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Catch Per Unit Effort and its Pattern of Variability in the Canadian Fishing Zone, January and February 1979

by

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INTRODUCTION

An understanding of fishing effort and catch per unit effort is fundamental to assessment and management of fish stocks. Effective management of most of the stocks in Canadian waters depends directly or indirectly on the amount of effort to be applied in the fishery and this in turn depends on the magnitude of the catch per unit effort. As well, one of the commonly used contemporary methods of estimating abundance of an exploited stockinvolve using catch per unit effort as an index of abundance (Rothchild 1977). For these reasons and also to facilitate valid comparisons from month to month of catch per unit effort, it is important to have good estimates,to know the variance of these estimates and to understand what causes the variance in the catch per unit effort.

This paper deals with the detailed catch per unit effort of the commercial catches of the five foreign countries taking significant amounts of fish in the Canadian zone, specifically from ICNAF areas 3, 4R, 4Vn and 3Ps in January and February of 1979. Catch per hour, catch per day, hours per day fished, sets per day fished and the coefficients of variation are examined and discussed. Also trends of catch per hour on a daily basis over time are examined.

METHODS

Catches and effort were broken down into the various categories as described below. The data used was collected by the Foreign Observer Program (Newfoundland) taken from direct observation of the catches and

from the vessels fishing and production logs. Only a portion of the sets were observed.

(1) Catch per hour

Define for one specific country, gear type, species, ICNAF division (or stock area) and month;

K = the number of observations (no. of sets)

F_i = the number of hours reported for the Kth observation, j = 1, 2, ...K,

Cj = the catch (metric tons) of the Kth observation

Catch per unit effort is estimated by,

$$(1)\quad C/F = \frac{\sum_{j=1}^{K} Cj}{\sum_{j=1}^{k} f_j}$$

The estimator defined above is in the class of ratio estimators since both the amount of fish caught and the number of hours spent in directly fishing for the species of interest, are random variables. Estimators in this class are generally biased, with bias of order 1/K (Cochran 1977).

Smith (1979) has proposed the use of the so-called first order 'Jack Knife' estimator in place of the usual estimator of C/F defined in (1). The Jack Knife technique removes bias of the order 1/K as well as providing a means for estimating the variance of the estimator.

The Jack Knife estimator used here, denoted by R_J, is the average of the K quantities;

$$(2)\quad R_{-j} = K\,(C/F) - (K-1)\,R_{-j}$$

where C/F is defined in (1) and $R_{-j} = \frac{\Sigma cj}{\Sigma fj}$ with the jth observation removed.

The estimator of the variance of R_J, $V\widehat{(R_J)}$ would be;

$$(3)\quad V\widehat{(R_J)} = \frac{1}{K(K-1)} \cdot \sum_{\Sigma}^{K} (R_{-j} - R_j)^2$$

This is an unbiased estimator of the variance if the R_{-j} can be considered to be independent estimates of the population ratio R (Cochran, 1977). The above variance was then used to derive the coefficient of variation (CV) of the catch per hour from the following:

$$(4)\quad CV = \frac{\frac{\sqrt{V\widehat{(Rj)}}}{\sqrt{K}}}{\overline{C/F}}$$

(2) Catch per day, hours per day fished, sets per day fished.

The coefficient of variation of the estimator for catch per day, hours per day fished and sets per day fished was calculated as follows:

Define V = variance

$\bar{M}$ = Mean (c/day, hrs/day, sets/day)

K = No. of observations (sets)

$$(5) \qquad CV_1 = \frac{\frac{\sqrt{V}}{\sqrt{K}}}{\bar{M}}$$

Less than 100% of all sets were observed (70-100%) therefore the calculations of catch per day was done using only the catches of observed sets but using actual time spent fishing. The observed catches were, adjusted to to the actual number of hours fished on a daily basis by the following equation:

Define:

n = total no. of sets recorded

L = number missing sets (effort recorded but not catch)

K = n-L (C missing)

C_i = catch (metric tons)

f_i = hours fished on the i^{th} day.

C^1 / F^1 = adjusted catch per day

$$(6) \qquad C^1 / F^1 = \sum_{i=1}^{M} \left[\frac{\left(\sum_{j=1}^{k} cij\right) \frac{\left(\sum_{j=1}^{n} fij\right)}{\left(\sum_{j=1}^{k} fij\right)}}{f_i} \right]$$

(3) Catch per hour (daily trends)

Catch per hour on a daily basis was plotted over time (Fig. 1-20). The vertical line represents the start of the fishery. The mean catch per hour (daily) was derived and the coefficient and variation of the population of points was calculated as follows;

Define V = variance of catch per hour (daily)

$\bar{M}$ = mean of catch per hour (daily)

$$(7) \qquad CV^{1} = \frac{\sqrt{V}}{\bar{M}}$$

RESULTS

The results are presented in Table 1 a,b,c,d and Figs. 1-20 for Cuba, France, GDR, Poland and Portugal by gear, month, species (directed) and ICNAF area.

Cuba

Although observers covered all days fished in January only five sets were done in 3K. This small number of observations accounted for the large variance of catch per day and per hour (cod). The hourly catch was quite high but catch per day was low because an average of only about five hours per day was spent fishing (2J + 3K). In February the hours and sets per day increased, the catch per hour remained nearly the same resulting in a higher daily catch rate.

Figs. 1 and 2 show that fishing activity was covered from the start of the fishery in 3K and nearly so in 2J. The pattern of variance about the mean catch per hour (daily) for both areas showed no apparent trend from the start of the fishery. The distribution of catch size over time is more clumped in 2J with a series of good fishing days followed by a series of bad days. No other trends are noticeable from this data.

France

Catch per hour for OT7's (Jan., 4R, cod) were slightly higher than for OT 6's (this was reversed for February) but the OT 6's spent more hours per day fishing resulting in almost identical per diem catch rates. In February a drop in hours per day fished due to reduction in set length by both vessel classes resulted in reduced daily catch rates. The catch per hour in 4R as taken by France was only about 35% of the catch rate per hour in 2J + 3KL as taken by Cuba. Catch rates per hour in 4Vn were nearly triple those in 4R (both fished by France) and this was reflected

in catch per day because the fishing pattern (hours and sets per day fished) was the same for both areas. Figs. 3 + 4 show that in 4Vn there was less variance in daily catch per hour than in 4R.

GDR

Only 8 sets were observed in Jan., 2J + 3KL, cod and the low catch rates are probably not indicative of the true pattern (note the large variance). In February the catch per day (2J + 3KL) was considerably higher and nearly the same for OT 5's (catchers) and 7's with catch rate slightly higher in 3K. Catch per hour was higher for OT 7's but greater time per day spent fishing tended to equalize the daily rates. Catch rates (per hour) in 2J+3KL for GDR and Cuba were comparable, Cuba having a slightly higher rate.

The variance in the pattern of daily catch rates (Figs. 7-10) for GDR was lower than that of Cuba and these results also show a more or less random daily pattern.

Poland

Catch rates for cod (hourly and daily) in 2GH are very low and hours spent fishing are low compared to the activity in 2J + 3KL. Catch per hour is much higher in 2J + 3KL and is slightly lower but similar to catch per hour for GDR and Cuba in the same area. However, catch per day for Poland is considerably higher because of the greater number of hours spent fishing per day. As found for other countries the pattern of daily catch per hour (Fig. 11, 12 & 13) appears random with a variance similar to GDR.

The catch per hour and day for witch is much lower than for cod in the same area and the daily pattern of catch per hour also shows no distinct pattern (Fig. 14).

Portugal

Hourly catch rates for Portugal OT 6 + 7 are considerably lower than GDR, Poland and Cuba for 2J + 3KL. Their fishing pattern (hours and sets per day fished) was similar to the above countries resulting in much lower daily catch rates. Daily catch per hour showed a random pattern and the variance of the points was similar to GDR and Polish patterns.

Coefficient of variation of catch per hour varied from 0.056 to 0.816. The high values were generally found when the number of observations was

low. In general CV(c/hr.) were similar for most areas having fairly low values near 0.10. The CV(c/day) was also quite low in most cases (near 0.10) but the mean catch per day varied independently of mean catch per hour because of activity differences (sets and hours per day fished). The CV (sets and hours per day fished) was low for most countries (usually less than 0.10).

The bycatch associated with the directed species is listed in Table 1 a, b, c, d and shows some distinct differences between areas and countries. The highest bycatches were taken by Poland in 2GH. In 2J + 3KL bycatch was low and varied from 2.0% to 9.8% in the cod directed fishery. Bycatches were similar in most cases for 4R and 4Vn. In the witch directed fishery a 27.4% bycatch was taken (Portugal, 3K).

DISCUSSION

The data used in this paper were very detailed and this level of detail was generally not available in the past on catch and effort. This type of data will allow the much needed analysis of catch and effort patterns and variance broken down by country, area and gear. This paper presents data from only the first two months in 1979 and therefore is lacking in time series sequences (several years of data) that would allow broader conclusions to be drawn, but there is sufficient data to comment on some of the differences and similarities found within the two month period. Cod and witch were the only directed species in these months and there was extensive data for cod. The discussion must be restricted to these two species but future data may show similar patterns for other species.

Catch per hour is a better relative index of abundance than catch per day because bias is introduced into catch per day by the highly variable number of hours (sets) fished per day between countries, vessel classes and areas. This is particularly apparent for Cuba where in the same area, catch per day is considerably lower than that for Poland but catch per hour is slightly higher. Mean catch per hour differences are much lower between countries within a given area but Portugal is the exception, having considerably lower values. Gear size and catchability is probably the major factor contributing to catch/hour differences

between countries (same vessel class) and patchy distribution of the species adds to the variance. The bias in catch/day because of time per day spent fishing is likely due to ice conditions causing incomplete access, weather conditions, gear problems and other unforeseen operational problems. These cause the daily effort to fluctuate from month to month and year to year.

The data also indicated that it may be more desirable to use catch/hour as a management tool when determining the amount of effort to be allocated to country for a given fishery.

