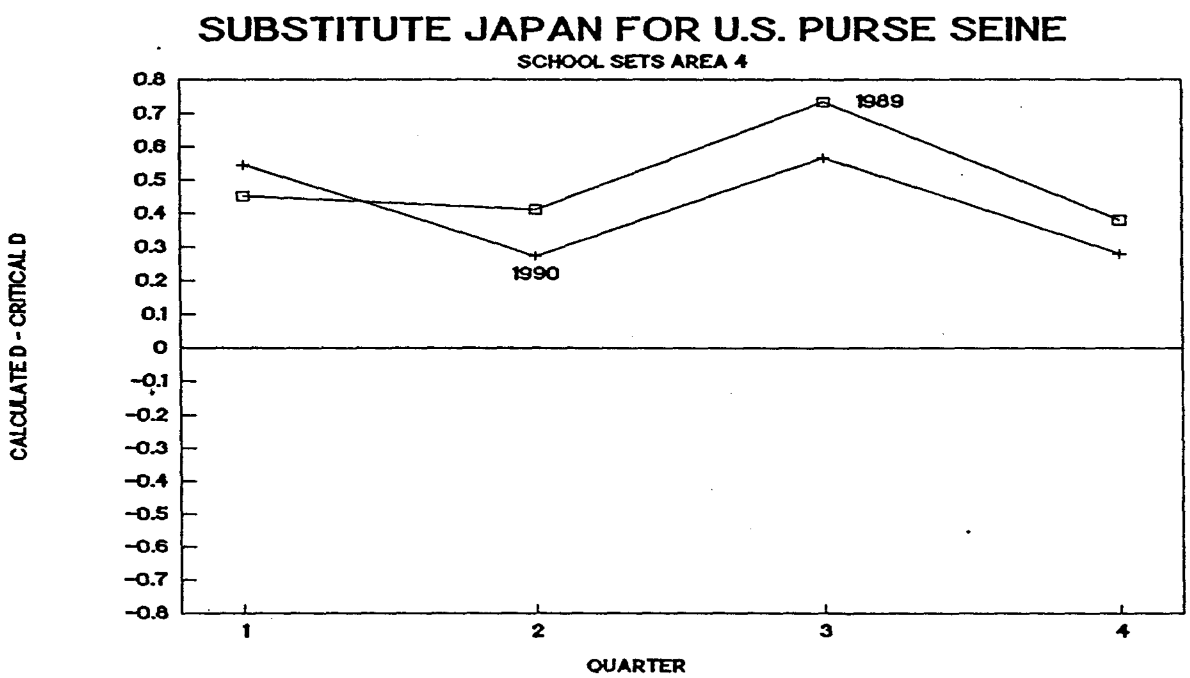
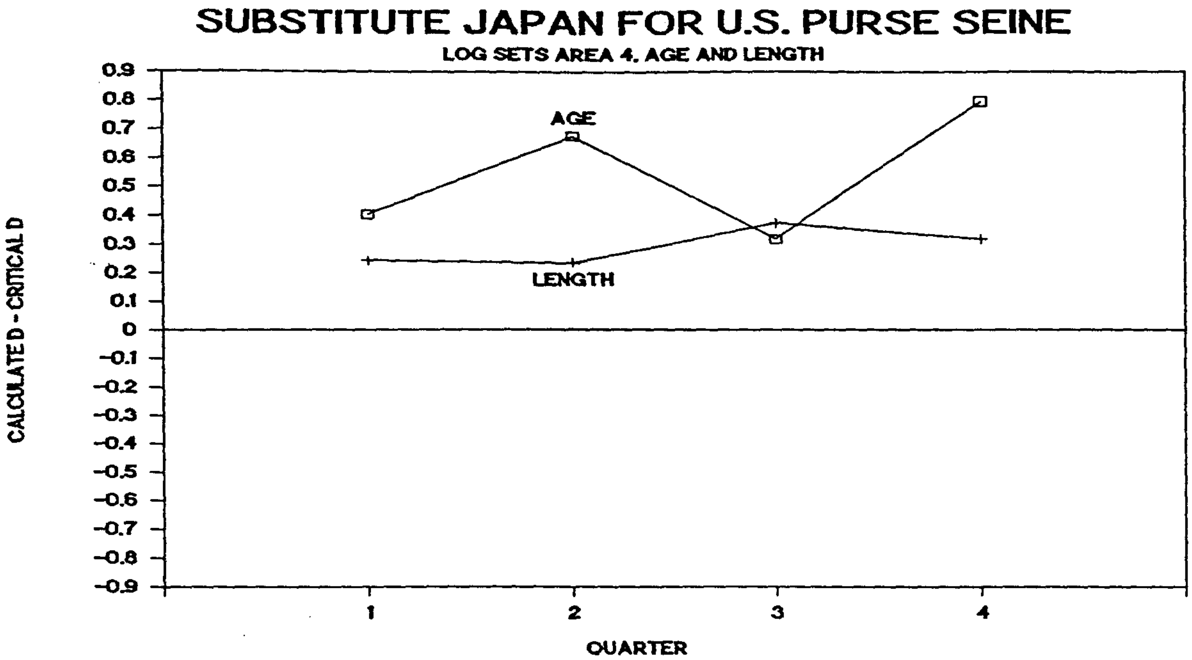


