ON THE POPULATION DYNAMICS OF THE INDO-PACIFIC MACKEREL (*RASTRELLIGER NEGLECTUS* VAN KAMPEN) OF THE GULF OF THAILAND

by

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ABSTRACT

This paper presents an analysis of catch and effort and biological data collected during 1962 - 1968 of the Indo-Pacific mackerel (*Rastrelliger neglectus* van Kampen) of the Gulf of Thailand with the aim of ascertaining population parameters to assess the level of the present fishery and the dynamics of the stock of this fish.

The results of the analysis indicated that the present mackerel fishing situation of the Gulf of Thailand is at the optimum level. For the stocks to be fished more rationally at the present fishing intensity, a slight reduction in the size at first capture would result only in little gain and that further increase of fishing effort, would result only in small increase in the total yield and certainly in a decrease of the catch per haul.

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INTRODUCTION

The Indo-Pacific mackerel (*Rastrelliger neglectus* van Kampen) resource of the Gulf of Thailand is one of the most economically important fishery resources of Thailand, yielding annually not less than 150 million Baht (US$7.5 million). Recognizing this fact, the Government of Thailand has established a long-term programme to conserve this valuable resource; hence, a programme of mackerel investigation has been carried out since 1958 to assess the size of the resource and the level of fishing with the aim of rationally managing the resource to obtain the maximum sustained benefit from it (Menasveta, 1965).

After a number of years of research and investigation on this fish species, the life history of the species in the Gulf is well documented (Boonprakob, 1965, Vanichkul and Hongskul, 1966, Hongskul and Petchoi, 1968, Indhapanya, 1968, Sucondhmarn, Tantiswetrat and Sriruangcheep, 1968, Decharak and Watanachai, 1970, Somjaiwang, Chullasorn and Supongpan, 1970 and Sriruangcheep, Tantisawetrat and Sucondhmarn, 1970). However, the dynamics of the populations of the fish have not yet been thoroughly understood. Since the inception of the programme, biological statistics in reference to space and time, including length frequency compositions, sex ratio, etc. of the species and the catch and effort data from the log book system established some four or five years ago have been compiled.

Therefore, this paper presents the first attempt to appraise the status of the resource and the effect of the present level of fishing on it by analysing the available data on hand.

MATERIAL AVAILABLE FOR THE STUDY

Division of the Existing Mackerel Fishing Grounds in the Gulf of Thailand

The mackerel fishing grounds in the Gulf of Thailand are arbitrarily divided into four statistical areas (Fig. 1) as follows:

Area I - The eastern coast of the Gulf

Area II - The inner Gulf

Area III - The upper western coast of the Gulf

Area IV - The lower western coast of the Gulf

Available Data for Analysis

Length Frequency Compositions

Samples of fish were taken regularly at various fish landing places including the Bangkok Fish Marketing Organization and the size compositions of them were ascertained. The available data on length compositions from 1962 to 1968 were used for the analysis.

Catch and Effort Data

The major types of fishing gear employed in the Indo-Pacific mackerel fishery are Chinese purse seine, Thai purse seine, encircling gill net and bamboo stake trap. Purse seiners and gill netters have been assigned log books by the Department of Fisheries since 1962. The available data on the catch and effort of the mackerel were obtained from the log books from 1962 to 1968, compiled by areas, types of fishing gear and months.

Tag-Recaptured Data

The Department of Fisheries has carried out a mackerel tagging programme from 1959 until the present. Tagged fish were released at various locations mainly in Areas II and III. The data used in the study were obtained from the tagging experiments since 1961 to assess migration, growth and mortality of the fish. The data obtained from rearing experiments were also used to evaluate the effect of tagging on the growth of the fish.

ASSESSMENT METHODS AND RESULTS

Principle Used in the Determination of the Total Fishing Effort

The catch per haul of each type of gear as recorded in the fishermen's log book was used in determining the catch per unit of effort.

The annual fluctuations in the amount of catch per haul are given for each type of fishing gear in Fig. 2. The relation between the catch per haul in different areas is illustrated in Figs. 3 and 4 for gill net and Chinese purse seine respectively. Fig. 5 shows the relation between the catches per haul by different gears in Area III. A high correlation was observed between catches of gill nets in different areas and between catches by different gears. These results indicate that when the gill netters catch plenty of fish, the purse seiners also get relatively high catches.

In this report, the catch per haul of the gill net, which is available since 1962, has been selected as the standard gear. To standardize the total effort, the following formula was applied:

$$\text{Standardized total effort} = \frac{\text{Total catch by all gears}}{\text{Catch per haul of the gill net}}$$

When we established the catch per haul of the gill net as a unit of fishing effort, the factors of the fishing power of the two types of purse seine were calculated by the method of comparison of the catch per haul of these types of gear. These factors are summarized in Table I.

TABLE I

The factors of the fishing power (Unit : gill net)

Gear \ Year	1962	1963	1964	1965	1966	1967	1968	Mean
Chinese purse seine	1.54	1.90	1.98	2.02	1.45	1.69	1.58	1.74
Thai purse seine	1.13	1.40	2.00	1.91	1.52	1.74	1.78	1.62

Assessment of Essential Parameters

Size Composition and Growth of Mackerel

Length and weight data of a great number of fish were collected every year and compiled by area, gear and month. Monthly length compositions in 1963 and 1966 are shown in Figs. 6 and 7 respectively.