Values of catch per hour are higher for OT 7's than for OT 6's for all countries except France. These differences are slightly inconsistent indicating some masking of the effect of vessel size on catch rate but it does indicate a need for standardization between classes by country. These factors would probably have to be updated by year to account for fleet changes but now that the more detailed data is becoming available it may be possible to fine tune catch and effort analyses to this level. It is also interesting to note that GDR OT5 catcher vessels working as part of the catcher-processor fleet have substantially higher catch rates than GDR OT7 vessels in the same area.

The catch per hour data if considered as relative index of abundance illustrates dramatic differences between areas. For France the catches/hour in 4R cod were only about 1/3 of those in 4Vn as fished by the same fleet. Hourly catch rate for 2J+3KL cod for other countries are closer to those of 4Vn. For 2J + 3KL cod during the winter (no migration) it can be seen from the concentrated, non-moving fleet activity and from tagging experiments (Lear, pers. comm.) that the cod show little movement or dispersion and are concentrated in a relatively small area. Therefore, catch/hour is probably a very good relative index of abundance (after adjustment for country and vessel class differences). This may also apply to cod in other areas during non-migratory phases.

It may be worth while exploring the relationships between other abundance indices and commercial catch/hour.

The variance of catch/hour and catch/day compares favourably to that of the landing data presented by Smith (1979) but one type of

variation in observer data is not accounted for in the catch/hour coefficient of variation values. It is the error in estimates of catch by observers. Every effort is made to reduce this error by increasing experience in eyeball estimation, by using volumetric estimation methods, by using back calculation data from processing logs and doing double checks through vessel captain estimates and processing log estimates. Observer estimates of by catch, regardless of estimation error, is probably the best available.

An additional source of error occurs in catch/day because less than 100% of sets are observed and catch values must be adjusted for those sets not observed. This error can be reduced by observing a greater percentage of the catches.

It has been hypothesized that catch/effort would tend to be lower at the start of a fishery and increase to asymtote. It was thought that the first few days of catch/effort should be removed. Fig. 1-20 for fisheries observed from the start shows that this is not the case. There is no such apparent pattern of daily catch/hour about the mean.

More detailed data is now becoming available and this should improve management of the fishery through a better understanding of catch/effort.

REFERENCES

Cochran, W.G. 1977. Sampling Techniques. J. Wiley and Sons, Toronto 428 pp.

Smith, S.J. 1979. On estimating the variance of the estimate of catch per unit effort. ICNAF Res. Doc. #

Rothchild, B.J. 1977. "Fishing Effort" in Fish Population Dynamics. J. Wiley and Sons, Toronto.

Table 1a Foreign Observer Program Catch and Effort Summary for all countries, Jan. & Feb./79.

Country	Vess. Type	Month	Directed Species	ICNAF Area	No. Sets Obs.	% Cover	Catch/Effort /Day	CV	/Hour	CV	Hours/ Day Fish.	CV	Sets/ Day Fish.	CV	% By-catch
Cuba	OT7	Jan.	Cod	2J	83		9.01	0.147	1.73	0.109	5.28	0.101	2.66	0.087	5.7
				3K	5		1.72	0.748	0.49	0.408	2.90	0.188	1.50	0.192	6.5
				2J+3KL	88	100	9.01	0.140	1.668	0.109	5.036	0.098	2.538	0.085	5.8
		Feb.	Cod	2J	39		14.36	0.313	2.16	0.195	6.66	0.125	3.14	0.120	2.2
				3K	71		13.07	0.223	2.03	0.132	6.11	0.100	3.23	0.106	2.0
				2J+3KL	110	100	13.518	0.177	2.083	0.111	6.31	0.077	3.20	0.080	2.1
France	OT6	Jan.	Cod	4R	43		12.81	0.214	0.57	0.143	18.04	0.030	6.58	0.035	24.8
	OT7			4R	57		12.85	0.217	0.79	0.127	16.39	0.083	7.15	0.084	4.4
	OT6+7			4R	100	15	12.828	0.149	0.681	0.096	17.184	0.044	6.88	0.048	13.2
	OT6	Feb.	Cod	4R	132		11.64	0.157	0.70	0.101	16.69	0.050	6.41	0.274	10.2
	OT7			4R	147		8.35	0.129	0.55	0.074	14.55	0.064	6.24	0.058	7.4
	OT6+7			4R	279	50	9.889	0.105	0.622	0.065	15.548	0.041	6.32	0.036	8.8
	OT6	Feb.	Cod	4Vn	100		27.41	0.109	1.76	0.085	15.87	0.013	5.81	0.042	2.8
	OT7			4Vn	114		25.87	0.109	1.68	0.083	15.73	0.036	6.52	0.048	1.9
	OT6+7			4Vn	214	48	26.61	0.076	1.724	0.060	15.61	0.028	6.18	0.033	2.4
	OT6	Feb.	Cod	3Ps	4	6	7.25	0.109	0.76	0.816	6.55	0.477	2.50	0.379	11.6

Table 1b Foreign Observer Program Catch and Effort Summary for all countries January and February, 1979.

Country	Vess. Type	Month	Directed Species	ICNAF Area	No. Sets Obs.	% Cover	Catch/Effort /Day	CV	/Hour	CV	Hours/ Day Fish.	CV	Sets/ Day Fish.	CV	% By-catch
GDR	OT7	Jan		3K	8		1.80	0.055	0.254	0.414	7.25	0.633	4.50	0.333	17.0
	OT7			2J+3KL	8		1.80	0.055	0.254	0.414	7.25	0.633	4.50	0.333	17.0
	OT5	Feb.	Cod	2J	61		12.52	0.155	1.86	0.123	6.67	0.126	3.68	0.119	14.1
	OT7			2J	20		12.36	0.292	1.09	0.283	11.75	0.084	5.00	0.289	4.1
	OT5+7			2J	81		12.49	0.135	1.66	0.114	7.552	0.108	3.91	0.099	
	OT5	Feb		3K	73		14.17	0.120	1.84	0.089	8.20	0.085	4.17	0.092	12.6
	OT7			3K	39		15.28	0.191	1.29	0.141	11.69	0.127	4.22	0.011	18.9
	OT5+7			3K	112		14.48	0.100	1.63	0.077	9.19	0.077	4.19	0.072	
	OT5	Feb.	*	2J+3K	174		15.17	0.086	1.62	0.062	9.15	0.048	4.60	0.035	14.2
	OT7		*	2J+3K	37		15.73	0.084	1.73	0.186	9.92	0.117	4.11	0.11	12.9
	OT5+7		*	2J+3K	211		17.83	0.163	1.64	0.060	9.26	0.044	4.53	0.050	
	OT5	Feb		2J+3KL	308		14.40	0.064	1.71	0.047	11.87	0.030	4.32	0.045	15.0
	OT7			2J+3KL	195		14.94	0.136	1.42	0.106	10.98	0.072	4.32	0.065	15.9
	OT5+7			2J+3KL	403		14.50	0.057	1.64	0.044	13.09	0.026	4.812	0.103	

* Fishing of both areas within the observed days prevented a breakdown to ICNAF area.

Table 1c Foreign Observer Program Catch and Effort Summary for all countries Jan. & Feb./79

Country	Vess. Type	Month	Directed Species	ICNAF Area	No. Sets Obs.	% Cover	Catch/Effort /Day	CV	/Hour	CV	Hours/ Day Fish.	CV	Sets/ Day Fish.	CV	% By-catch
Poland	OT7	Jan.	Cod	2H	43		1.96	0.635	0.210	0.393	10.44	0.156	3.62	0.170	49.5
				2GH	43	72	1.96	0.635	0.210	0.393	10.44	0.156	3.62	0.170	49.5
			Cod	2J	127		22.47	0.096	1.36	0.075	17.13	0.048	5.16	0.043	5.4
				2J+3KL	127	69	22.47	0.096	1.36	0.075	17.13	0.048	5.16	0.043	5.4
		Feb.	Cod	2J	95		21.04	0.120	1.59	0.085	13.92	0.064	5.04	0.069	3.6
				3K	64		20.98	0.161	1.52	0.082	13.71	0.092	5.33	0.098	9.8
				2J+3KL	159	66	21.02	0.095	1.56	0.061	13.85	0.052	5.150	0.056	
			Witch	3K	131		8.54	0.108	0.63	0.072	13.47	0.060	3.81	0.059	8.5
				2J+3KL	131	-	8.54	0.108	0.63	0.072	13.47	0.060	3.81	0.059	8.5
Portugal	OT6	Feb.	Cod	2J	92		7.49	0.113	0.586	0.080	13.34	0.073	4.6	0.326	3.8
	OT7			2J	8		12.10	0.677	0.969	0.275	13.5	0.356	5.0	0.400	3.2
	OT6+7			2J	100		7.84	.119	0.616	0.078	13.35	0.070	4.66	0.068	
	OT6			3K	88		6.85	0.098	0.427	0.079	16.0	0.066	4.7	0.064	8.3
	OT7			3K	39		9.07	0.243	0.600	0.182	14.11	0.126	5.6	0.134	0
	OT6+7			3K	127		7.44	0.103	0.47	0.080	15.48	0.058	5.3	0.059	

Table 1d Foreign Observer Program Catch and Effort Summary for all countries Jan. & Feb./79

Country	Vess. Type	Month	Directed Species	ICNAF Area	No. Sets Obs.	% Cover	Catch/Effort /Day	CV	/Hour	CV	Hours/ Day Fish.	CV	Sets/ Day Fish.	CV	% By-catch
Portugal	OT6	Feb.	Cod	2J+3KL	180		7.192	0.076	0.51	0.058	14.6	0.050	4.9	0.048	
	OT7			2J+3KL	46		9.68	0.223	0.67	0.153	13.9	0.113	5.5	0.122	
	OT6+7			2J+3KL	226	37	7.63	0.077	0.54	0.056	14.5	0.046	7.5	0.045	
	OT6		Cod	3M	9		14.0	0.363	0.652	0.149	22.03	0.136	4.0	0	0
	OT7		Witch	3K	19		5.48	0.347	0.383	0.221	13.5	0.128	5.60	0.192	27.4

