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Notes on changes in efficiency of certain fleets fishing in SA 5 and 6 during 1960-1973

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Introduction

In recent years interest in documenting changes in efficiency of fleets operating in ICNAF Subareas 5 and 6 has risen due to the need to accurately measure the fishing mortality generated by these fleets, and subsequently to recommend measures to control this fishing mortality. Previously, Brown et al. (1976) developed a learning function which adjusted reported effort of fleets entering a new fishery so that a unit of effort in an early year in a fishery was equivalent to a unit of effort in a later year. This adjustment had the effect of permitting relative catchability coefficients to be estimated more accurately, since a major source of bias in the data was thereby eliminated. Because of the lack of detailed records of effort directed at individual species, this learning function could not be followed through time. However, there is evidence that changes in efficiency have continued; for example, a simulation of 1973 fishing patterns based on 1971 data suggested that a 25% reduction over the 1971 level would be necessary to reduce fishing to F_{msy} in 1973 (ICNAF, 1973a). Reported 1973 data suggest that such a reduction would have produced a 15% increase in fishing effort, due to changes in catchability of fleets (ICNAF, 1975a). In addition, representatives of various countries fishing in Subareas 5 and 6 have reported changeovers from bottom trawling operations to pelagic trawling (ICNAF, 1974a), and this factor has not been evaluated.

This paper presents indices for measuring changes in efficiency, along with an extension of the learning function of Brown et al. (1976). Fleets operating in ICNAF Subareas 5 and 6 for more than six years were considered except for Canadian trawlers, which caught such small amounts that they were not considered representative of their respective tonnage-class category. Measures by area or directed fishery were not considered. In this way, a more complete set of data was available for inspection.

Methods and materials

ICNAF monthly catch and effort data for 1960-1973, Subareas 5 and 6 were used in this study (ICNAF, 1962-1972, 1973b, 1974b,1975b). The data sets included are given in Table 1. USSR tonnage classes 4 and 5 (151-900 GRT) were combined to provide a more complete data set over years. All Spanish pair trawlers were considered to be one class, since earlier inspection of the data revealed little difference in catch per unit effort (CPUE) between tonnage classes for these trawlers. Differentiation between midwater and otter trawlers, as recorded in the ICNAF Statistical Bulletins, was not made, since the intent of this study was to determine if the data itself showed when such switches in gears occurred.

Standard error (SE) of CPUE

It seems logical that if a fleet attempts at all times to maximize its CPUE, then the standard error (SE) of CPUE will decrease from year to year. Moreover, any sudden increase in this statistic would indicate the onset of a new fishing pattern: either by a technical change in fleet operations, a marked change in the distribution, availability, etc., of a previously fished species, or a shift to a new fishery.

Figure 1 shows no marked increase or decrease in SE of CPUE for the USA fleets during 1960-1973, while the Spanish pair trawler data show a considerable decline in SE during 1964-1973. The GDR vessel class 7 data (1801+ GRT) (Figure 2A) exhibit considerable fluctuation during the past years, while the Polish tonnage class 7 data (Figure 2B) show a gradual decline in SE during the early years in the fisheries (1965-1969) and an increase in the 1970's. This latter phenomenon could perhaps be attributed to the switch to pelagic gear; a steady increase in CPUE of about 50% is evident in this period (Figure 4). The Polish tonnage class 5 (501-900 GRT) vessels show a continual decline in SE of CPUE until the last year when fishing halted in July 1973. The data of the Soviet fleet (tonnage class 4-5) show a trend toward constant SE (Figure 3). The larger Soviet vessel data (tonnage class 7), on the other hand, show a decreasing trend, but year to year fluctuations in SE through 1973, possibly indicating continued changes in fishing patterns.

Average CPUE ($\overline{CPUE}$)/SE of CPUE

The standard error of catch per unit effort, while elucidating some of the phenomena of fishing not evident in the CPUE statistics, has the disadvantage of not being independent of changes in CPUE. Another statistic which measures changes in fishing efficiency, but which does not have this disadvantage, is

$$X_i = \frac{\overline{CPUE_i}}{SE_i}, \tag{1}$$

where $\overline{CPUE_i}$ = average catch per unit effort during year i,

SE_i = standard error of CPUE during year i, and

i = 1960 . . . 1973.

If CPUE is maximized throughout the year for all years, then $\overline{CPUE_i}$ will be maximized, SE_i will decrease to a constant level, and X_i will approach a maximum value X_∞. However, an assumption here is that there is not a year to year change in strategy from, say, maximizing CPUE of certain species to maximization over all species. Figure 5 shows X_i for the USA and Spanish fleets. The Spanish fleets, fishing cod consistently throughout the decade, show no significant trend in X_i. On the other hand, the USA fleets show changes in X_i with which can be associated changes in species composition of total catch. (See Tables 2A-2C, percent species composition). These changes are in sharp contrast to the USSR-4,5 fleets (Figure 7) which also underwent changes in species composition of total catch but which show a monotonic increase in X_i. The USSR-7 fleets exhibit a leveling off of X_i to the same values as that of the USSR-4,5 fleets but large year to year fluctuations. The low value of X_i at time i = 10(X_i = 10.65) of the USSR-7 fleets coincided with a 200,000 MT drop in catch of that fleet in the entire ICNAF area in 1970, and indicates an interaction between catch and fleet operations. The USSR-4,5 vessels did not experience a marked drop in catch from 1969 to 1970. The Polish and GDR fleets (Figures 6A and 6B) show a leveling off of X_i during the past three years, except for the Polish-5 vessels which show a marked decline in 1973. This latter phenomenon is perhaps related to the fishery ending in July of 1973, an event not occurring in the preceding years. It is interesting to note that the USSR fleets show a tendency toward a value of X_∞ = 22.00, while the GDR and Polish fleets are approaching a value considerably lower (X_∞ = 10.00). This is perhaps indicative of different fishing purposes: the USSR perhaps desiring to maximize overall CPUE at all times, and the other nations preferring to maximize CPUE for predetermined species regardless of the CPUE these species yield.

Cyclical trends in CPUE

A third indication of a change in fleet operations is a shift in the monthly CPUE cycle within a year. Inspection of the data revealed that GDR-7 data showed a pronounced increase in CPUE in 1971 over the earlier years of fishing (1966-1970). This occurred with the entrance into the mackerel fishery during the early months of the year. The previous two indices of changing fishing patterns (SE and $X = \overline{CPUE}/SE$) did not indicate that such a change has occurred (Figures 2A and 6A). To examine this aspect, monthly CPUE data were fit to the model:

$$CPUE\ (t,\ y) = a_1 + a_2 \sin \frac{2\Pi t}{12.0} + a_3 \cos \frac{2\Pi t}{12.0} + a_4 * y * \sin \frac{2\Pi t}{12.0} + a_5 * y * \cos \frac{2\Pi t}{12.0} \qquad (2)$$

where a_i = constants fitted to the data

t = month, t = 1 . . . 12

y = year in the fishery, y = 1 . . . 8

CPUE(t, y) = catch per unit effort during month t and year y.

Two runs were made using GDR-7 data for years 1966-1970 and 1971-1973 separately. Table 3 lists the results of these runs and Figure 8 shows the original data and the fitted curve. There was no marked decrease in the standard error of the predicted CPUE with the inclusion of more trigonometric independent variables than in the above equation. Only a small percentage of the overall variation in the data is accounted for by the time series (see values of R^2). However, after adjusting for yearly variation, area, and seasonal changes in abundance, this model may prove to be critical for predicting future seasonal patterns. Other fleets were not characterized by such cycles, nor did they exhibit such a marked shift.

Learning related to fishing mortality

Since the primary purpose in investigating learning and other changes in fleet operations is to discover sources of changes in q and correct the data for them accordingly, it is critical that estimates of such changes be independent of stock abundance. The function developed in Brown et al. (1976) was fishery-specific, in the sense that data related to a specific main species sought provided the basis for the model. It was assumed that if greater than 20% of the annual catch in an area by a country-gear-tonnage class category consisted of a given species, a directed fishery for that species existed. The effort attributed to that directed fishery was prorated according to the percentage catch of the given species, except when that percentage exceeded 80%, at which time a "pure" fishery was said to have existed. The function developed attributed a twofold increase in CPUE during the second year in a fishery, and a fourfold increase during the third year (over the first year in the fishery), to learning. For purposes of review the model fit was:

$$l_i = \frac{O_i}{P_i} \qquad (3)$$

where l_i = learning gained by a fleet in the i^{th} year in a fishery,

O_i = observed catch per effort by the fleet in the i^{th} year in the fishery,

P_i = predicted catch per effort for the fleet in the i^{th} year in the fishery assuming no learning,

$P_1 = O_1$

$l_1 = 1$

$i = 1,2,3 \ldots$

The predicted catch per effort, P_i, was defined algebraically to be:

$$P_i = \frac{(Z_i)}{(Z_{i-1})} * P_{i-1}$$

where Z_i is an independent estimate of the abundance of the species in the i^{th} year in the fishery. By recursion:

$$P_i = \prod_{j=2}^{i} \frac{(Z_j)}{(Z_{j-1})} * P_{i-1}$$

$$= \frac{(Z_i)}{(Z_1)} * P_1 \qquad (4)$$

$$P_i = \frac{(Z_i)}{(Z_1)} * O_1$$

as $P_1 = O_1$.

The observed catch per effort in the first year in the fishery, O_1, was taken to be the predicted catch per effort, P_1.

An assumption was made in applying a learning function that learning ceased when the ratio (1) decreased from year i to year i+1, i.e. when l_{i+1} was less than l_i.