Judging from the change of the monthly size distributions we could observe two different strong broods in 1963. In May, the first new group entered the fishery with the mode at 16.5 cm. This was caught from May to December, then the fish disappeared from the commercial catches having reached a size of about 19 cm. The second group entered in October with the mode then at 15.5 cm and were caught till April or May of the following years. Based on the study on the growth of mackerel (Sucondhmarn et al. 1968), the early size group was speculated to hatch out in January and the late group in July.

The length - weight relationship of the mackerel was examined, using the data presented by Vanichkul and Hongskul (1966), the following allometric formula was obtained.

$$W = 0.00617\ L^{3.13}$$

where W = weight in g; L = Length in cm

As to the growth equation of the mackerel of the Gulf of Thailand, the growth equation (von Bertalanffy equation) was calculated by Sucondhmarn et al. (1958) based on the analysis of the size composition of the fish. The growth parameters are shown in Table II.

TABLE II

The parameters of von Bertalanffy growth equation

	K	L_{∞}	t_o (month)
early size group	0.294	19.96 cm	0.22
late size group	0.345	19.62 cm	0.58

The validity of these results was ascertained by the analysis of the tagging data (Sucondhmarn, Ibid.).

Estimation of the Mortality Coefficient

In this study, two methods for the estimation of the instantaneous mortality coefficient were applied.

(a) Estimation of the Mortality Coefficient Using Catch Statistics

Based on the numbers of fish per haul of successive months, the total mortality coefficient (Z) in the i^{th} month was calculated and plotted against the effort (f) in gill net units (Fig. 3).

In Fig. 8, it was difficult to fit a linear regression line to the scattered points in order to estimate the catchability coefficient (q) and natural mortality coefficient. The dots for two successive months were then connected with lines on the scatter diagram. The line rising on the right side only was selected because these lines indicate the decreasing trend of fish abundance, which might indicate a relationship with the increasing fishing intensity. The median value of slope of these lines was 0.084 and was applied as the catchability coefficient q. We then estimated fishing mortality coefficient per month. Table III represents the estimated fishing mortality since 1962 using the above catchability coefficient and number of hauls in a month.

TABLE III

Estimated fishing mortality coefficient per month

Year	1962	1963	1964	1965	1966	1967	1968
Fishing mortality coefficient	0.18	0.21	0.28	0.23	0.21	0.34	0.32

(b) Estimation of the Mortality Coefficient Using Tagging Data

Since 1961, a total of 24,482 tagged Indo-Pacific mackerel have been released and 3,976 recaptured. The recapture rate of 16.2 percent was high as compared with other fishes. The data from these tagging experiments were used to estimate the fishing mortality coefficients and the other-loss coefficients.

The fishing mortality coefficients were estimated to be between 0.04 and 0.44. The data from the tagging experiments conducted from October to January in the Inner Gulf gave a higher value than those from April to August conducted along the western coastal areas of the Gulf. As to the other-loss coefficients, the values were found to be between 0.57 and 0.93. These are high when compared with the fishing mortality coefficient. The results obtained from the analysis of the tagging data from 1968 - 1969 show no differences from earlier data.

To determine the effect of the season in which the tagging experiments were carried out, specimens were divided into two groups under the presumption that the tagged fish were subjected to a uniform fishing effort in a particular fishing season. F and X, were then estimated separately from the fitted linear regression lines (see Fig. 9). The estimated values are shown in Table IV, as are the survival rate, S and the rate of exploitation, E.

TABLE IV

Estimated Population Parameters (Unit : Month)

	F	X	S	E*
October-January (Inner Gulf)	0.306	0.715	0.36	0.19
April-August (Western Coast)	0.069	0.755	0.44	0.05

* Rate of exploitation per month.

$$E = \frac{F}{F + X} (1 - e^{-(F + X)})$$

In the Inner Gulf 20 percent of the fish were caught per month. In both areas some 60 percent of the tagged fish disappeared in a month. As to the other-loss, these included loss from various causes such as natural mortality of the fish, the dispersion of the fish from the fishing ground; the added mortality by tagging, tag-shedding and others. The data derived from rearing experiments carried out since 1967 were useful. Using these rearing-experiment data, the mortality coefficient were estimated to be:

Untagged fish $M = 0.12$

Tagged fish $M = 0.20$

The coefficient of added mortality by tagging is, therefore, approximately 0.08.

The Yield Curve and the Yield Isopleth Diagram

From the estimates obtained of growth and mortality yield curves were calculated. For the ease of calculation a single value, 0.30, of the growth parameter K was used derived from the values in Table II. With respect to the maximum size of mackerel (L_∞) and the size at first capture (l_c), L_∞ was taken as 23 cm and l_c as 14 cm, based on the size frequency distributions of the commercial landing of this species.

In the "Table of Yield Functions for Fishery Assessment" presented by Beverton and Holt (1964), c is defined as follows:

$$c = \frac{l_c}{L_\infty}$$

Therefore c was estimated as 0.60 for the Indo-Pacific mackerel of the Gulf of Thailand.