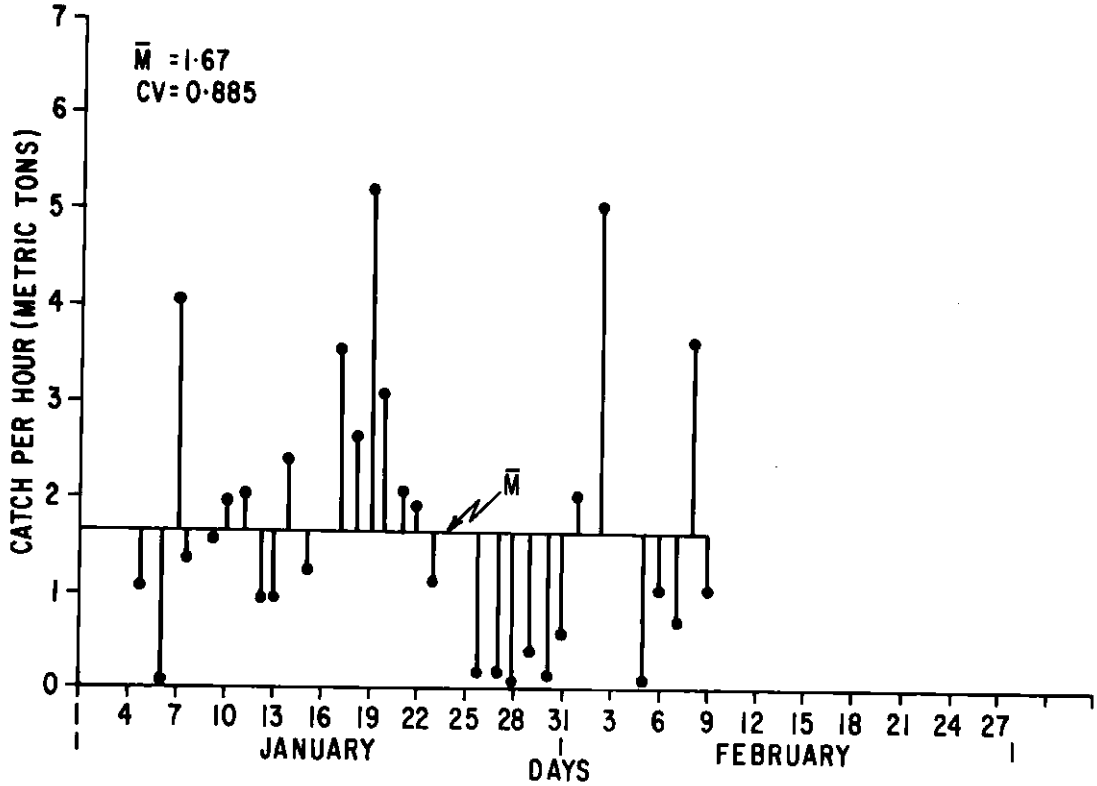

Fig. 1. Catch per hour on a daily basis for Cuba, OT7 in 2J, cod of the catch rate (1 of 2 vessels, 2 started Jan. 1).

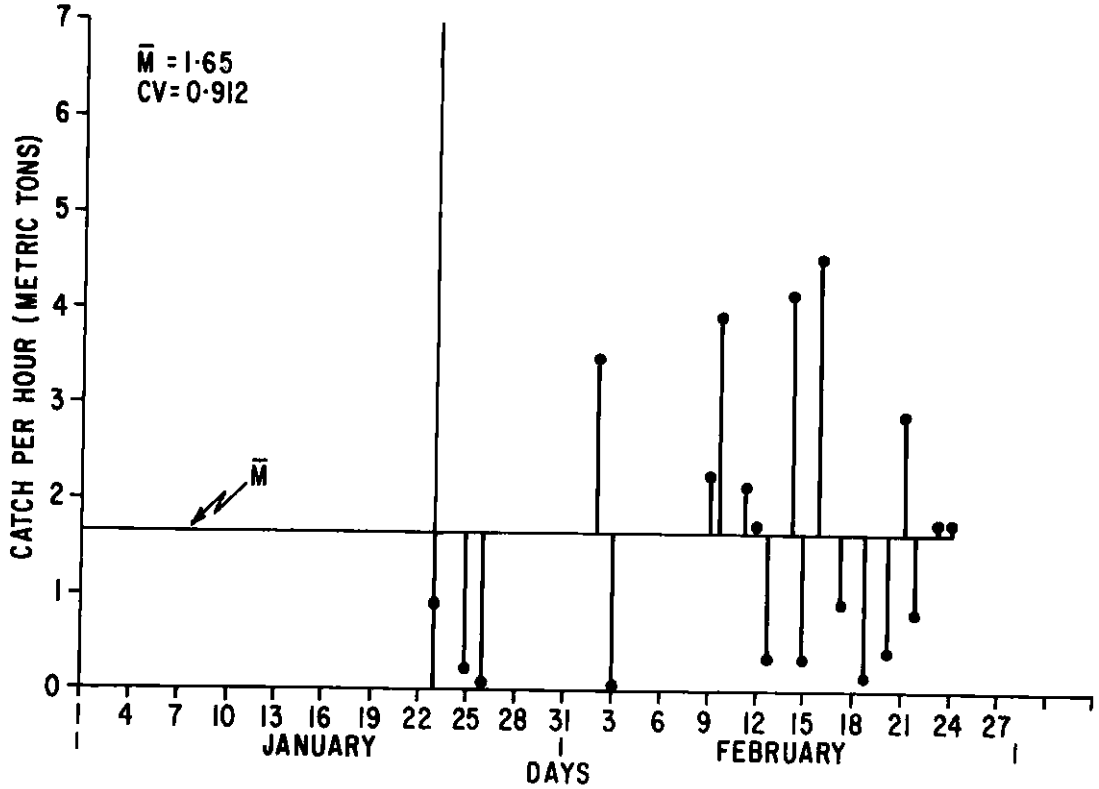

Fig. 2. Catch per hour on a daily basis for Cuba, OT7, in 3K, cod showing variability of the catch rate (fishery started Jan. 23).

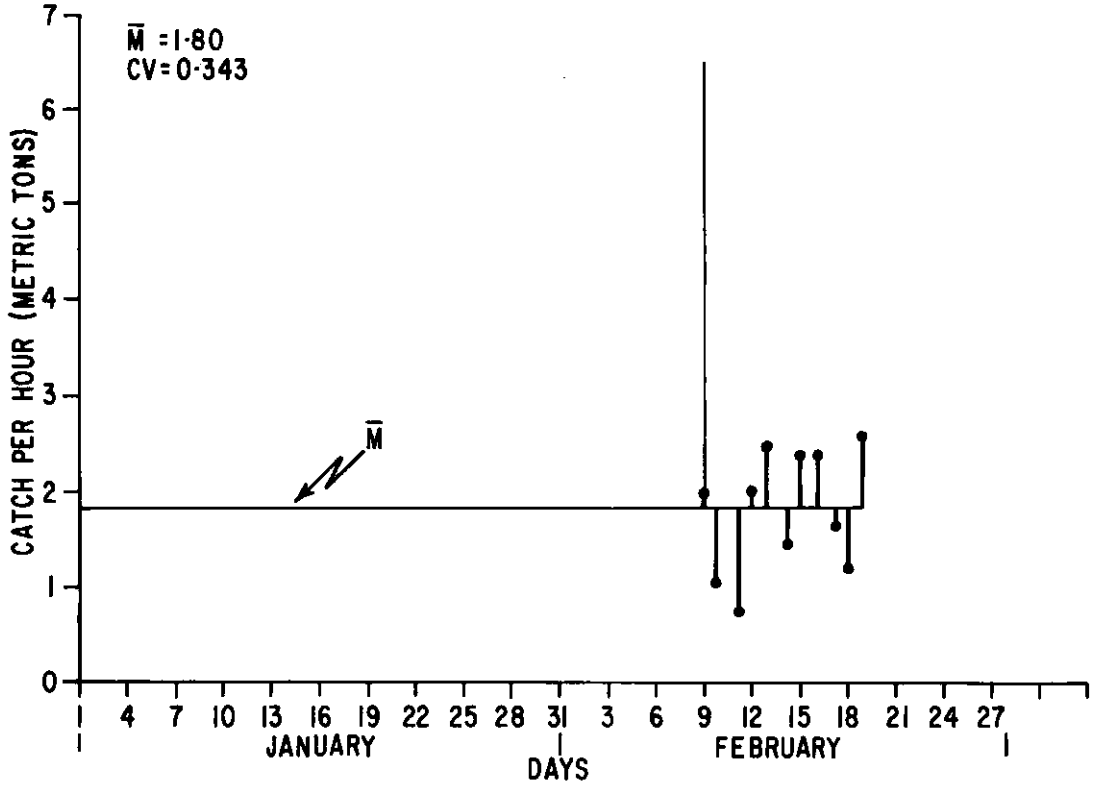

Fig. 3 Catch per hour on a daily basis for France, OT7, in 4Vn, for cod, showing variability of the catch rate. (Started February 9).