An independent measure of the abundance of a species was provided by the catch (pounds per tow) of the USA *ALBATROSS IV* bottom trawl during its annual surveys. Fisheries were selected for analyses of the learning factor for which survey cruise indices of the species sought had been developed.

In most cases where l_i could be estimated for 4-5 successive years, l_i declined in the fourth year in the fishery. It was concluded, therefore, that in general the learning process was completed by the end of the third year in the fishery.

An exponential curve was fit to a fleet's data for the first three years in the fishery.

$$l_i = \frac{O_i}{P_i} = [\exp(a(i-1))]e_i\text{, where}$$

$$P_i = O_1 * \frac{Z_i}{Z_1} \qquad (5)$$

O_i = the observed commercial catch per unit effort in the i^{th} year in the fishery after entrance, where i = 1,2,3...

Z_i = the stock abundance in the same year

e_i = the residual error, where $\ln(e_i)$ has a $N(0,\sigma^2)$ distribution, and

a = constant.

This curve was selected since the ideas underlying the model seemed to coincide with the underlying notion of learning: that the learning gained by time t_i was dependent on the learning gained by time t_{i-1} as well as the time interval t_i-t_{i-1}. Since there was no trend to the differences in the values of l_i for the different fleets, pooled data were used to fit the curve. A least squares linear fit of $\ln l_i$ on i yielded the curve:

$$l_i = .48 \exp(.735i),\ i = 1...3$$

with a coefficient of determination of .82.

From this equation:

$l_1 = 1.00$

$l_2 = 2.09$

$l_3 = 4.35$

As mentioned earlier, this is approximately equivalent to having the fishing effort on that species halved and quartered during this learning period compared to the reported units of fishing activity.

The effort data was adjusted so that a unit of effort in the years prior to full learning experience was made equivalent in this respect to a unit of effort in later years. The adjustment involved is:

$$X_1, \text{adj.} = \frac{0_i}{1_i} * 1_3$$

$$\text{for } i = 1 \ldots 3 \qquad (6)$$

where X_i, adj. = adjusted catch/effort for the i^{th} year in a fishery by a fleet, and 0_i, 1_i, and 1_3 are as defined previously.

A proposed new model for measuring learning uses equation (3), as before, except that i refers to the i^{th} year fishing in ICNAF Subarea 5 or 6. The predicted catch per effort, P_i, is defined as:

$$P_i = \prod_{j=2}^{i} Z_j^! * P_{j-1} / Z_{j-1}^!$$

$$= Z_i^! * 0_1 / Z_1^!$$

where $P_1 = 0_1$,

$$Z_i^! = \sum_{t=1}^{s} a_{it} * z_{it}, \text{ and}$$

0_1 = observed CPUE in the first year fishing in Subarea 5 or 6, for

a_{it} = percent of total catch in year i which is species t,

z_{it} = independent index of stock size of species t in year i, and

s = number of species taken in year i.

The stock size indices z_{it} were calculated using weighting coefficients derived in Clark and Brown (1975) and multiplying these by yearly values of lbs/tow by species taken from USA *ALBATROSS IV* autumn surveys, 1963-1973, for Southern New England, Georges Bank, and Gulf of Maine areas. To preserve consistency, abundance index data for the Middle Atlantic area, which were collected for all species only after 1966, were not included in the analysis. The weighting coefficients proposed by Clark and Brown were used to adjust for selectivity of the survey gear. Tables 2A-J list the percentages (a_{it}) used in computing each Z! for each vessel category, along with the calculated value of l_i. Figures 9-11 show l_i vs. year for the categories considered. Figures 10 and 11 suggest a possible bias in the 1969 and 1972 research vessel abundance indices for species for which these vessels were fishing. Data for the Polish-5 vessels is normalized relative to 1967 rather than 1965 since there are no data for 1966.

Values of l_i calculated for the USA and Spanish fleets (Tables 2A-C, 2J and Figure 9), and class 4-5 GDR, USSR and Poland (Figure 10) show little change throughout 1963-1973, compared to the changes in l_i for the larger vessel fleets (Figure 11). The data of the USA, 51-150 GRT in particular, showed little change throughout the period. Data of the USSR-4,5 fleets, for which the values of X_i (Equation 1) were relatively stable through time, exhibited considerably more variability than data of GDR and Poland. This latter phenomenon could perhaps be attributed to the variability in the abundance indices used for the species fished, and since the species composition varied considerably more for the USSR fleets throughout the period than for the GDR or Polish vessels.

Values of l_i for the larger vessels of GDR, Poland, and USSR (Table 2E, 2G, 2I) show a gradual increase throughout 1963-1973, with the data of GDR showing the largest increase (from l_i = 1.00 in 1966 to l_i = 28.64 in 1973) (Figure 11). The marked increase could perhaps be attributed to the switch to the mackerel fishery in 1971 (Table 2I). The values of l_i of Poland, if standardized to the initial value of l_i for 1966, would show an increase in l_i of 1.00 to 16.84, and the relative change of the USSR data would decrease slightly. These readjusted values of l_i provide a more meaningful comparison among countries.

In Brown et al. (1976) effort data of the first two years in a fishery were adjusted for learning. Since the new values of l_i are not calculated for years prior to 1963 (due to the lack of stock size estimates from *ALBATROSS IV* autumn surveys prior to 1963), such an adjustment is unfeasible. Furthermore, these values of l_i are based on total catch per effort throughout the year; thus, entrance into a new fishery, say, during the autumn of some year, is masked. Lastly, these values are based on all data of SA 5 and 6; to measure learning more precisely, calculations of l_i should be made by a smaller area-stock block.

Conclusions

Certain basic statistics (SE, $\overline{CPUE}$/SE) calculated on catch and effort data of several fleets operating in SA 5 and 6 during 1960-1973 were found to be informative in suggesting when changes in fleet operations occurred. Such changes (e.g. entrance of Poland /vessel class 7/ into a new mode of fishing in 1970 /Figure 2B/) are not usually evident from inspection of CPUE data alone (Figure 4). A new index of learning suggests that sharp increases in efficiency have occurred for the larger vessels of USSR, GDR, and Poland since these vessels entered SA 5 and 6, while the data of smaller vessels of these countries did not exhibit such increases. Finally, since l_i for USA OtSi 51-150 GRT vessels proved to be more constant throughout time than the 0-50 GRT class (Figure 9), it is suggested that this tonnage class be nominated as a standard against which to measure fishing intensity.

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Table 1. Fleets examined for changes in efficiency during 1961-1973.

Country	Gear-tonnage class	Years data available
Poland	Otter trawlers - 5	1962, 1965, 1967-1973
Poland	Otter trawlers - 7	1962-1973
USSR	Otter trawlers - 4, 5	1963-1973[1]
USSR	Otter trawlers - 7	1961, 1963-1973[1]
GDR	Otter trawlers - 5	1967-1973
GDR	Otter trawlers - 7	1966-1973
Spain	Pair trawlers	1964-1973
USA	Otter (side) trawlers - 2	1960-1961, 1963-1973[2]
USA	Otter (side) trawlers - 3	1960-1961, 1963-1973[2]
USA	Otter (side) trawlers - 4	1960-1973[2]

[1]Effort data not reported to ICNAF in 1962.

[2]All catch and effort data for 1962 tonnage classes 2-4 reported as one tonnage class.

Table 2A. Values of percent species caught by year (a_{it}) for designated vessel class; calculated values of $Z_i' = Z$ and l_i; and CPUE and total catch by year. Note: Prior to 1965, silver hake catches were recorded as "other groundfish", and are therefore included in "PCT OTH FISH" for years earlier than 1965.

CT GR-TCL
USA Ot Si
0-50 GRT

Yr	Zx10^-5	CPUE	l	PCT COD	PCT HADD	PCT REDF	PCT S HAKE	PCT FL	PCT HERR	PCT OTH PEL	PCT OTH FISH	MT'S TOT CTCH
60				.04	.04	.03	.00	.22	.00	.00	.67	67053
61				.04	.04	.04	.00	.21	.00	.00	.67	71313
62[1]												
63	15.83	7.26	1.00	.02	.03	.02	.00	.27	.00	.02	.64	81760
64	10.62	8.30	1.70	.02	.03	.01	.00	.25	.00	.01	.67	94835
65	5.38	6.91	2.80	.03	.04	.01	.35	.26	.01	.01	.29	76308
66	4.64	6.81	3.20	.03	.05	.01	.35	.28	.01	.00	.27	70215
67	4.03	7.61	4.12	.05	.04	.00	.30	.25	.01	.01	.33	66062
68	5.23	6.65	2.77	.05	.03	.00	.35	.21	.01	.01	.35	62948
69	7.38	5.70	1.68	.08	.02	.00	.24	.21	.03	.01	.41	56744
70	4.60	3.35	1.59	.10	.01	.02	.21	.23	.06	.01	.36	46467
71	4.34	4.21	2.12	.09	.01	.02	.17	.23	.12	.01	.33	43843
72	4.91	3.38	1.50	.09	.01	.02	.14	.28	.11	.00	.36	35999
73	5.99	3.56	1.30	.09	.00	.01	.20	.23	.02	.01	.44	35055

[1] All catches reported as tonnage class 0-500 GRT.

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Table 2B. See caption with Table 2A for explanation of entries in Table. All catches for 1962 taken by 0-500 GRT vessels.