From the data of catch statistics and of tagging experiments, the estimate of the fishing mortality coefficient appeared to be in the range between 0.2 and 0.3 during the last decade. As to the natural mortality of the stock of the fish, we were not able to make any sound estimation. The data obtained from the tagging experiments show a high value of the other-loss coefficient as approximately 0.7. On the other hand, from the data from the rearing experiment of the mackerel in 1967, the natural mortality coefficient was estimated as 0.12. The growth coefficient (K) of these reared fish was about 0.11 - 0.13, approximately equal to M. Beverton and Holt (1957) showed M being equivalent to K for clupeoid fishes and Tanaka (1960) considered the negative relation between the length of the life span and the natural mortality coefficient.

Based on this information, 0.30 was taken as the natural mortality coefficient for the stock of the Indo-Pacific mackerel of the Gulf of Thailand. But naturally, great variations will be expected for the natural mortality, since it may be readily affected by environment. So, the yield curves are also considered at the different levels of natural mortality.

The simple yield model developed by Beverton and Holt (1957) was applied. The yield assessments were made on a relative basis using the Tables presented by Beverton and Holt (1964).

The Relation between Yield and Fishing Effort

Taking K as 0.3 and c as 0.60, the yield per recruitment against the fishing effort (F) for five levels of the natural mortality (M = 0.15 - 0.60) is shown in Fig. 10.

At the higher levels of natural mortality (M = 0.45, 0.60), no peak is found in the yield curve, so more yield is expected with increased fishing intensity.

At the higher levels of natural mortality in the order of 0.30 or less, more yield is expected with increased fishing for values of F up to 0.20 or thereabouts. For values of F of 0.3 or more, the yield approaches an asymptote and we can expect no appreciable gain in yield from increasing effort.

The Relation Between the Yield and the Size at First Capture

The yield per recruitment against the size at first capture for five levels of natural mortality is shown in Fig. 11, where F and K are held constant. At the higher levels of natural mortality (M = 0.45, 0.60), an increase in yield of 10 - 20 percent could be obtained by reducing the size at first capture from 14 cm to 10 cm or so (i.e. from c = 0.6 to c = 0.4).

At the range of levels of M from 0.20 to 0.30, we can expect the maximum yield at c = 0.55 - 0.60.

The yield against the size at first capture for four levels of fishing mortality is shown in Fig. 12, for M = 0.30.

From the observation of change in the yield curve by the different levels of natural and fishing mortality, it may be deduced that with respect to the size at first capture, the fishery utilized rationally the mackerel resources during the period under study.

The Relation Between the Catch Per Unit of Effort and the Fishing Effort

Fig. 13 shows the catch per unit of effort and the yield plotted against the fishing effort at four levels of the size at first capture (K = 0.30 and M = 0.30).

It is apparent that if the fishing intensity is increased two fold over the present intensity, $F = 0.2$ to 0.3, it would result for any size at first capture, at best only in 20 percent increase in yield and 40 percent decrease in the catch per unit of effort.

Isopleth Diagrams of Yield and Catch Per Unit of Effort

Fig. 14 shows the steady-state yield and the catch per unit of effort from any combination of F and c values, at $M = 0.30$ and $K = 0.30$. The thick lines indicate the contour lines of yield, the fine lines, the contour lines of the catch per unit of effort, and the dotted lines, a eumetric fishing curve. Point A represents the probable value of F and c at the present stage of the mackerel fishery. The horizontal transect through point A has been represented by Fig. 10 ($M = 0.30$) and Fig. 13 ($c = 0.60$).

The shaded area indicates the directions for the improvement of the present fishery; that is, by the fishing condition in the shaded area, we may expect more yield, without reduction of the catch per unit of effort, increased catch per unit of effort without loss of yield, or increases in both yield and catch per unit of effort.

For the stock to be fished more rationally at the present fishing intensity, it would be necessary to reduce c slightly. The shaded area, however, is small and we may expect only little gain from these improvements for the present fishery.

Discussion of the Results

The analysis carried out in the foregoing sections have provided the following results.

Both the rise in the landing and in the catch per haul during the last decade, which might be due somewhat to the increase in the fishing intensity and to the improvements of fishing, did not result in any further decreasing of the recruits to the fishing grounds.

It appears from these results that the level of the fishing intensity in the period under consideration did not cause any depletion of the Indo-Pacific mackerel resources of the Gulf of Thailand.

The theoretical yield curves, based on the observed and assumptive probable values of the population parameter on growth and mortality, revealed that for the Indo-Pacific mackerel resources to be fished at a higher level in total landings as well as in the catch per haul by the present fishing intensity, a slight reduction in the size at first capture would result only in little gain and that further increase of effort would result only in a small increase in the total yield and certainly in a decrease of catch per haul.

In other words, it seems that the present fishery utilizes rationally the mackerel resources at the level of optimal total yield.

From the tagging experiments, the other-loss was estimated at about 3 times the fishing mortality coefficient, it is probable that some of the other-loss may be due to the dispersion of the fish schools from the fishing grounds.