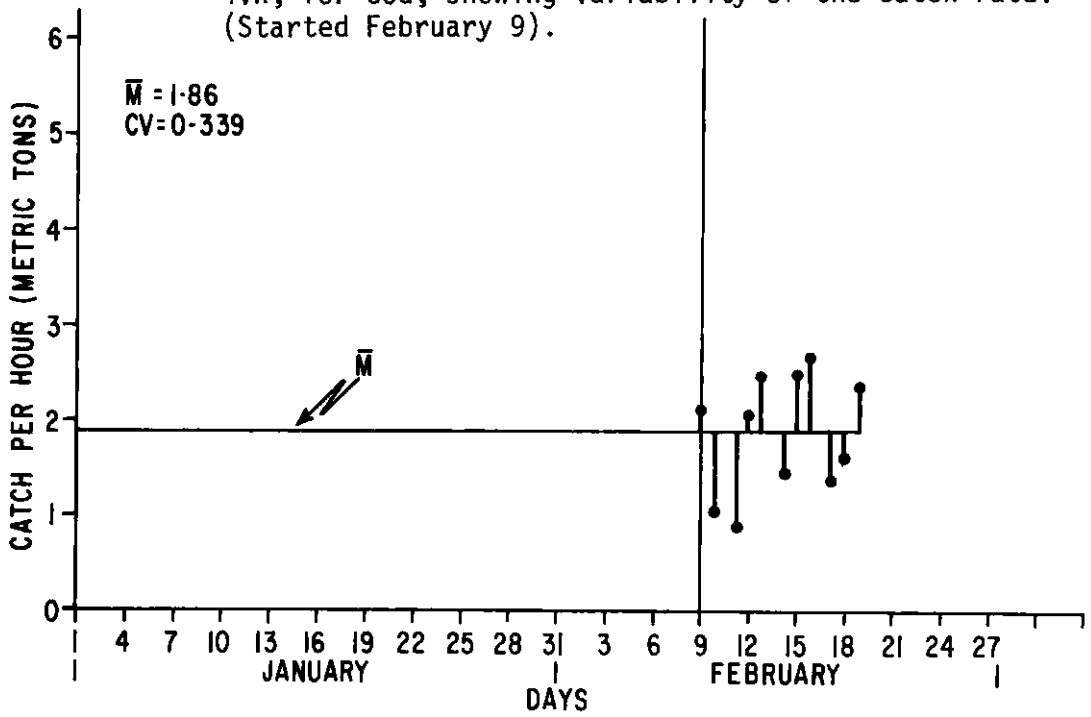

Fig. 4. Catch per hour on a daily basis for France, OT6, in 4Vn, for cod, showing variability of the catch rate. (Started February 9).

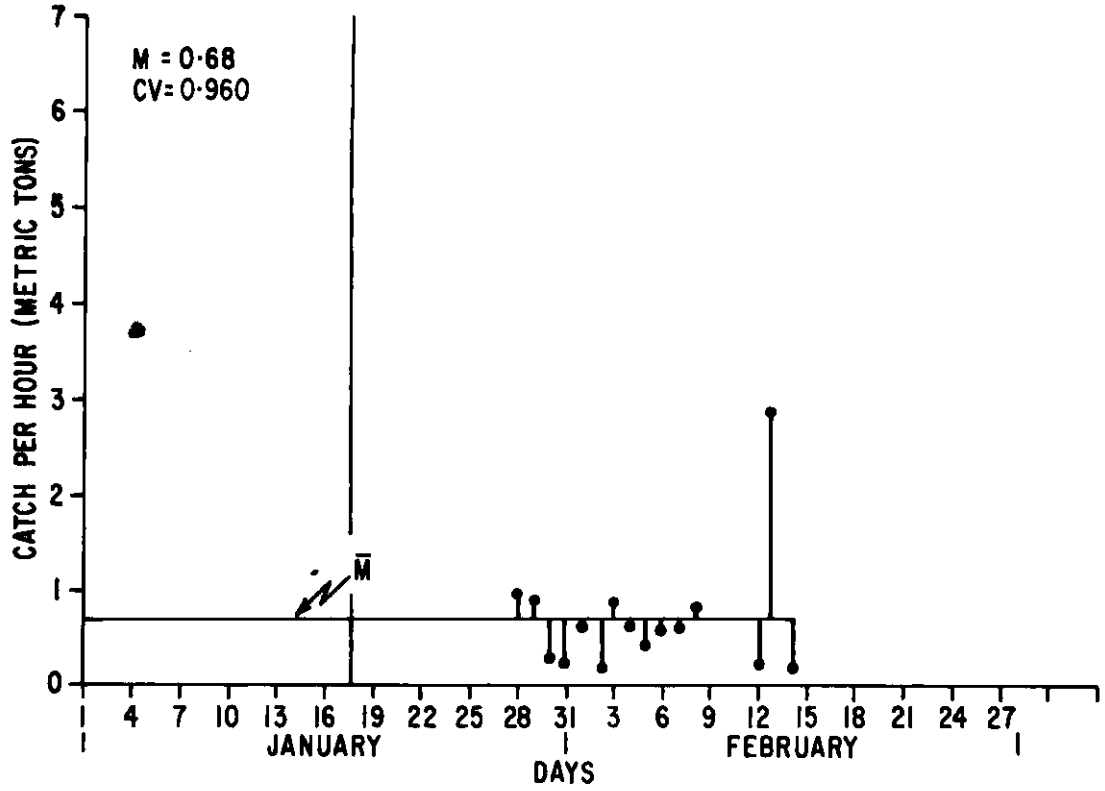

Fig. 5 Catch per hour on a daily basis for France OT6, 4R, cod showing variability of catch rate (fishery started Jan. 18 before observers boarded).

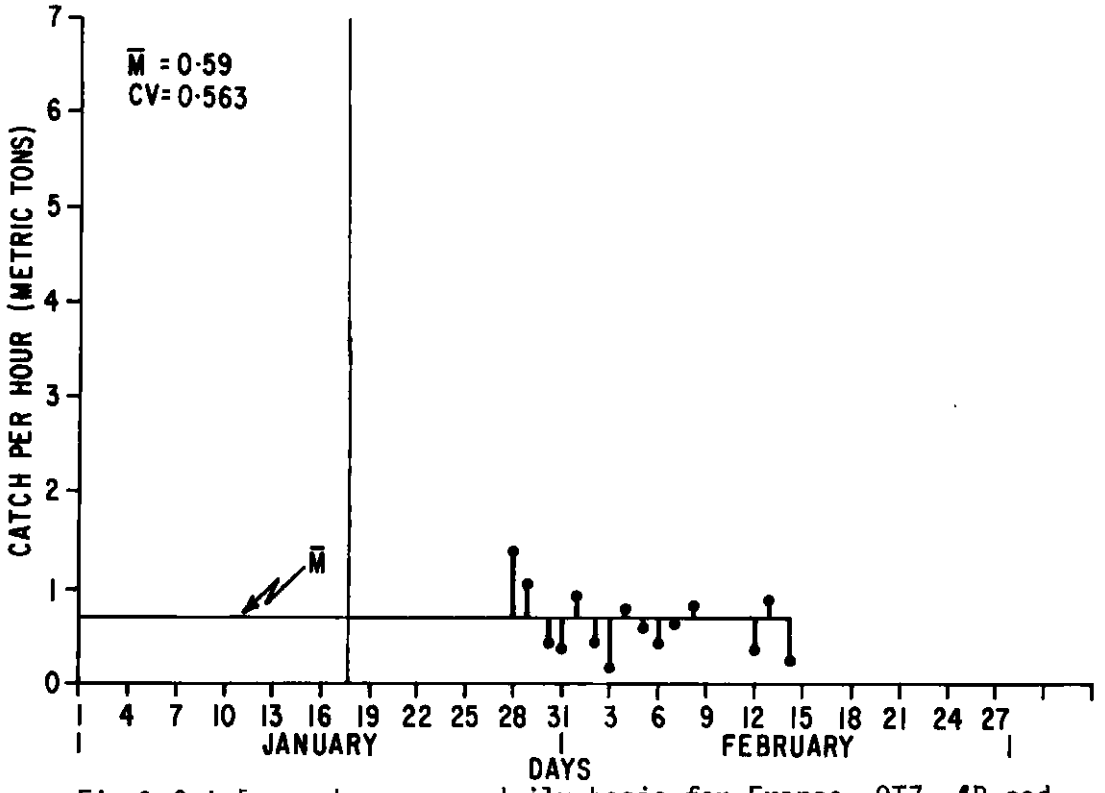

Fig.6 Catch per hour on a daily basis for France, OT7, 4R cod showing variabilities of catch rate (fishery started Jan. 18 before observers boarded).

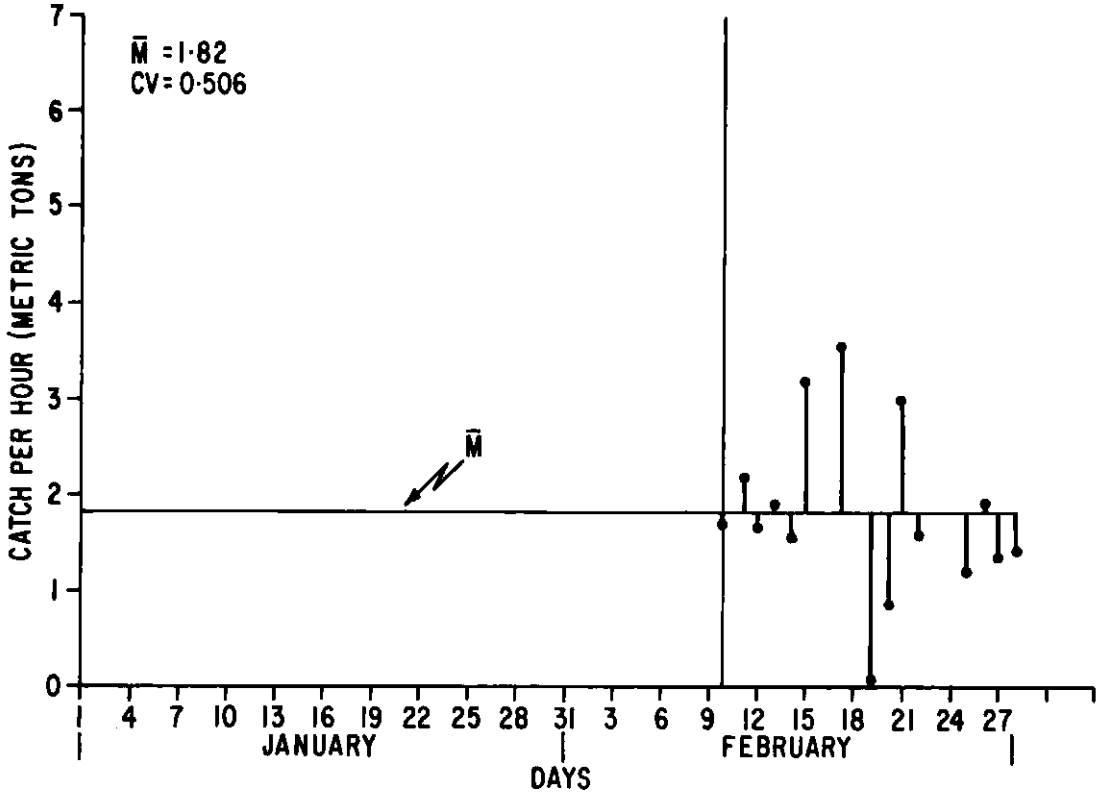

Fig.7 Catch per hour on a daily basis for GDR OT5, 2J cod showing variability of the catch rate (1st day of fishing on Feb. 10).