USA Ot Si

51-150 GRT

Yr	$Zx10^{-5}$	CPUE	1	PCT COD	PCT HADD	PCT REDF	PCT S HAKE	PCT FL	PCT HERR	PCT OTH PEL	PCT OTH FISH	MT'S TOT CTCH
60				.06	.28	.10	.00	.15	.00	.00	.42	80161
61				.07	.31	.11	.00	.16	.00	.00	.35	86268
63	6.07	7.72	1.00	.06	.25	.06	.00	.24	.00	.01	.39	102945
64	5.11	7.19	1.11	.06	.25	.05	.00	.28	.00	.00	.35	108944
65	3.42	5.95	1.37	.06	.27	.05	.14	.32	.00	.00	.14	99565
66	2.55	5.55	1.71	.06	.30	.04	.17	.31	.00	.00	.12	96320
67	2.47	5.05	1.61	.10	.26	.03	.14	.31	.00	.00	.17	78786
68	2.99	5.47	1.44	.10	.17	.01	.15	.35	.00	.00	.18	86281
69	4.45	5.44	.96	.13	.11	.03	.07	.42	.03	.01	.19	81965
70	3.25	5.73	1.39	.10	.06	.04	.10	.42	.07	.01	.19	85784
71	3.17	5.09	1.26	.12	.06	.07	.07	.36	.13	.00	.18	75594
72	3.00	4.19	1.10	.12	.04	.08	.04	.44	.10	.00	.17	66360
73	3.38	4.96	1.15	.14	.03	.09	.12	.42	.01	.00	.20	64987

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Table 2C. See caption with Table 2A for explanation of entries in Table.

USA Ot Si

151-500 GRT

Yr	$Zx10^{-5}$	CPUE	I	PCT COD	PCT HADD	PCT REDF	PCT S HAKE	PCT FL	PCT HERR	PCT OTH PEL	PCT OTH FISH	MT'S TOT CTCH
60				.16	.65	.03	.00	.02	.00	.00	.15	29602
61				.20	.63	.07	.00	.02	.00	.00	.09	32259
62				.08	.26	.06	.00	.19	.00	.01	.40	204978[1]
63	5.65	7.16	1.00	.21	.64	.03	.00	.03	.00	.00	.09	30665
64	4.50	6.87	1.20	.15	.67	.04	.00	.06	.00	.00	.07	30099
65	3.29	6.55	1.57	.12	.69	.04	.02	.06	.00	.00	.07	36746
66	1.72	6.19	2.84	.13	.64	.08	.01	.09	.00	.00	.06	35948
67	1.47	6.26	3.36	.14	.46	.27	.00	.08	.00	.00	.05	29493
68	1.55	6.15	3.13	.19	.42	.23	.01	.10	.00	.00	.06	25549
69	1.88	7.27	3.05	.17	.26	.35	.01	.12	.00	.00	.08	26489
70	1.68	7.56	3.55	.15	.13	.47	.03	.12	.00	.00	.09	23241
71	1.41	7.06	3.95	.15	.11	.49	.01	.12	.00	.00	.11	21115
72	1.85	6.19	2.64	.16	.06	.52	.01	.14	.00	.00	.10	13427
73	2.05	7.08	2.73	.16	.04	.43	.05	.22	.00	.00	.10	13085

[1]All catches reported as taken by 0-500 GRT vessel.

Table 2D. Values of percent species caught by year and vessel category (a_{it}); calculated values of Z_i and l_i.

Note: Prior to 1965, silver hake catches were recorded as "other groundfish." CPUE = total catch/ total days fished.

CT GR TCL

USSR Ot Si- 4,5

Yr	Zx10^{-5}	CPUE	l	PCT COD	PCT HADD	PCT REDF	PCT S HAKE	PCT FL	PCT HERR	PCT OTH PEL	PCT OTH FISH	MT'S TOT CTCH
62				.02	.00	.00	.00	.00	.84	.00	.13	21873
63	27.63	6.13	1.00	.02	.00	.00	.00	.00	.62	.01	.34	67991
64	5.32	7.13	6.04	.01	.00	.00	.00	.00	.86	.00	.12	87003
65	7.36	11.39	6.97	.04	.15	.00	.61	.00	.07	.02	.10	97647
66	9.15	8.74	4.30	.04	.10	.00	.44	.00	.07	.02	.33	110909
67	14.48	11.83	3.68	.00	.01	.00	.20	.00	.63	.02	.14	147523
68	6.70	6.89	4.64	.00	.00	.00	.03	.00	.63	.15	.17	154088
69	35.43	6.35	.81	.00	.00	.00	.01	.00	.49	.35	.14	168191
70	5.79	7.28	5.67	.00	.00	.00	.03	.00	.29	.59	.08	141831
71	5.58	6.87	5.55	.00	.00	.02	.09	.00	.32	.45	.12	120069
72	7.91	6.81	3.88	.00	.00	.04	.12	.02	.10	.41	.31	117888
73	5.92	9.39	7.15	.02	.00	.00	.22	.00	.10	.27	.37	86797

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Table 2E. See caption with Table 2A for explanation of entries in Table.

USSR Ot Si-7	Yr	$Zx10^{-5}$	CPUE	1	PCT COD	PCT HADD	PCT REDF	PCT S HAKE	PCT FL	PCT HERR	PCT OTH PEL	PCT OTH FISH	MT'S TOT CTCH
	61				.73	.00	.15	.00	.04	.00	.00	.08	75
	62				.05	.01	.02	.00	.00	.45	.01	.46	98254
	63	24.83	36.02	1.00	.03	.01	.01	.00	.00	.31	.02	.63	154801
	64	12.26	41.50	2.33	.02	.02	.00	.00	.00	.21	.00	.75	243786
	65	7.48	47.16	2.96	.01	.13	.00	.60	.00	.06	.00	.18	362334
	66	20.44	42.40	1.43	.02	.07	.00	.35	.00	.26	.02	.28	434661
	67	9.84	40.02	2.80	.00	.01	.00	.36	.02	.20	.10	.31	167166
	68	6.76	44.59	4.55	.00	.00	.00	.31	.03	.23	.11	.32	174237
	69	18.42	39.93	1.49	.00	.00	.00	.26	.10	.10	.13	.41	246045
	70	5.66	37.12	4.52	.00	.00	.00	.24	.04	.11	.31	.31	110331
	71	5.14	34.59	4.64	.00	.00	.00	.29	.03	.11	.27	.30	268682
	72	7.78	38.45	3.41	.00	.00	.00	.26	.03	.04	.23	.43	333754
	73	5.84	38.77	4.58	.00	.00	.02	.32	.01	.05	.30	.31	295850

F 2

Table 2F. See caption with Table 2A for explanation of entries in Table.

CT GR TCL

POLAND Ot Si-5 Yr	$Zx10^{-5}$	CPUE	1	PCT COD	PCT HADD	PCT REDF	PCT S HAKE	PCT FL	PCT HERR	PCT OTH PEL	PCT OTH FISH	MT'S TOT CTCH
62				.27	.00	.00	.00	.00	.47	.26	.00	443
65	2.95	8.87		.77	.00	.00	.00	.00	.00	.00	.23	630
67	18.91	12.52	1.00	.00	.00	.00	.00	.00	.94	.01	.04	28607
68	5.93	11.56	2.96	.01	.01	.00	.01	.00	.91	.06	.01	61016
69	25.19	8.64	.54	.01	.00	.00	.00	.00	.68	.24	.08	49574
70	7.87	8.99	1.75	.01	.00	.00	.00	.00	.68	.25	.07	57010
71	7.17	7.82	1.67	.00	.00	.00	.00	.00	.62	.26	.11	45761
72	7.40	6.51	1.33	.01	.00	.00	.00	.00	.34	.58	.07	32940
73	4.12	12.34	4.58	.01	.00	.00	.00	.00	.22	.58	.20	21383

Table 2G. See caption with Table 2A for explanation of entries in Table.

Poland Ot Si-7 Yr	$Zx10^{-5}$	CPUE	1	PCT COD	PCT HADD	PCT REDF	PCT S HAKE	PCT FL	PCT HERR	PCT OTH PEL	PCT OTH FISH	MT'S TOT CTCH
62				.24	.00	.00	.00	.00	.76	.00	.00	92
64	13.54	21.20	1.00	.07	.00	.00	.00	.00	.05	.00	.88	723
65	12.47	27.50	1.41	.35	.01	.01	.00	.02	.37	.00	.25	3913
66	58.02	34.48	.38	.02	.00	.00	.00	.00	.90	.00	.08	16103
67	18.00	37.67	1.34	.00	.00	.02	.00	.00	.86	.02	.10	8168
68	6.37	25.14	2.52	.07	.02	.00	.02	.00	.62	.23	.03	26200
69	27.79	23.17	.53	.02	.02	.00	.01	.01	.43	.25	.27	26456
70	5.96	29.97	3.21	.00	.00	.00	.00	.00	.35	.60	.04	90111
71	5.61	38.51	4.38	.00	.00	.00	.00	.00	.37	.58	.05	110679
72	8.49	40.32	3.03	.00	.00	.00	.00	.00	.21	.73	.06	111521
73	3.24	42.11	8.30	.00	.00	.00	.00	.00	.27	.63	.10	94596

F 3

Table 2H. See caption with Table 2A for explanation of entries in Table.

GDR Ot Si-5	Yr	$Zx10^{-5}$	CPUE	1	PCT COD	PCT HADD	PCT REDF	PCT S HAKE	PCT FL	PCT HERR	PCT OTH PEL	PCT OTH FISH	MT'S TOT CTCH
	67	11.93	10.71	1.00	.36	.00	.11	.00	.00	.52	.04	.00	68
	68	6.06	8.32	1.53	.00	.00	.00	.00	.00	.87	.03	.10	1396
	69	13.65	9.34	.76	.00	.00	.00	.00	.00	.48	.07	.45	4435
	70	7.36	8.65	1.31	.01	.00	.04	.00	.00	.52	.19	.23	2367
	71	6.91	7.16	1.15	.00	.00	.00	.01	.00	.22	.10	.67	9844
	72	7.26	4.60	.71	.01	.00	.00	.01	.00	.30	.30	.38	7685
	73	3.99	4.38	1.22	.01	.00	.00	.01	.00	.40	.33	.26	5716

F 4

Table 2I. See caption with Table 2A for explanation of entries in Table.