On the other hand, the high value of the survival rate during the fishing season, shown in the monthly change of the catch per haul in number as compared with the one calculated using the estimated fishing mortality coefficient, may suggest that continuous recruitment of fish groups to the fishing ground occurred as the general characteristics of the pelagic fishes.

If there is indeed appreciable movement of fish into and out of the exploited grounds from more distant areas, this could make big differences to many of the conclusions. Thus the fishing mortality on the population as a whole is likely to be appreciably smaller than that on the part of the stock present in the Inner Gulf. If for the whole population F is much less than the value of 0.2 to 0.3 used in the calculation, then it would be possible to increase the total catch substantially by increasing fishing, especially on those areas where fishing is presently light, e.g. in the western coastal area.

Such opportunities for increased catch depend on the extent of movements of the fish, and on the fishing intensity in those parts of the distribution of the stock other than those studied in the present paper.

The validity of the conclusions, of course, also depend on the degree of accuracy of the values of the parameters used in the calculation. Continued investigations are necessary in order to provide a more firm basis for the conclusion.

Along with the evaluation of the rational utilization of the Indo-Pacific mackerel resources, studies to forecast the movement route of the fish schools and the amounts of catch by fishing are also important in the management of this resource because in the pelagic fishes, large fluctuations in the abundance of offsprings and in the availability for fishing commonly occur. As the next step of our future study, we have to ascertain not only the movement of the mature fish but also of the younger ones not found in the commercial catch, and to estimate the level of abundance of each brood before fishing in connection with their environmental conditions in the seas.

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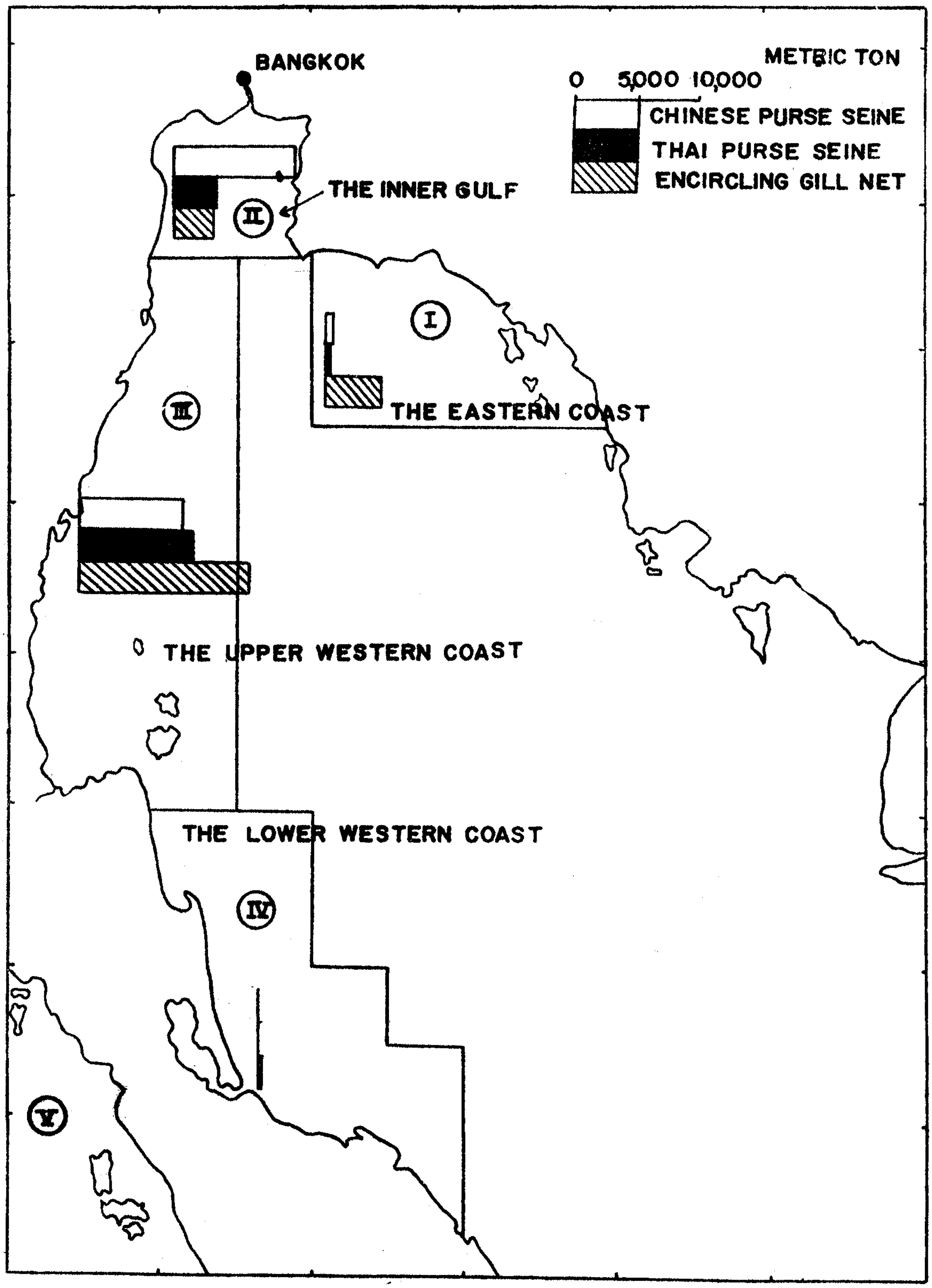

Figure 1. The Gulf of Thailand showing arbitrarily divided statistical areas and landings by three main types of fishing gear.