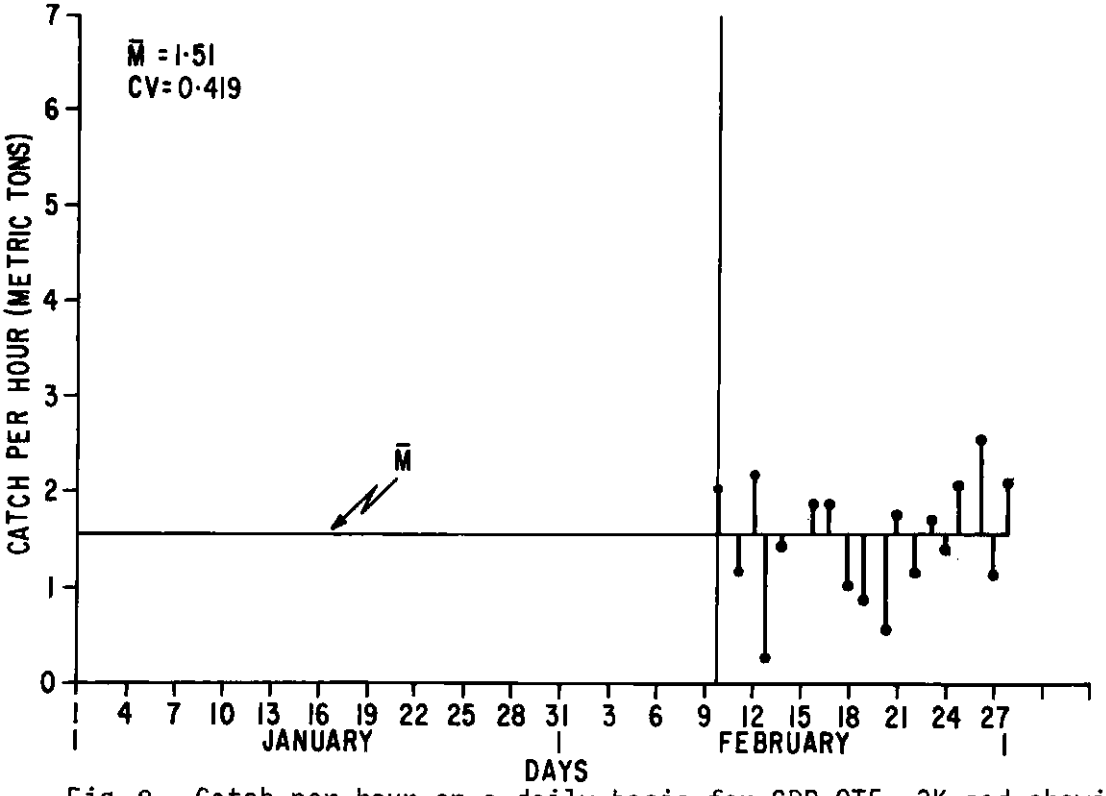

Fig. 8 Catch per hour on a daily basis for GDR OT5, 3K cod showing variability of the catch rate (1st day of fishing on Feb. 10).

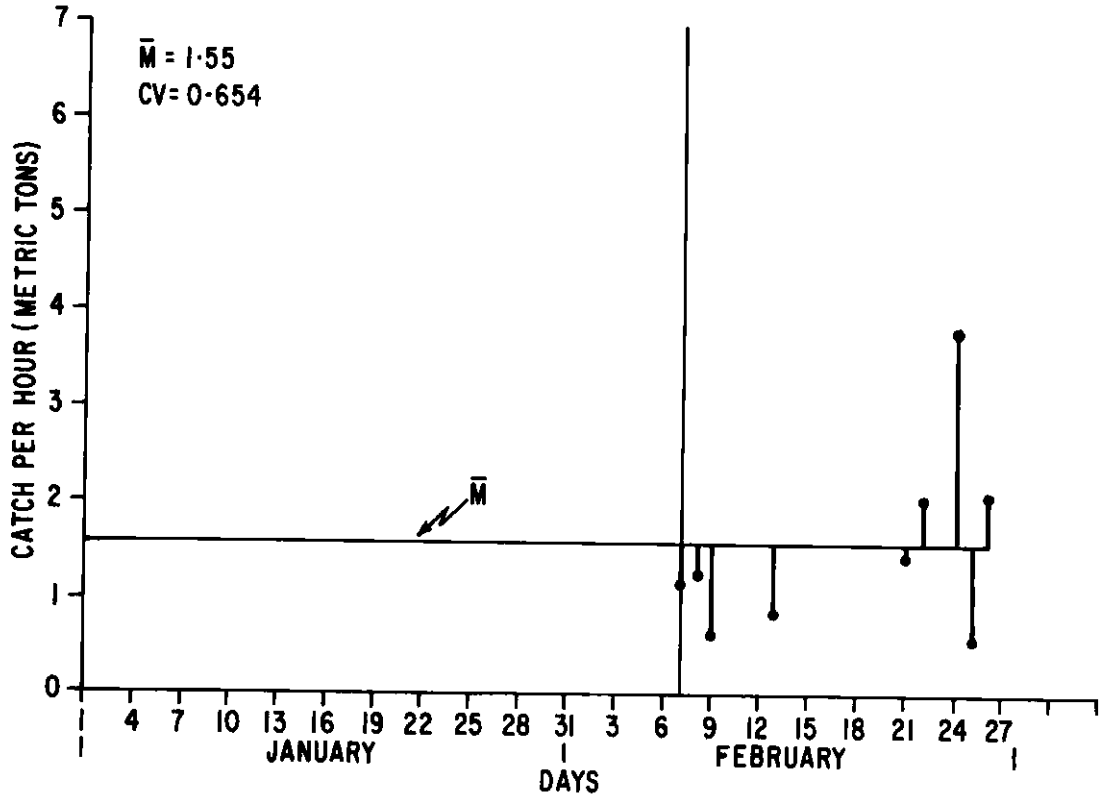

Fig.9 Catch per hour on a daily basis for GDR, OT7, 2J, cod, showing variability of catch rate (fishery started February 7).

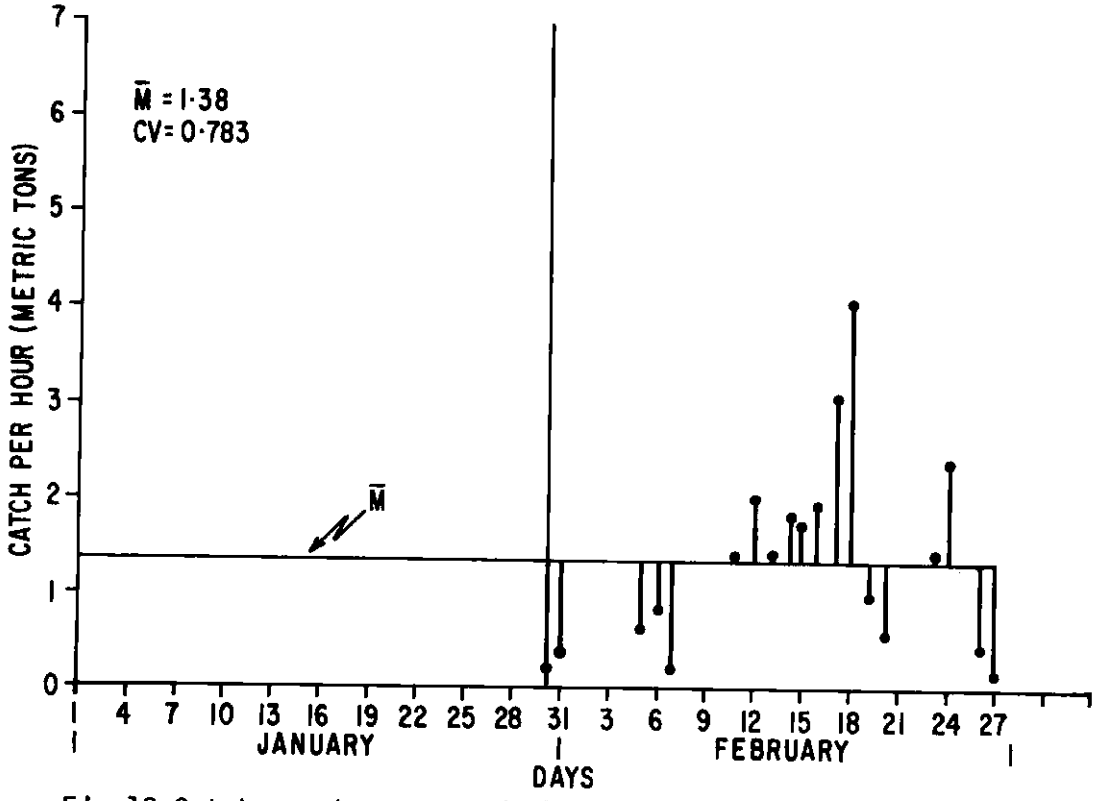

Fig.10 Catch per hour on a daily basis for GDR, OT7, 3K, cod, showing variability of catch rate (fishery started January 30).