CT GR TCL GDR OT-7	Yr	$Zx10^{-5}$	CPUE	1	PCT COD	PCT HADD	PCT REDF	PCT S HAKE	PCT FL	PCT HERR	PCT OTH PEL	PCT OTH FISH	MT'S TOT CTCH
	66	43.90	33.56	1.00	.00	.09	.00	.00	.00	.67	.19	.05	5648
	67	19.77	38.00	2.51	.00	.00	.00	.00	.00	.97	.03	.00	22346
	68	5.84	34.94	7.83	.00	.00	.00	.00	.00	.94	.05	.00	44519
	69	7.89	29.36	4.87	.00	.00	.00	.00	.00	.84	.04	.12	27395
	70	8.01	40.48	6.61	.00	.00	.02	.00	.00	.65	.15	.18	27119
	71	4.29	68.61	20.92	.00	.00	.00	.00	.00	.15	.83	.02	76666
	72	8.16	54.60	8.75	.00	.00	.00	.00	.00	.26	.73	.01	104192
	73	2.93	64.11	28.64	.00	.00	.00	.00	.00	.29	.66	.06	114492

Table 2J. See caption with Table 2A for explanation of entries in Table.

Spain	PT	Yr	$Zx10^{-5}$	CPUE	1	PCT COD	PCT HADD	PCT REDF	PCT S HAKE	PCT FL	PCT HERR	PCT OTH PEL	PCT OTH FISH	MT'S TOT CTCH
		64	2.82	7.33	1.00	.82	.09	.00	.00	.00	.00	.00	.09	18
		65	1.83	13.80	2.90	.86	.14	.00	.00	.00	.00	.00	.00	59
		66	.97	21.91	8.69	.88	.12	.00	.00	.00	.00	.00	.00	8375
		67	1.79	17.90	3.85	.91	.08	.00	.00	.00	.00	.00	.01	14730
		68	1.29	19.67	5.87	.81	.17	.00	.00	.00	.00	.00	.02	14622
		69	1.29	15.70	4.68	.89	.09	.00	.00	.00	.00	.00	.02	13749
		70	1.28	17.59	5.29	.89	.10	.00	.00	.00	.00	.00	.00	7249
		71	1.10	18.31	6.40	.83	.15	.00	.00	.00	.00	.00	.02	7619
		72	2.03	15.13	2.87	.83	.14	.00	.00	.00	.00	.00	.01	6704
		73	3.36	18.72	2.14	.82	.06	.00	.00	.00	.00	.00	.12	5632

Table 3. Results of multiple regressions of CPUE vs. trigonometric functions of time, for GDR-7 vessels, 1966-1973.

t = month, y = year, $\hat{CPUE}$ = predicted catch per unit effort

All data 1966-1970 $\hat{CPUE} = 32.58 + 10.90 \cos\left(\frac{2\pi t}{12.0}\right)$

AOV:	S.S.	df	M.S.	F-value
Regr	2216	1	2216	11.51**
Error	6545	34	192.50	
Total	8761	35		

Regr/Total - .25

All data 1971-1973 $\hat{CPUE} = 55.96 + 21.47 \sin\left(\frac{2\pi t}{12.0}\right)$

AOV:	S.S.	df	M.S.	F-value
Regr	8299	1	8299	18.08**
Error	15603	34	458.9	
Total	23903	35		

Regr/Total = .35

1971-1973 $\hat{CPUE} = 55.96 + 21.47 \sin \frac{2\pi t}{12.0} + y^{*2.32} * \cos \frac{2\pi t}{12.0}$

AOV:	S.S.	df	M.S.	F-value
Regr	13100	2	6550	20.01 * *
Error	10802	33	327.35	
Total	23903	35		

Regr/Total = .55

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO.
46 1513

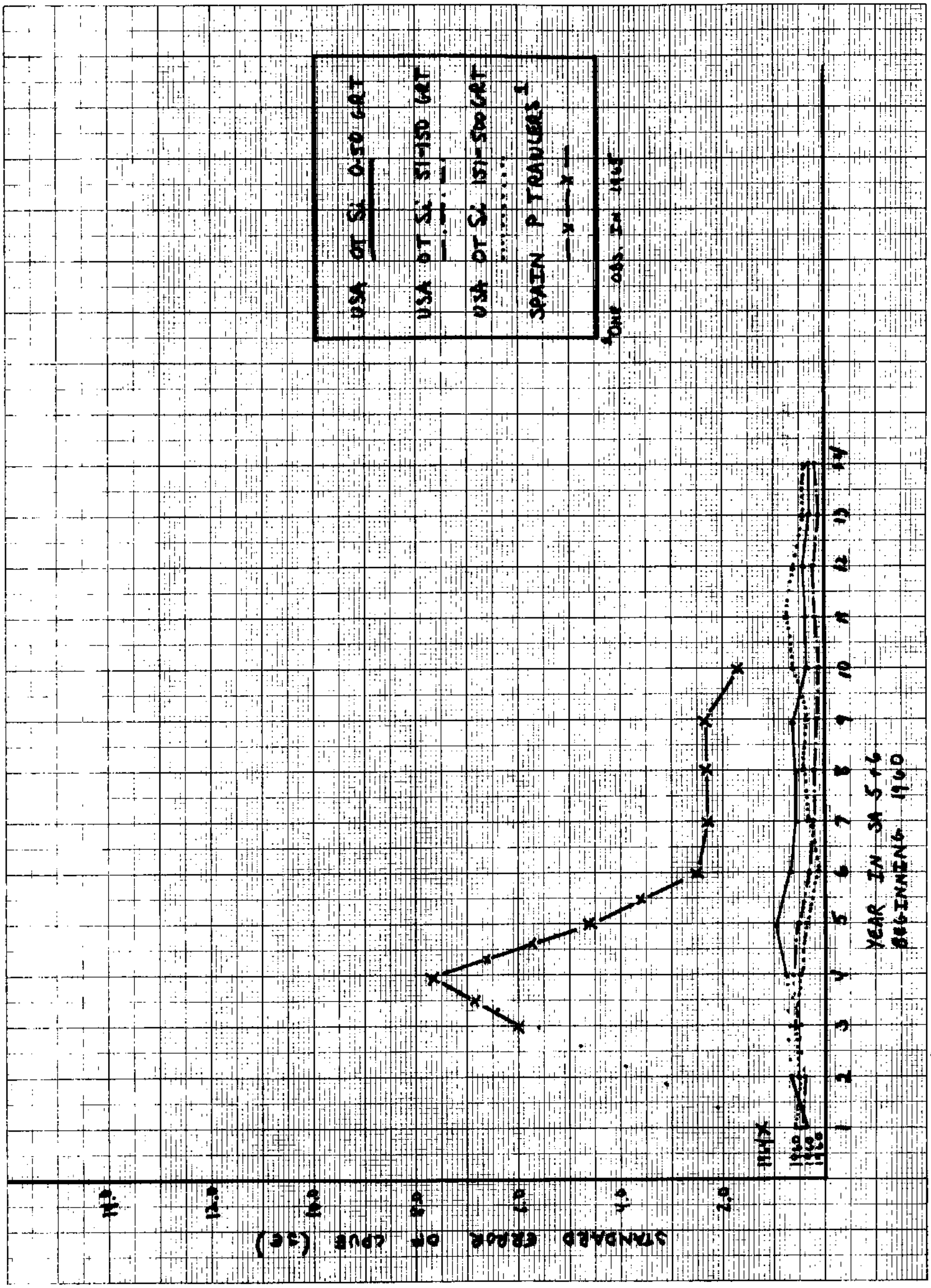

FIGURE 1. PLOTS OF STANDARD ERROR OF MONTHLY CATCH PER EFFORT BY YEAR FOR FLEETS LISTED.