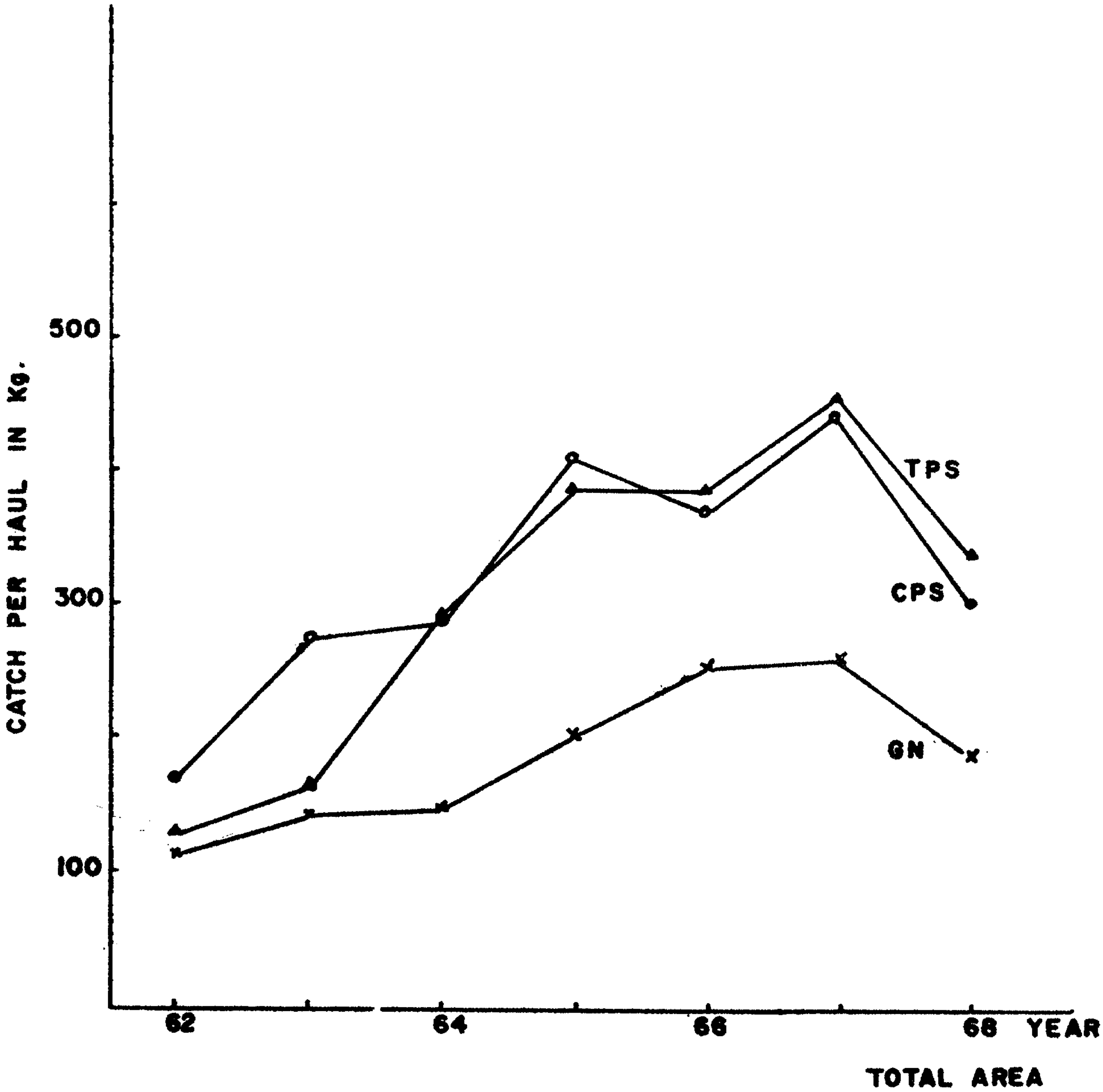

Figure 2. Average catch per haul of each of the three types of fishing gear used by the mackerel fishery in the Gulf of Thailand from 1962 to 1968.