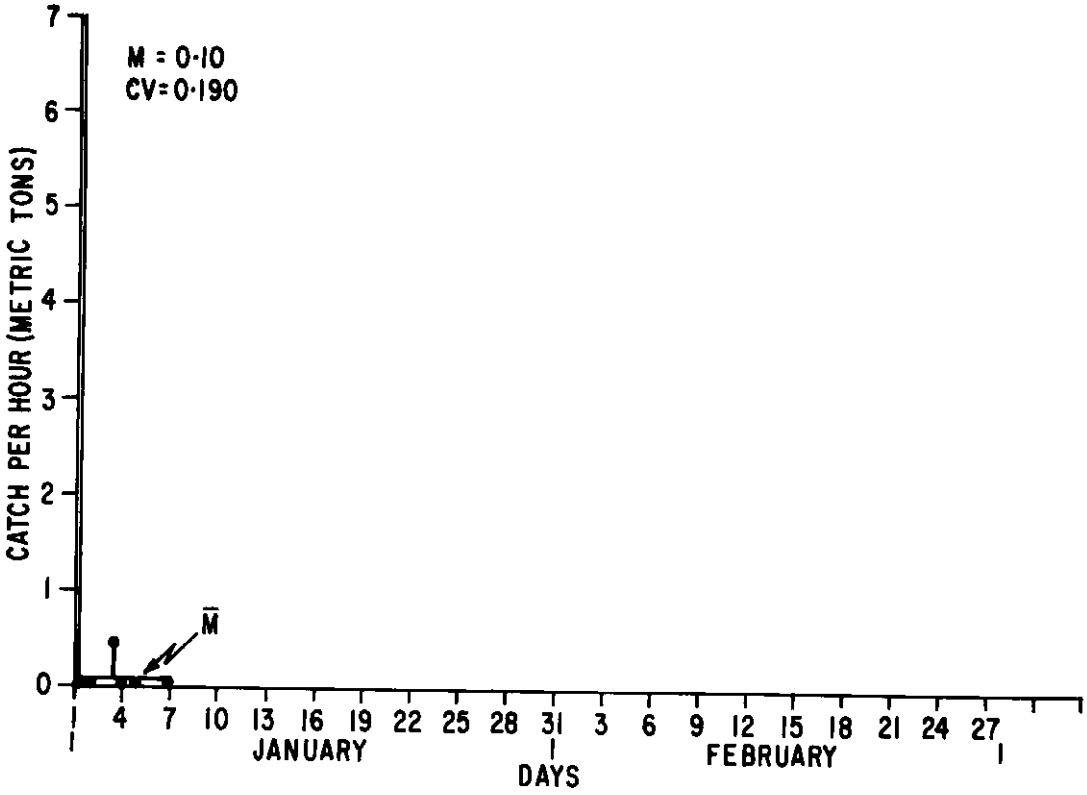

Fig.11 Catch per hour on a daily basis for Poland, OT7, in 2H, for cod, showing variability of the catch rate. (Started January 1).

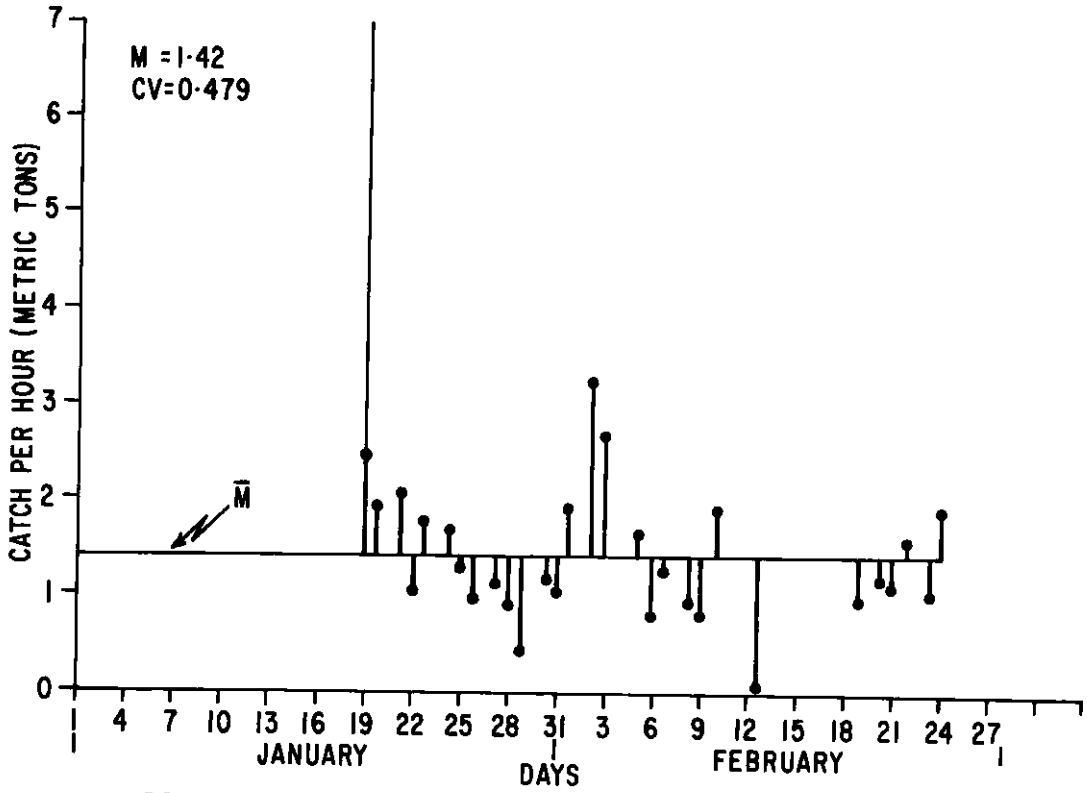

Fig.12 Catch per hour on a daily basis for Poland, OT7, in 2J, for cod, showing variability of the catch rate. (Started January 19).

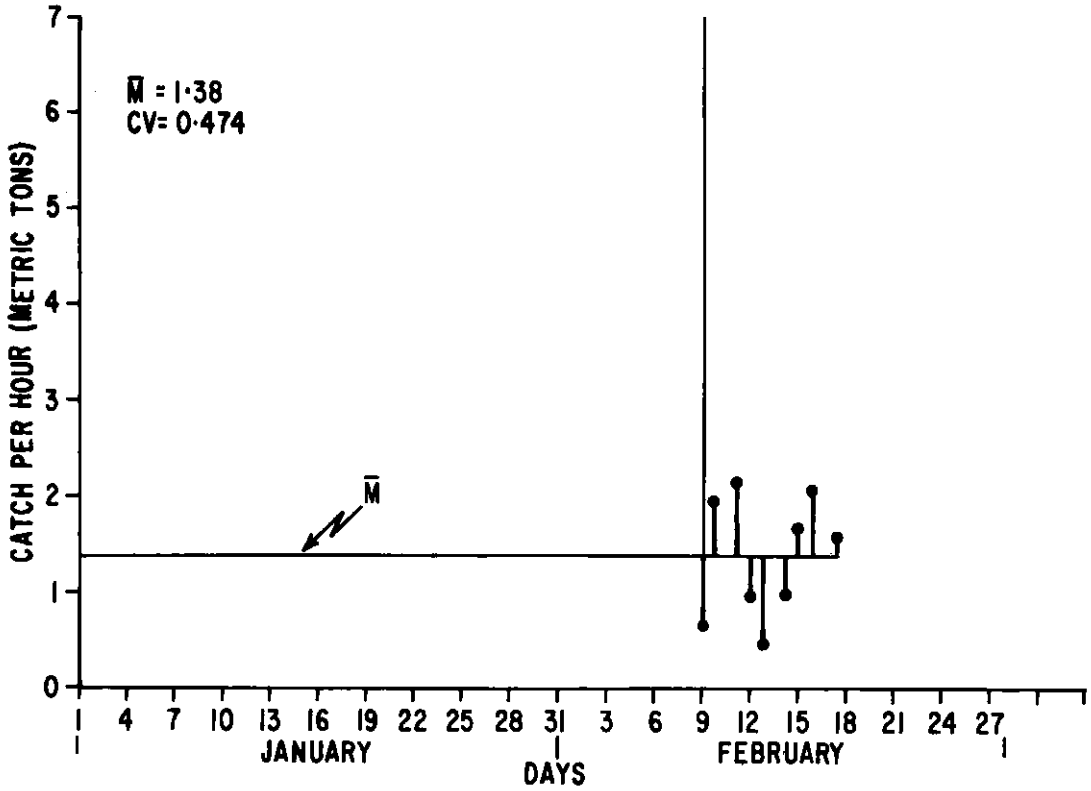

Fig. 13. Catch per hour on a daily basis for Poland, OT7, in 3K for cod, showing variability of the catch rate, (Started February 9).