K&E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO.
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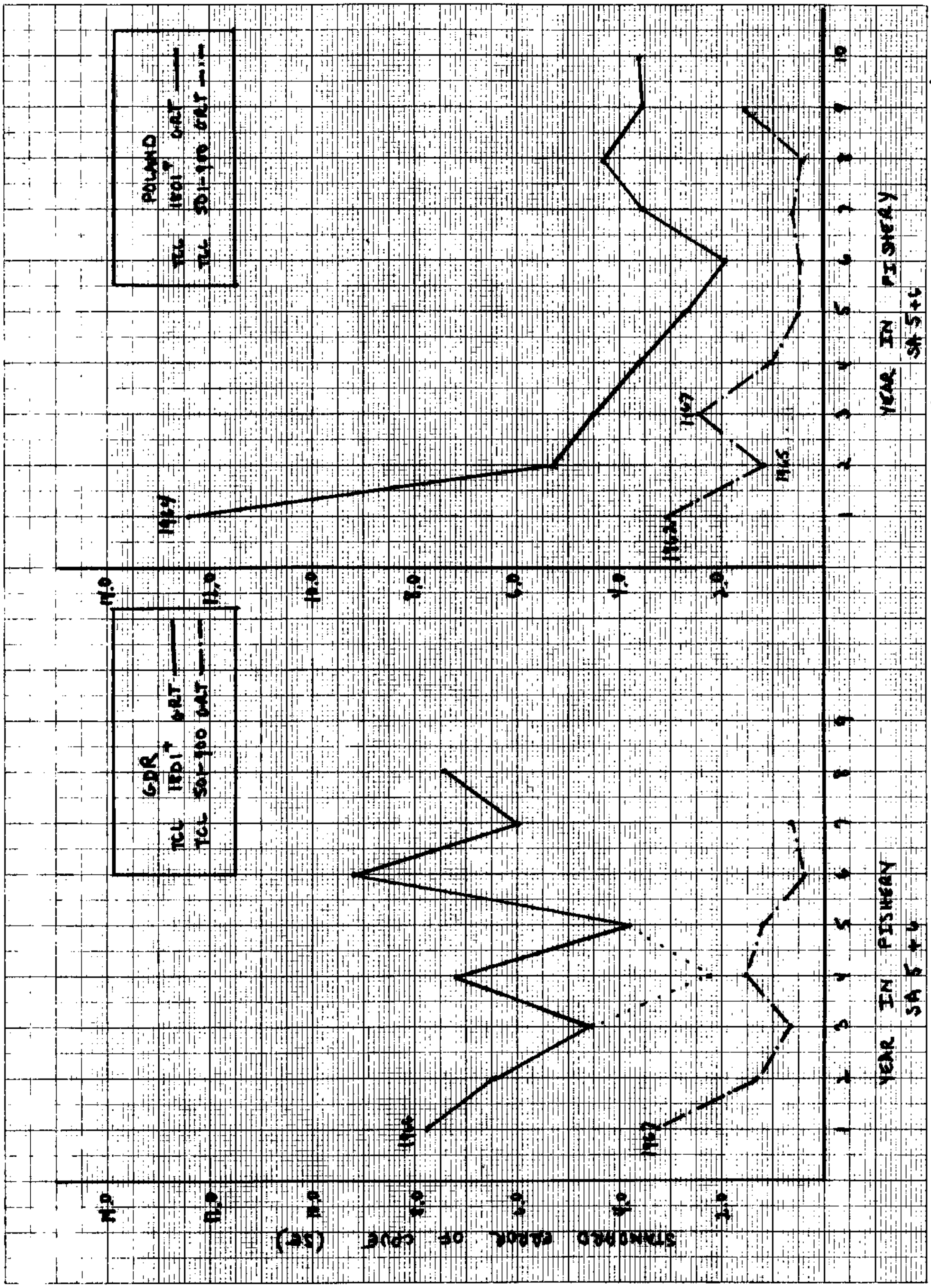

FIGURE 2A. (SEE CAPTION OF FIGURE 1.)

FIGURE 2B. (SEE CAPTION OF FIGURE 1.)

K-E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
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FIGURE 3.

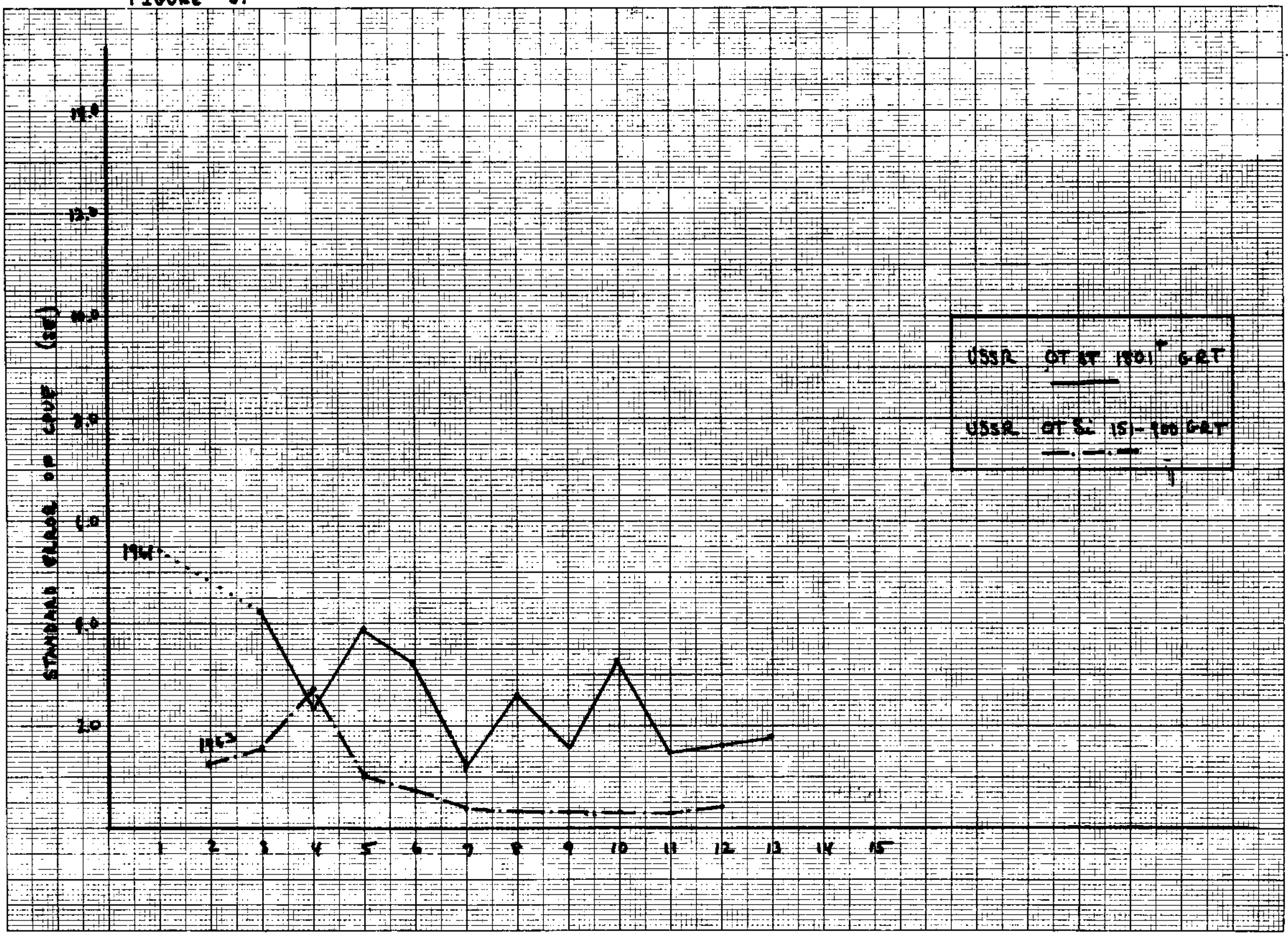

FIGURE 3. SEE CAPTION OF FIGURE 1 FOR EXPLANATION OF PLOT.

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1513

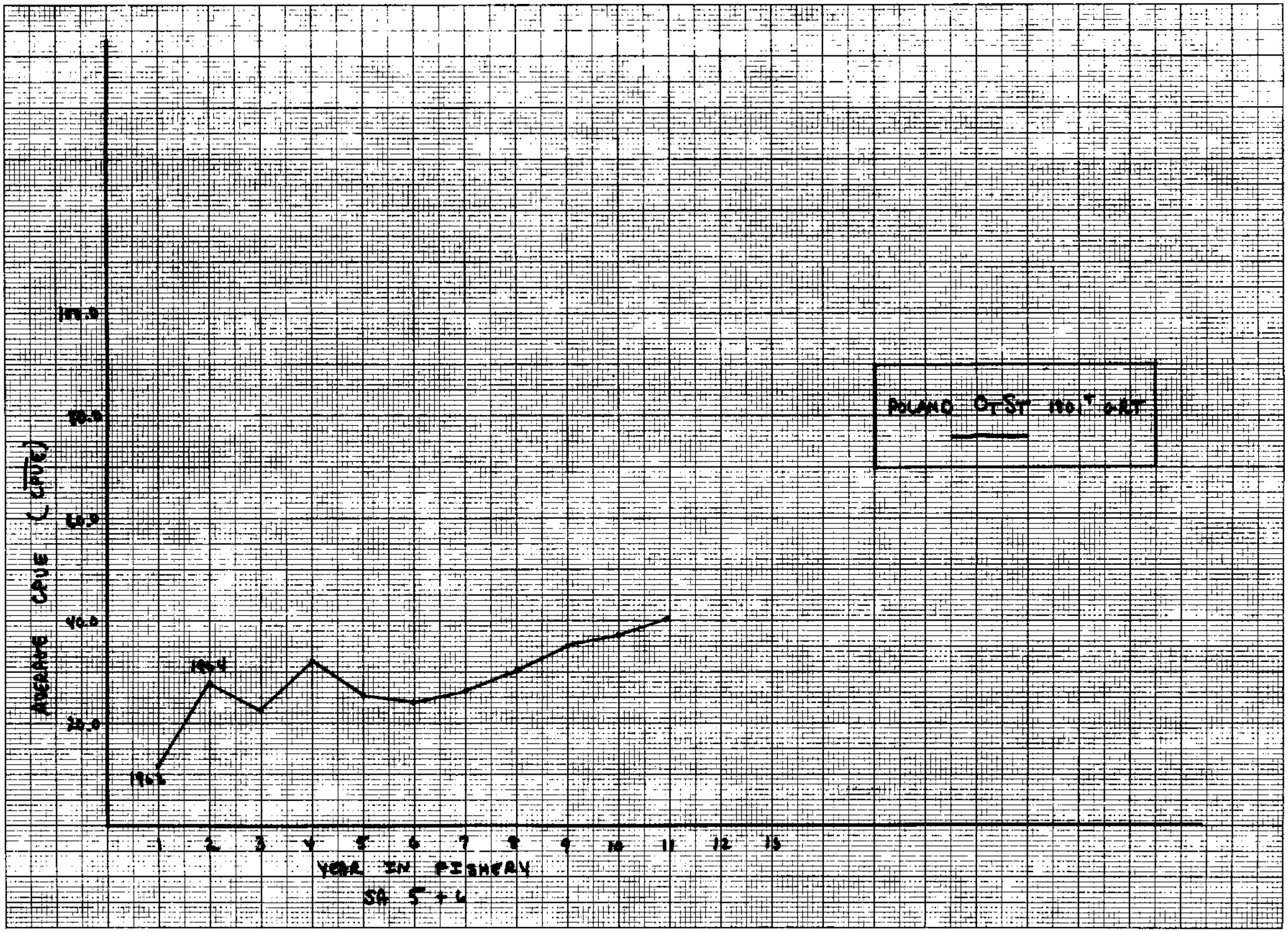

FIGURE 4. PLOT OF AVERAGE CPUE BY YEAR FOR DATA OF POLISH 1801+ GRT VESSELS. DATA OF 1962 CONSISTED OF ONE OBSERVATION.