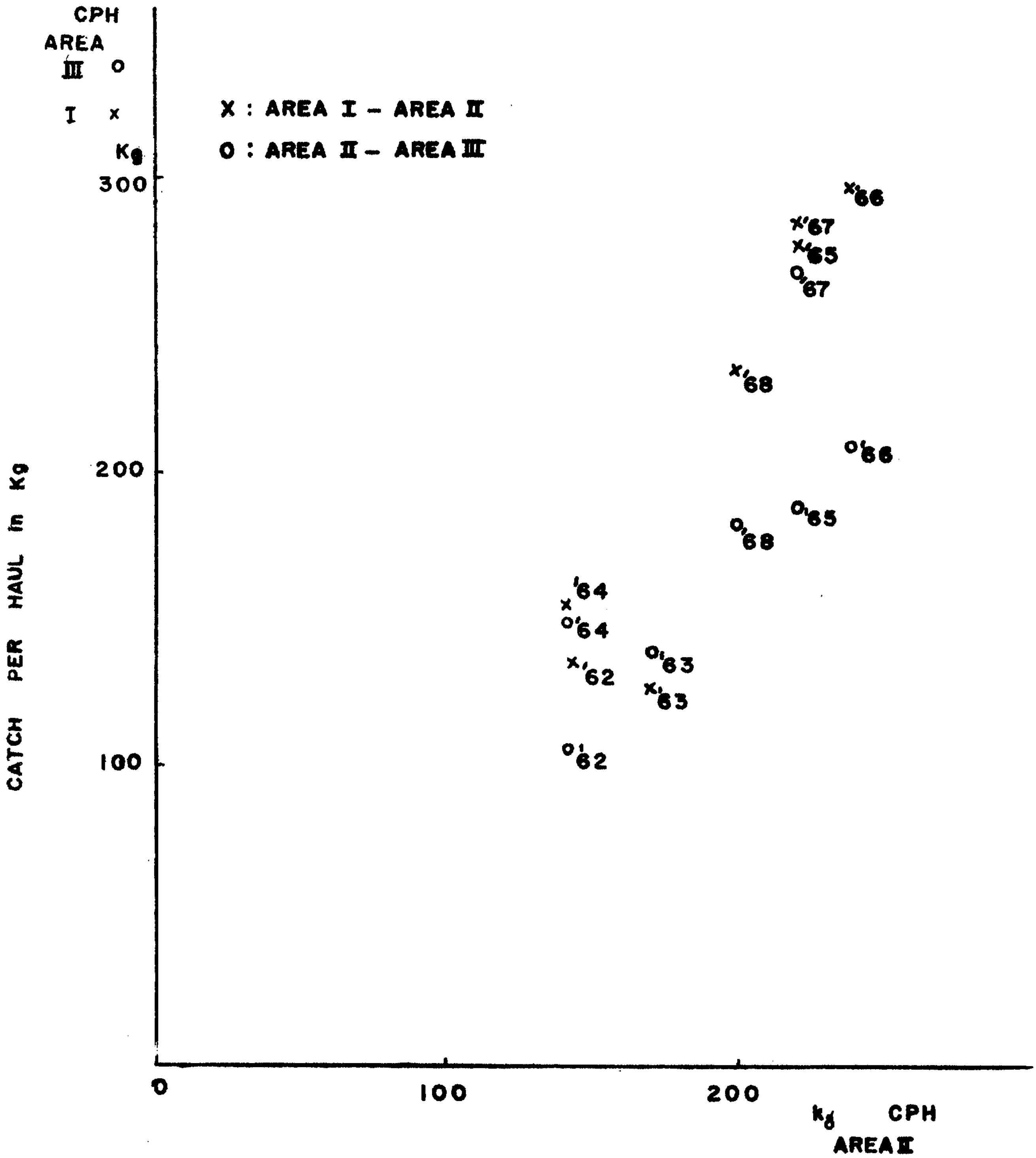

Figure 3. Area relationship in catch per haul of gill net.