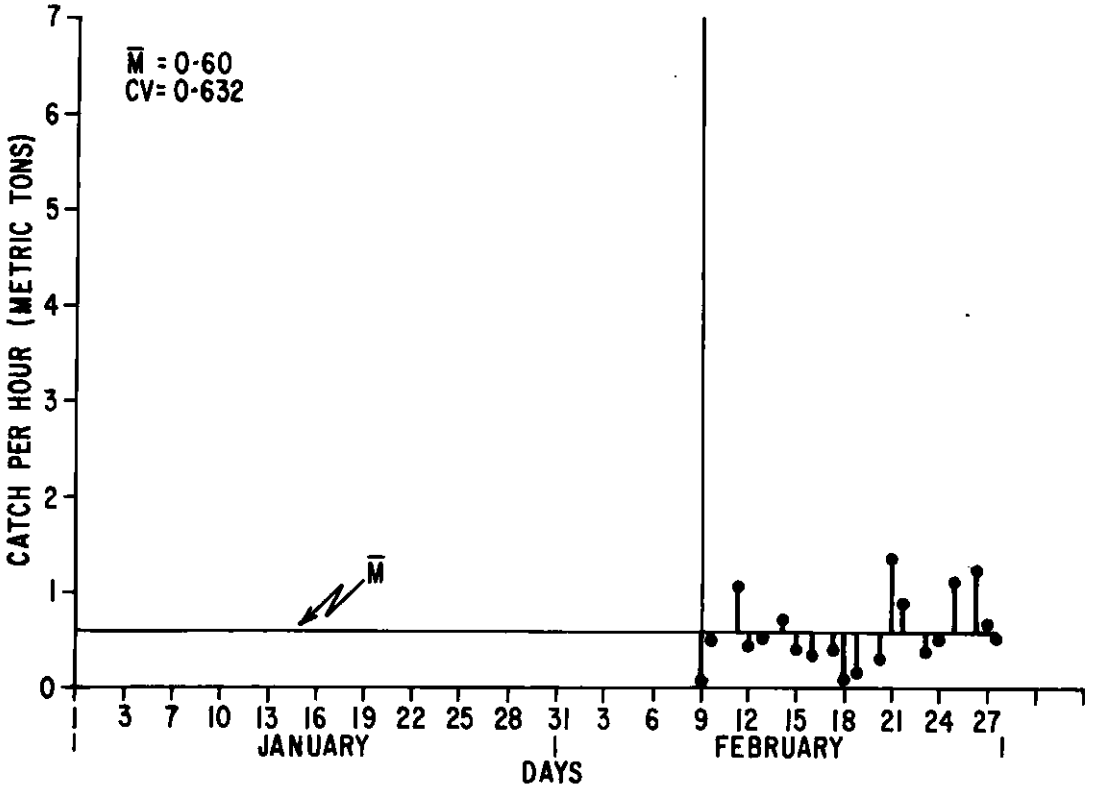

Fig. 14. Catch per hour on a daily basis for Poland, OT7, in 3K, for witch, showing variability of the catch rate. (Started February 9).

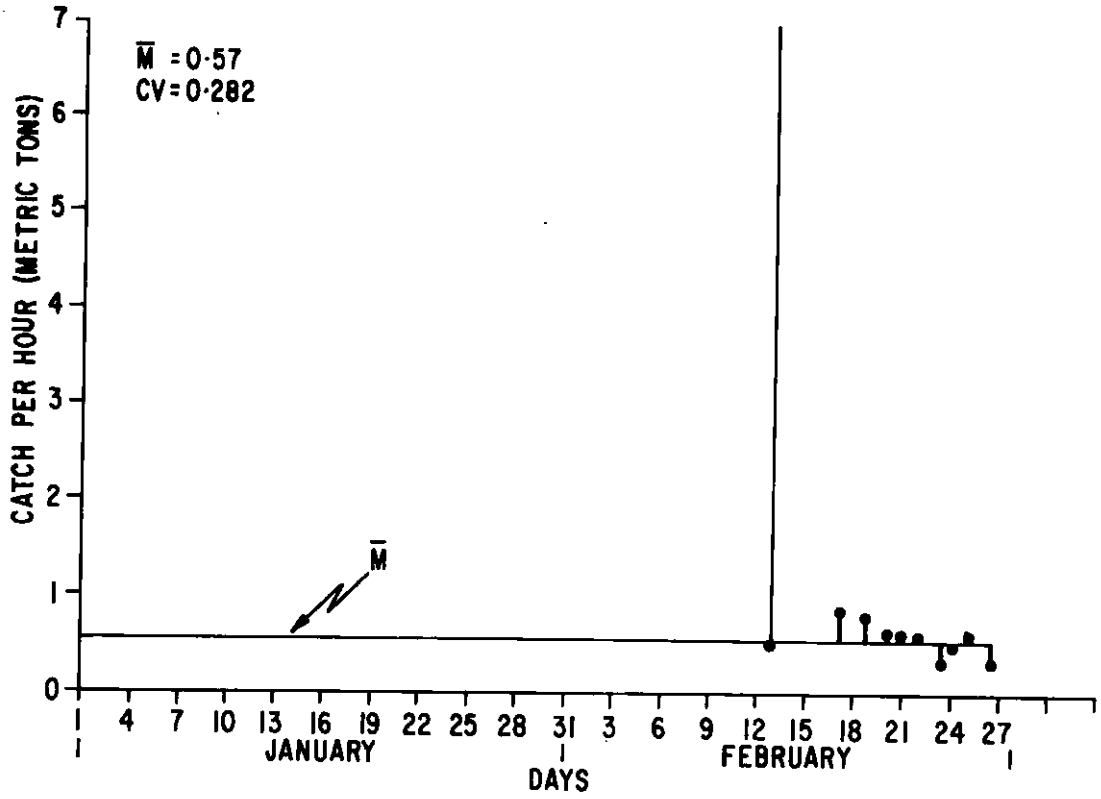

Fig. 15 Catch per hour on a daily basis for Portugal, OT6, in 2J, for cod, showing variability of the catch rate. (Started February 13).

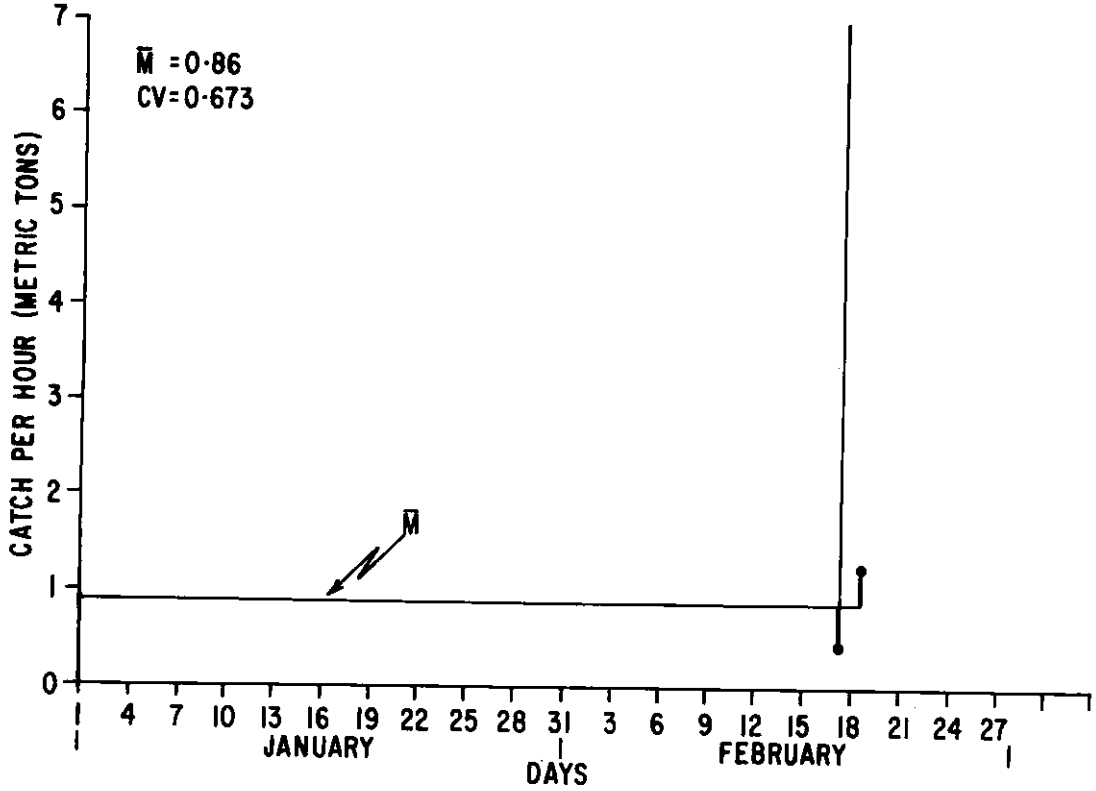

Fig.16. Catch per hour on a daily basis for Portugal, OT7, in 2J, for cod, showing variability of the catch rate. (Started February 17).

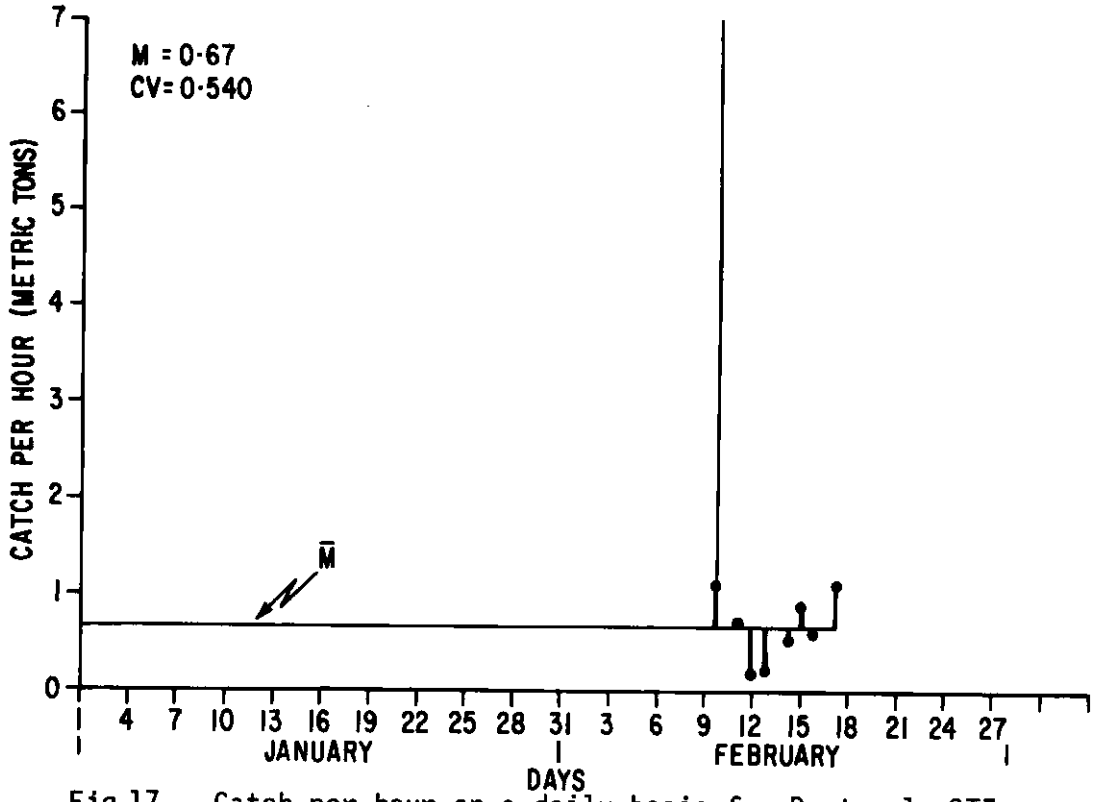

Fig.17. Catch per hour on a daily basis for Portugal, OT7, in 3K, for cod, showing variability of the catch rate. (Started February 10).