K&E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO. MADE IN U.S.A.

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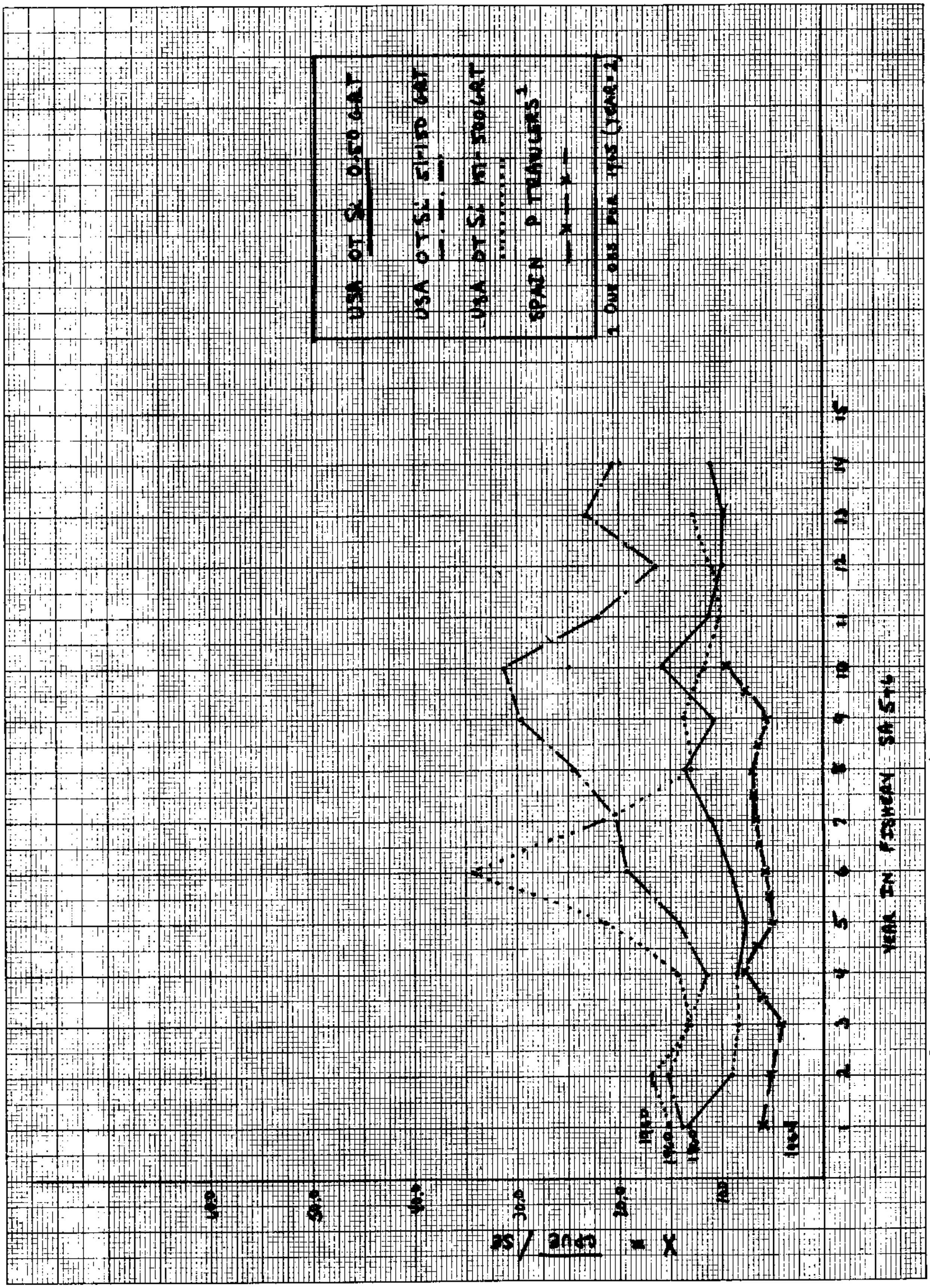

FIGURE 5. PLOTS OF AVERAGE CPUE / STANDARD ERROR OF CPUE BY YEAR IN FISHERY FOR VESSEL CLASSES LISTED.

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
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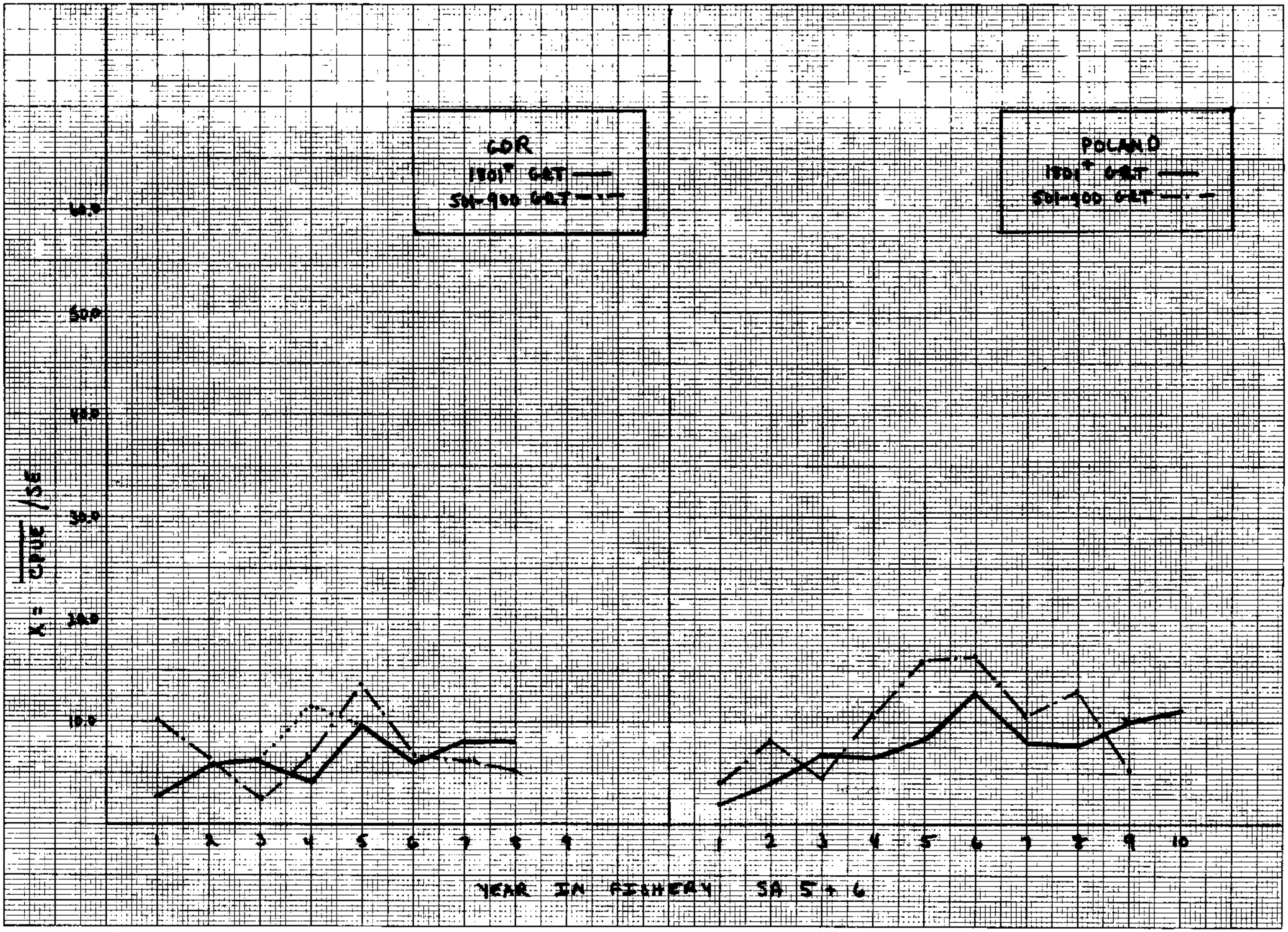

FIGURE 6A. SEE CAPTION WITH FIGURES. FIGURE 6B. SEE CAPTION WITH FIGURE 5.