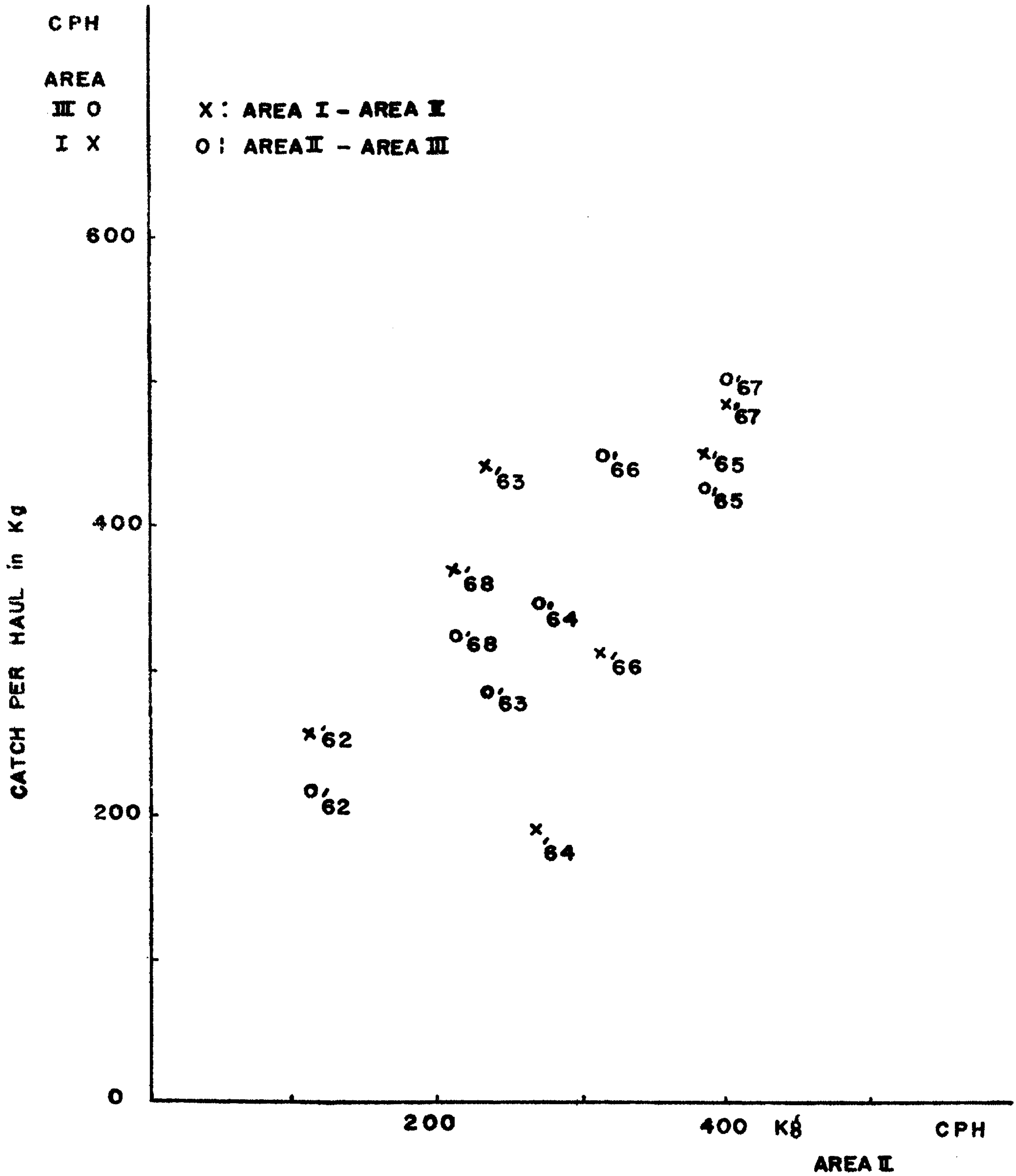

Figure 4. Area relationship in catch per haul of Chinese purse seine.