Figure 8: Comparisons of Kolomogorov-Smirnov D values (calculated D and critical D) obtained from substitutions of Japanese purse seine length-frequency samples for U.S. purse seine catches in area 4, by year and type of set, log (top) and school (bottom). Values above the zero line would indicate a rejection of the null hypothesis and values below or on the line, an acceptance.



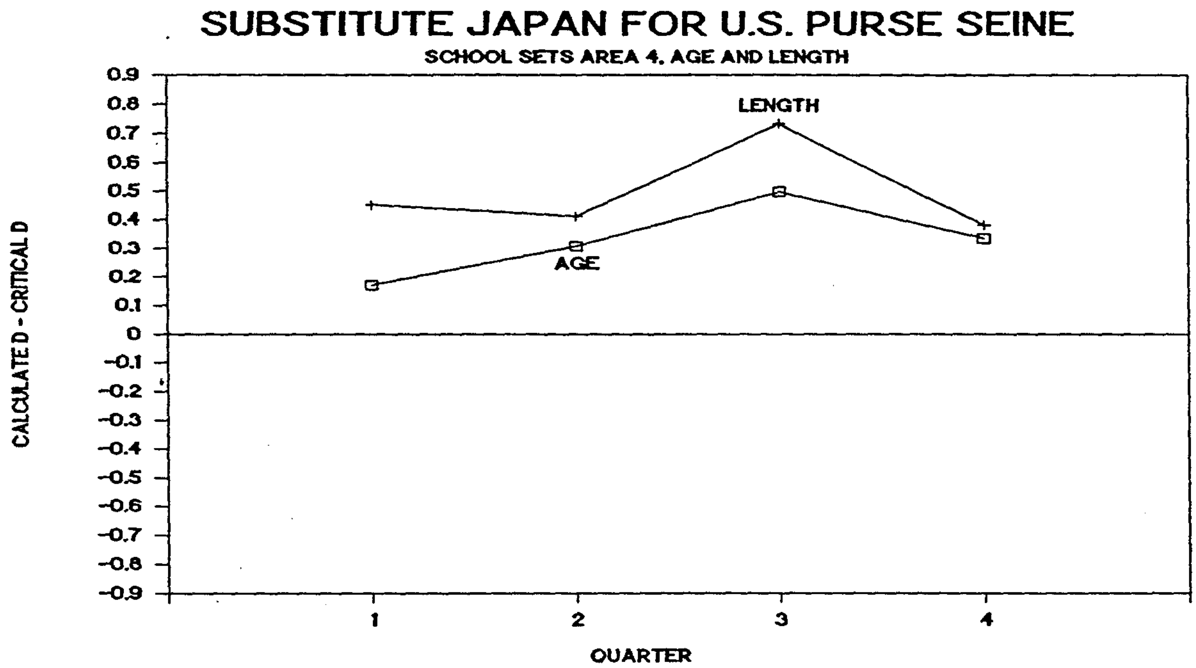
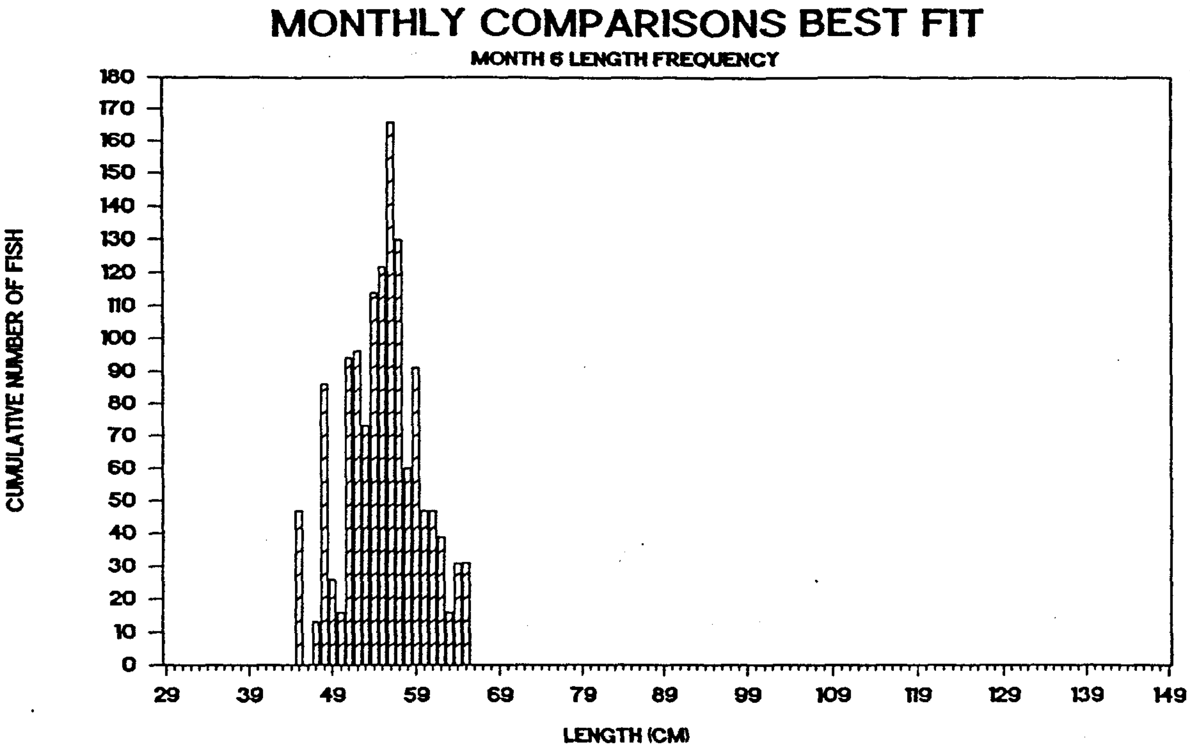