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
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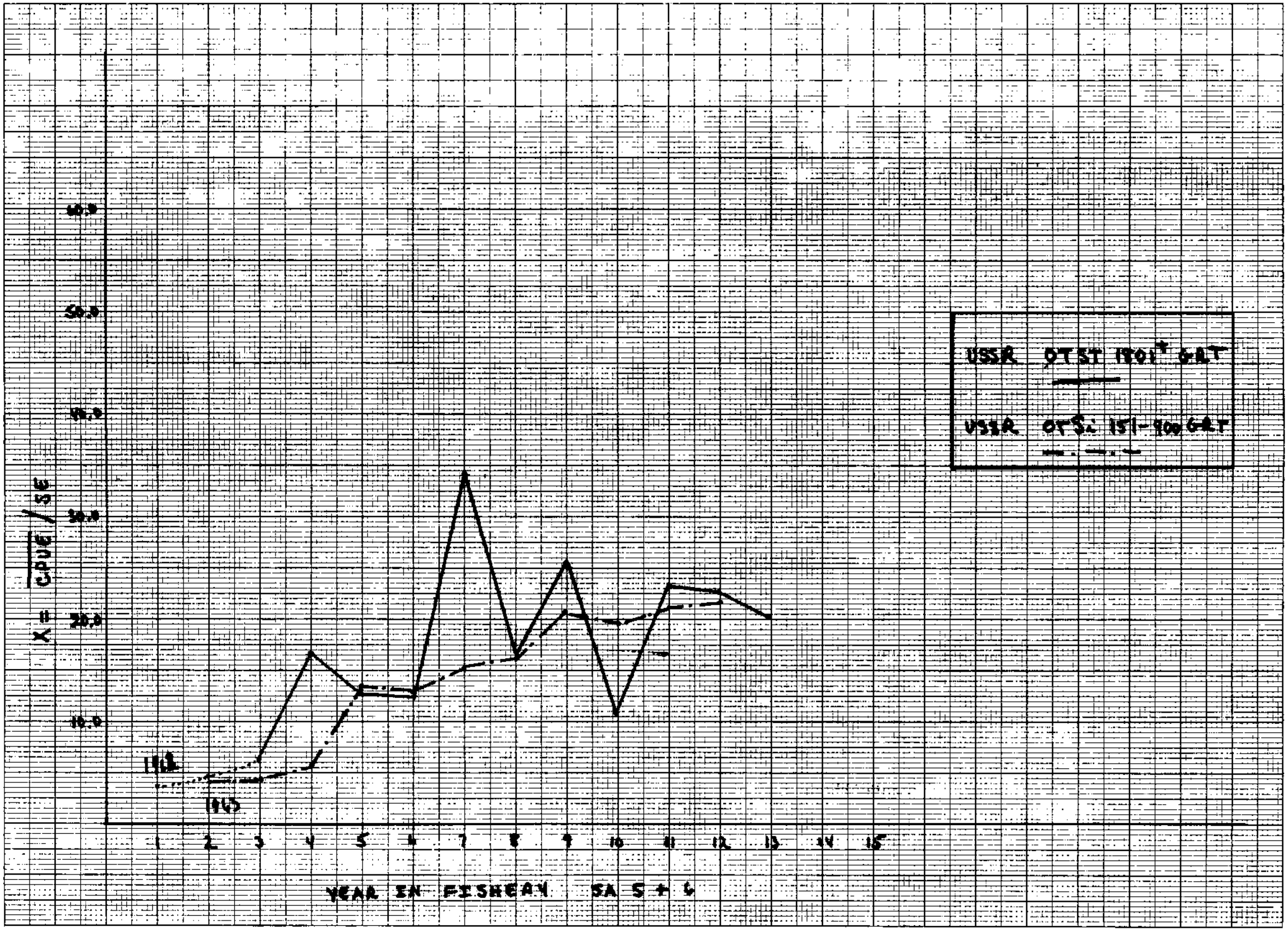

FIGURE 7. SEE CAPTION WITH FIGURE 5 FOR EXPLANATION OF PLOT.

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.
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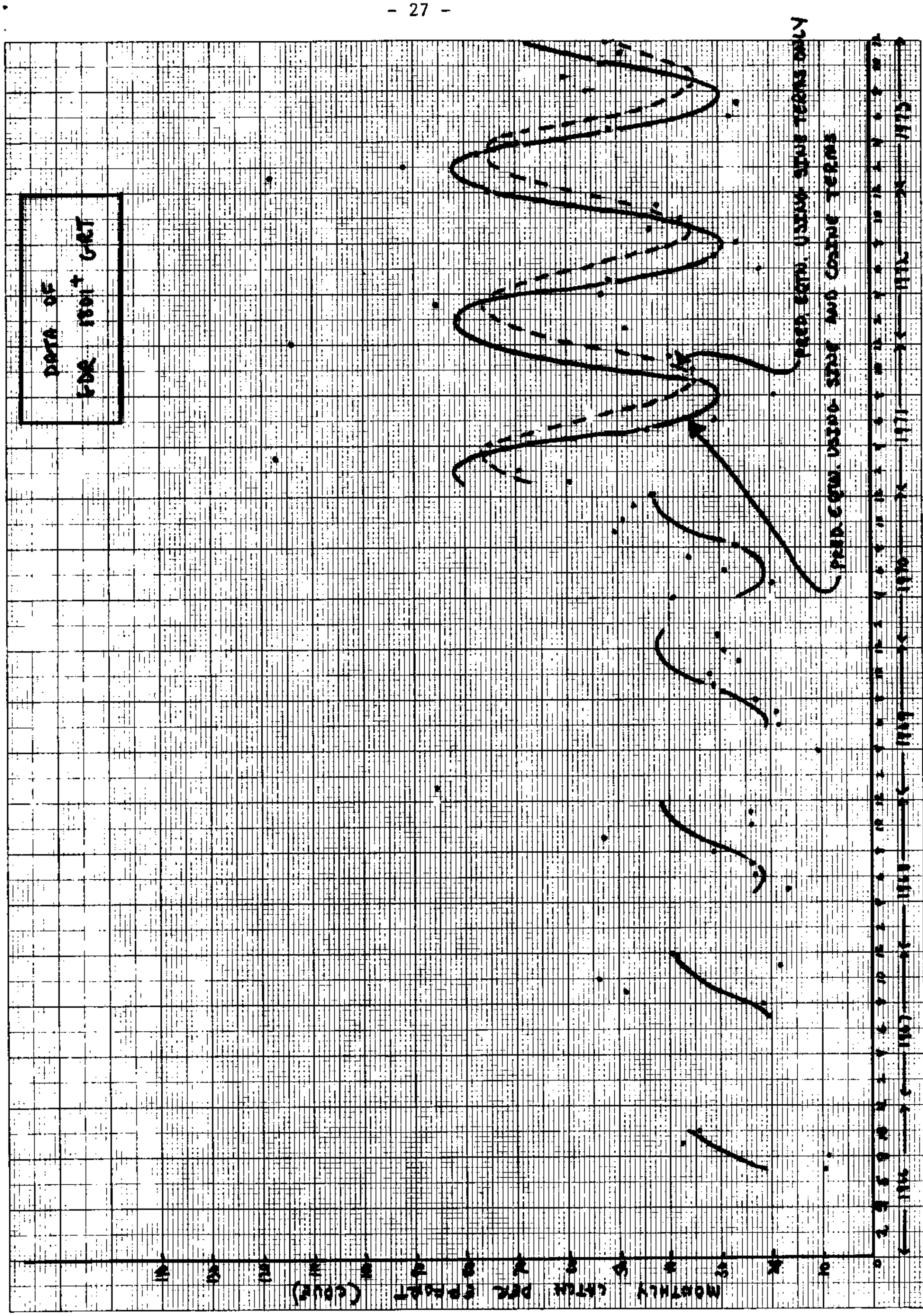

FIGURE 8. PLOT OF CPUE BY MONTH AND PREDICTED CPUE FROM MULTIPLE LINEAR REGRESSION RUNS.
DATA OF GDR - 1801+ GRT.

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO. MADE IN U.S.A.
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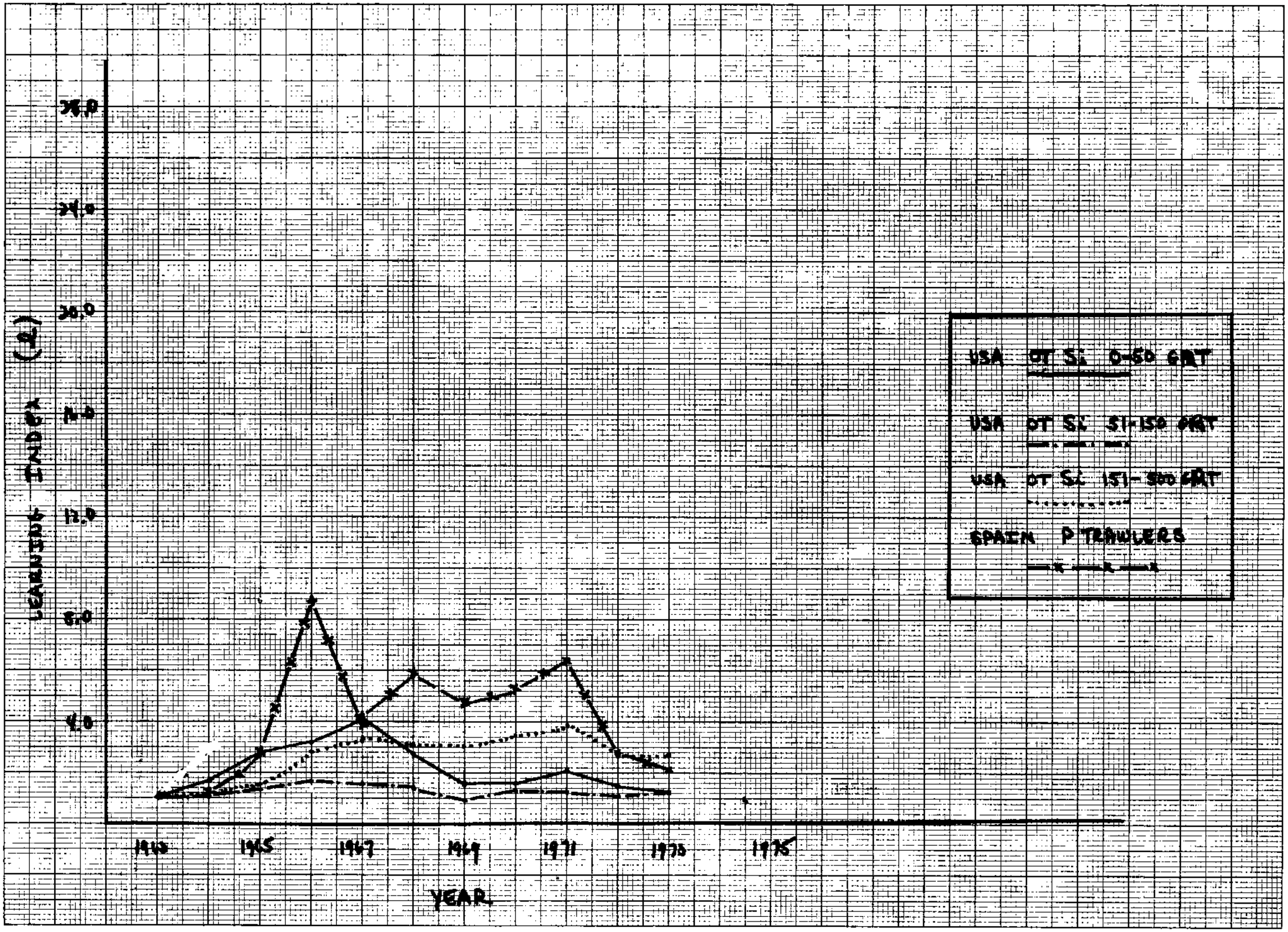