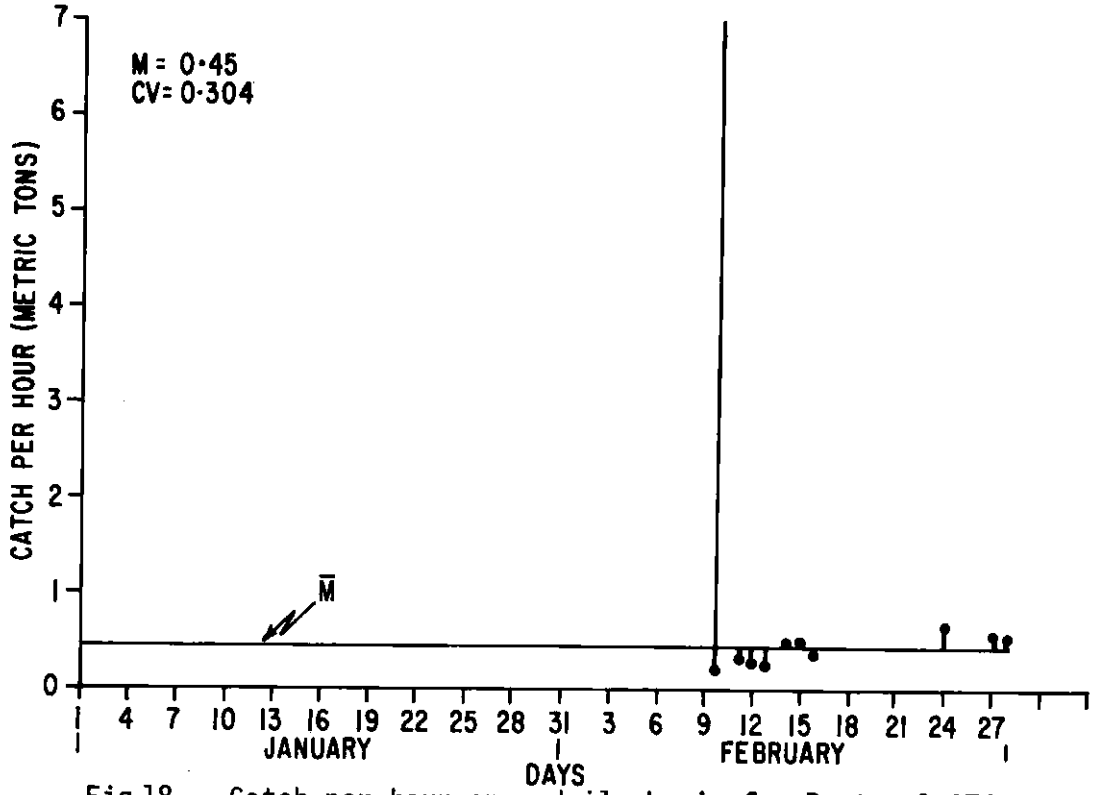

Fig.18. Catch per hour on a daily basis for Portugal OT6, in 3K, for cod, showing variability of the catch rate. (Started February 10).

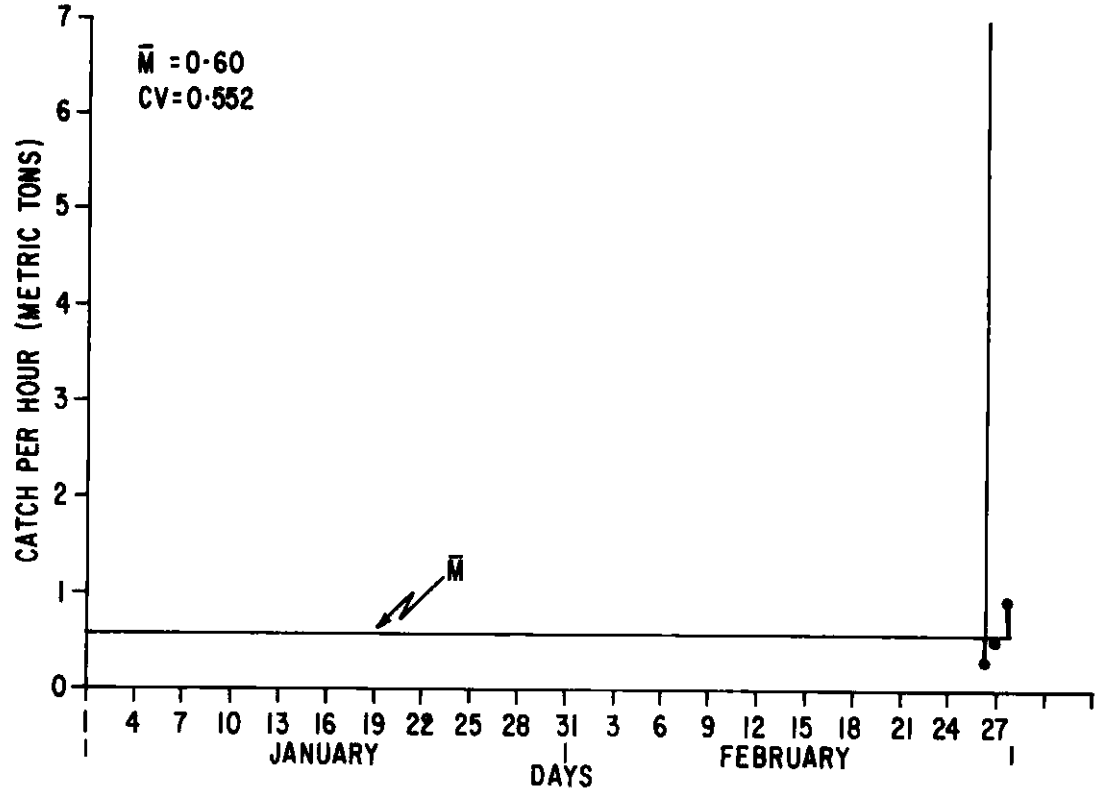

Fig.19. Catch per hour on a daily basis for Portugal, OT6, in 3M, for cod, showing variability of the catch rate. (Started February 26).

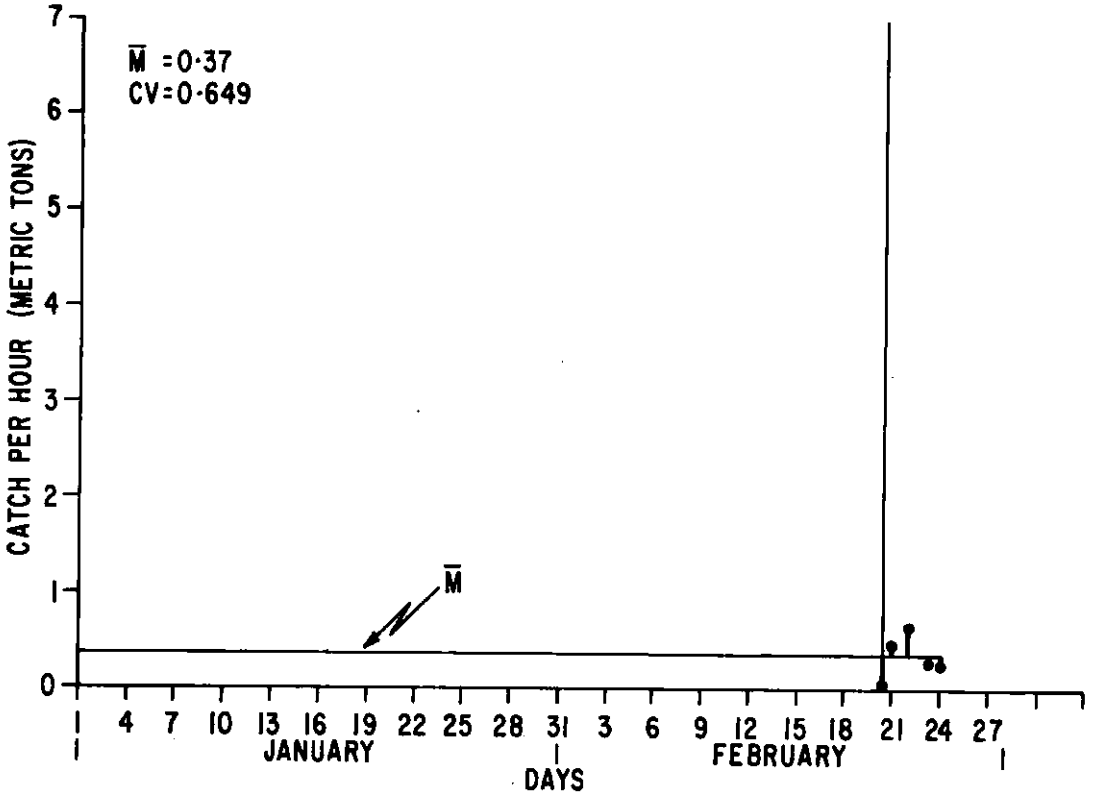

Fig.20. Catch per hour on a daily basis for Portugal, OT7, in 3K, for witch, showing variability of the catch rate (Started February 20).