Figure 9: Comparisons of Kolomogorov-Smirnov D values (calculated D and critical D) obtained from substitutions of Japanese purse seine length-frequency or age-frequency samples for U.S. purse seine 1989 catches in area 4, and type of set, log (top) and school (bottom). Values above the zero line would indicate a rejection of the null hypothesis and values below or on the line, an acceptance.



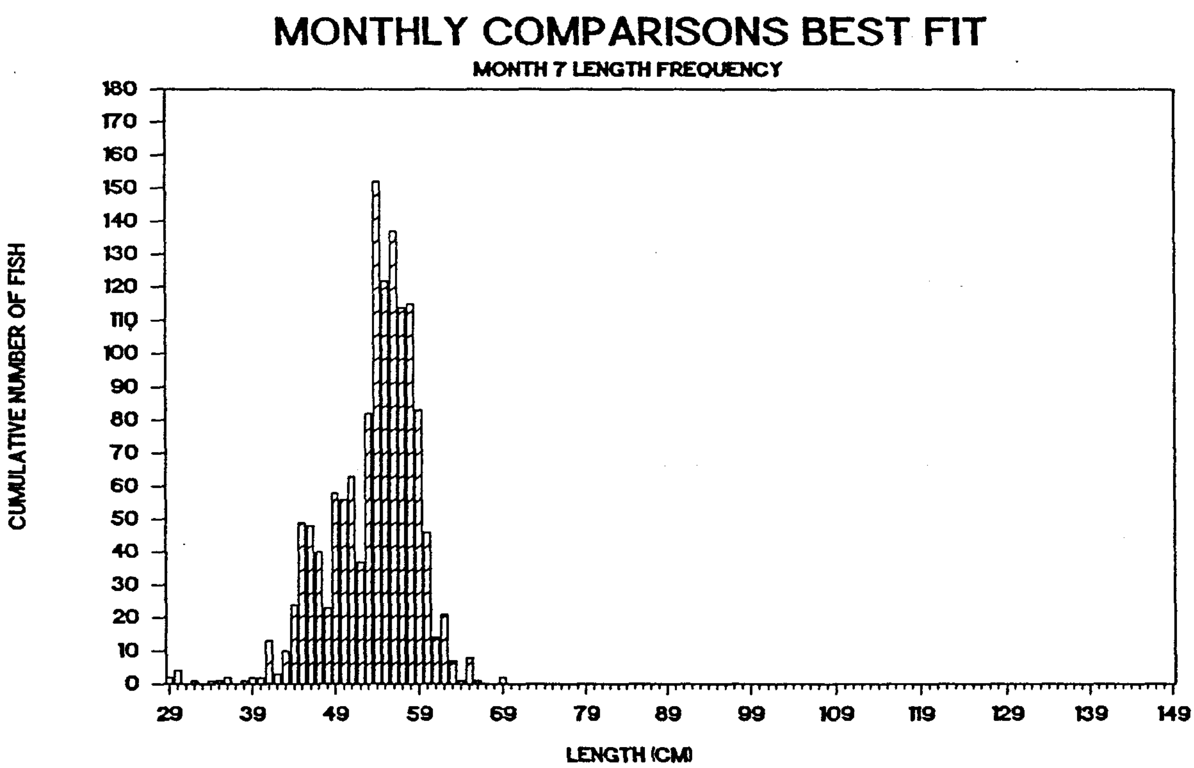


Figure 10: Two monthly length distributions of log sets in 1990, that look very similiar yet were rejected using the Kolomogorov-Smirnov nonparametric statistical distribution test.