Figure 9. PLOT OF LEARNING FUNCTION BY YEAR FOR VESSEL CLASSES DESIGNATED.

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1513

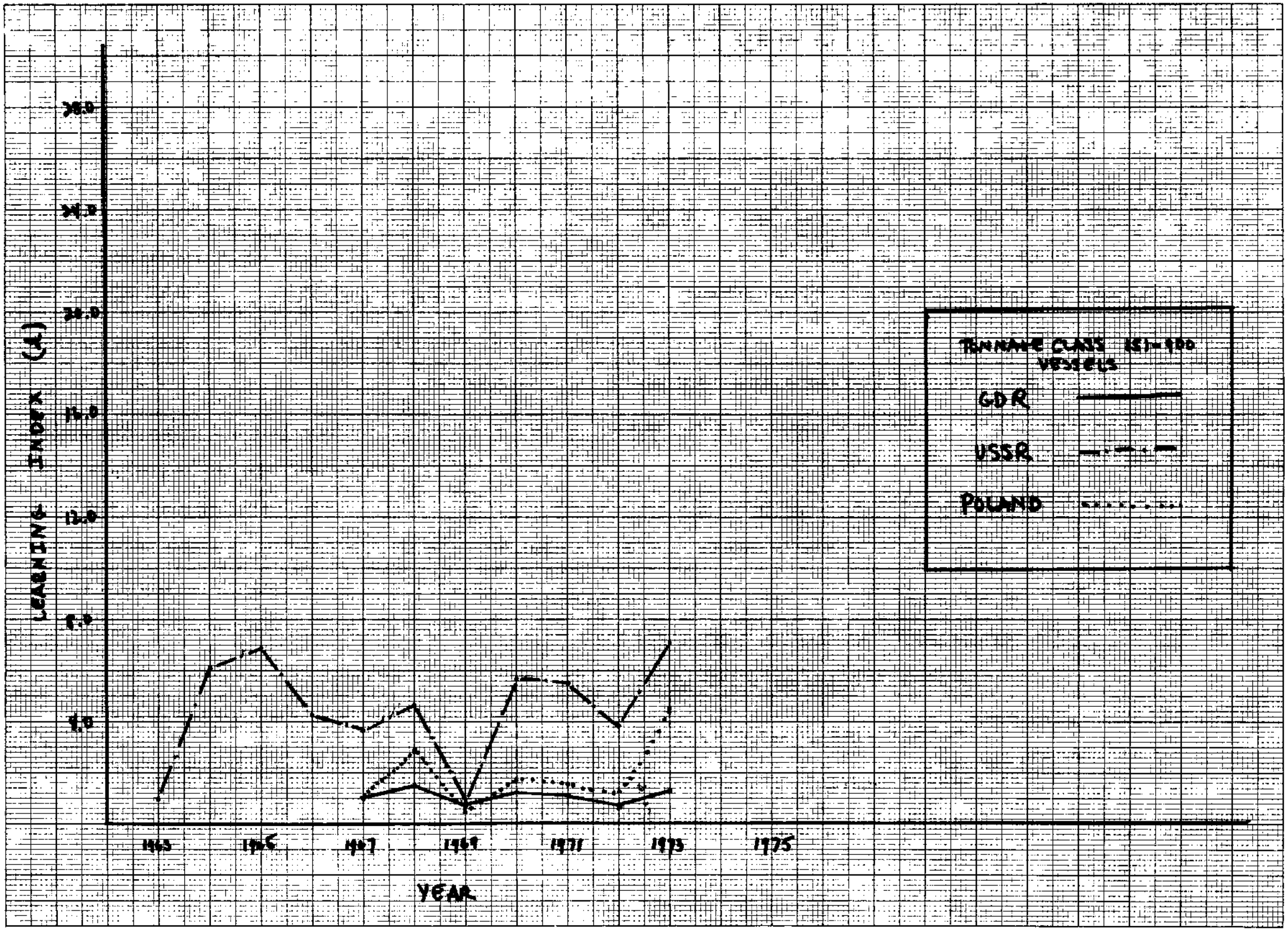

FIGURE 10. PLOT OF LEARNING FUNCTION BY YEAR FOR VESSEL CLASSES DESIGNATED.

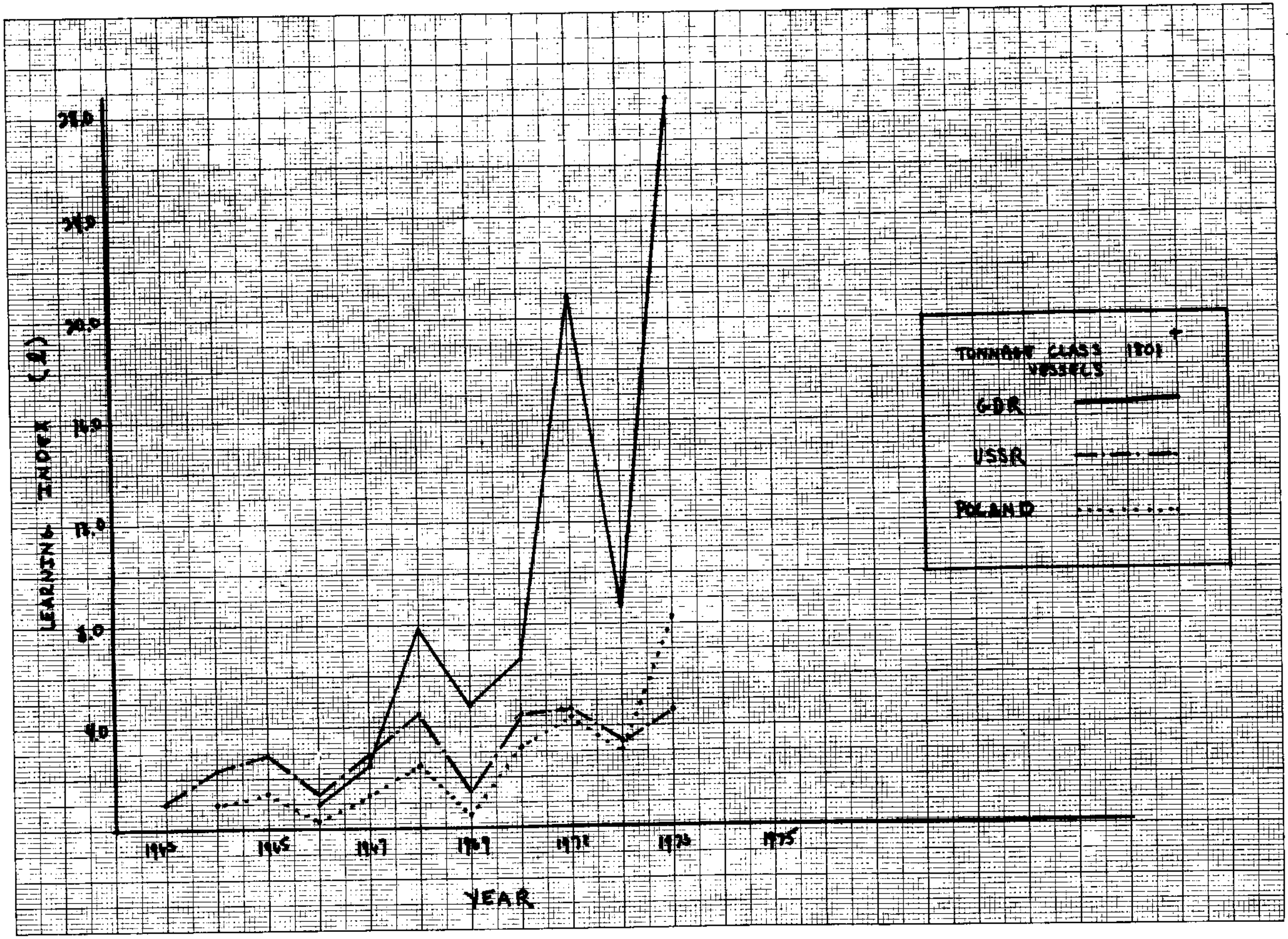

Figure 11. Plot of learning function by year for vessel classes designated.

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