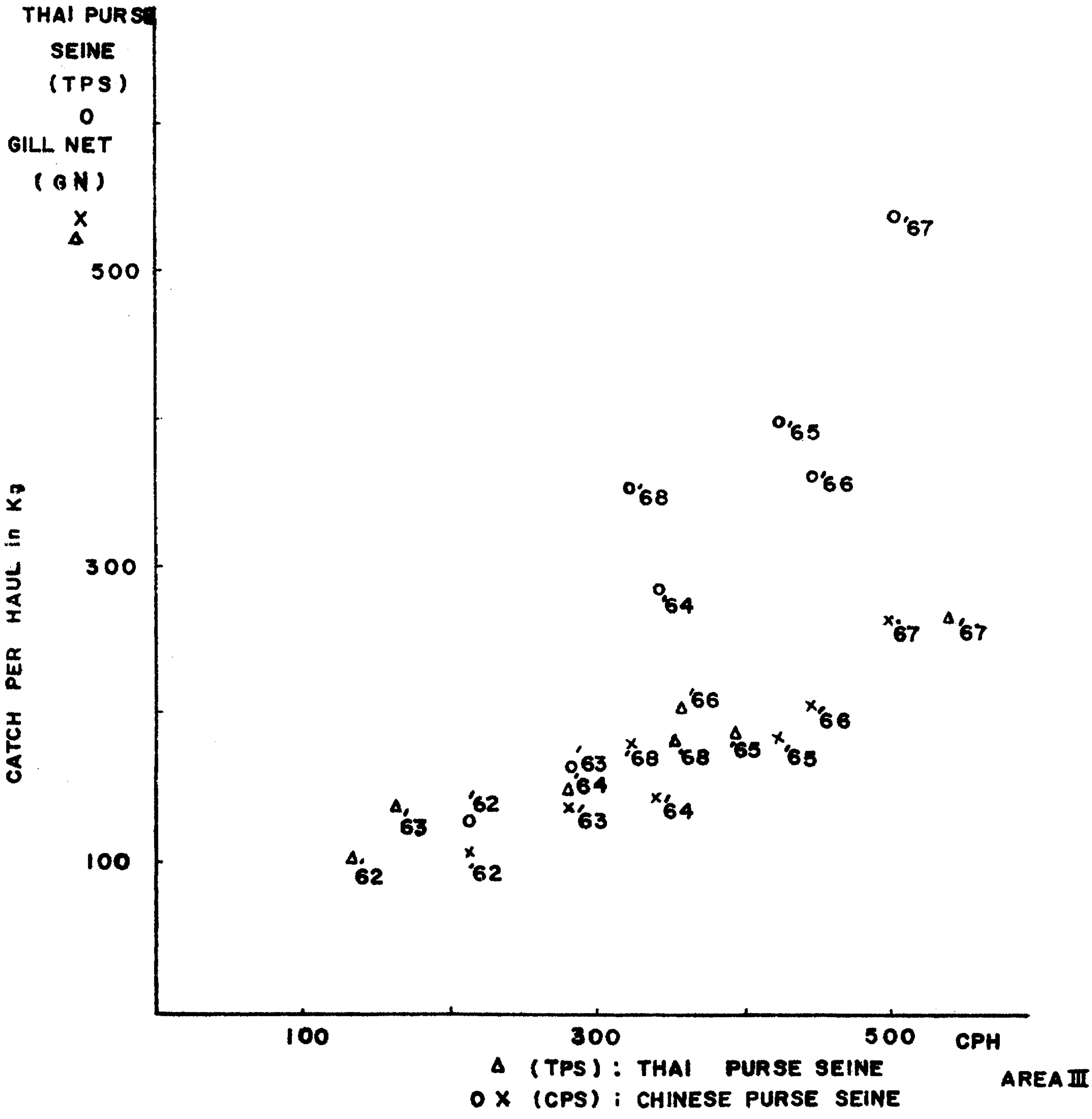

Figure 5. Gear relation in catch per haul.

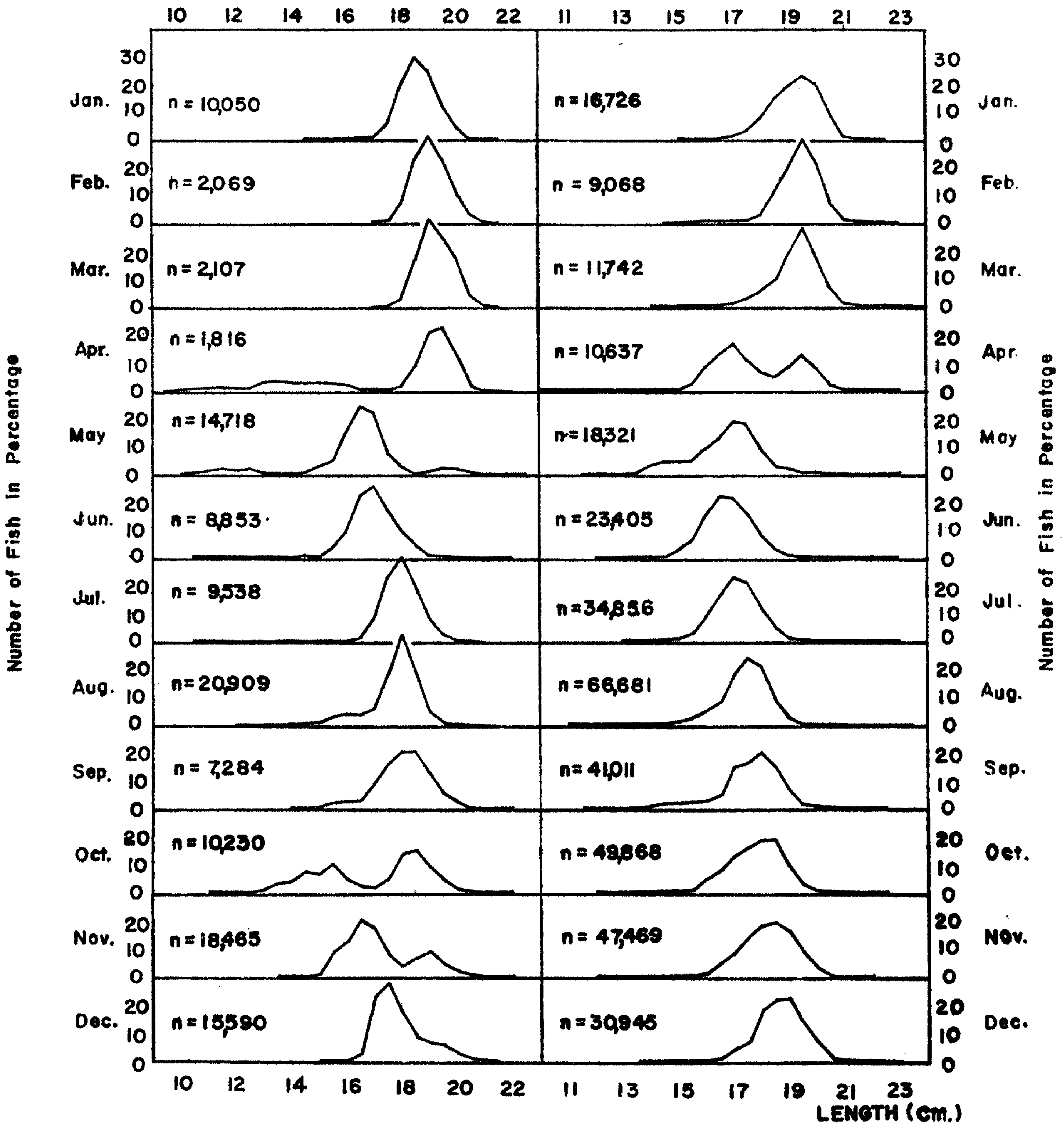

FIGURE 6. Monthly length frequency distributions of the Indo-Pacific mackerel caught in the Gulf of Thailand in 1963.

FIGURE 7 Monthly length frequency distributions of the Indo-Pacific mackerel caught in the Gulf of Thailand in 1966.

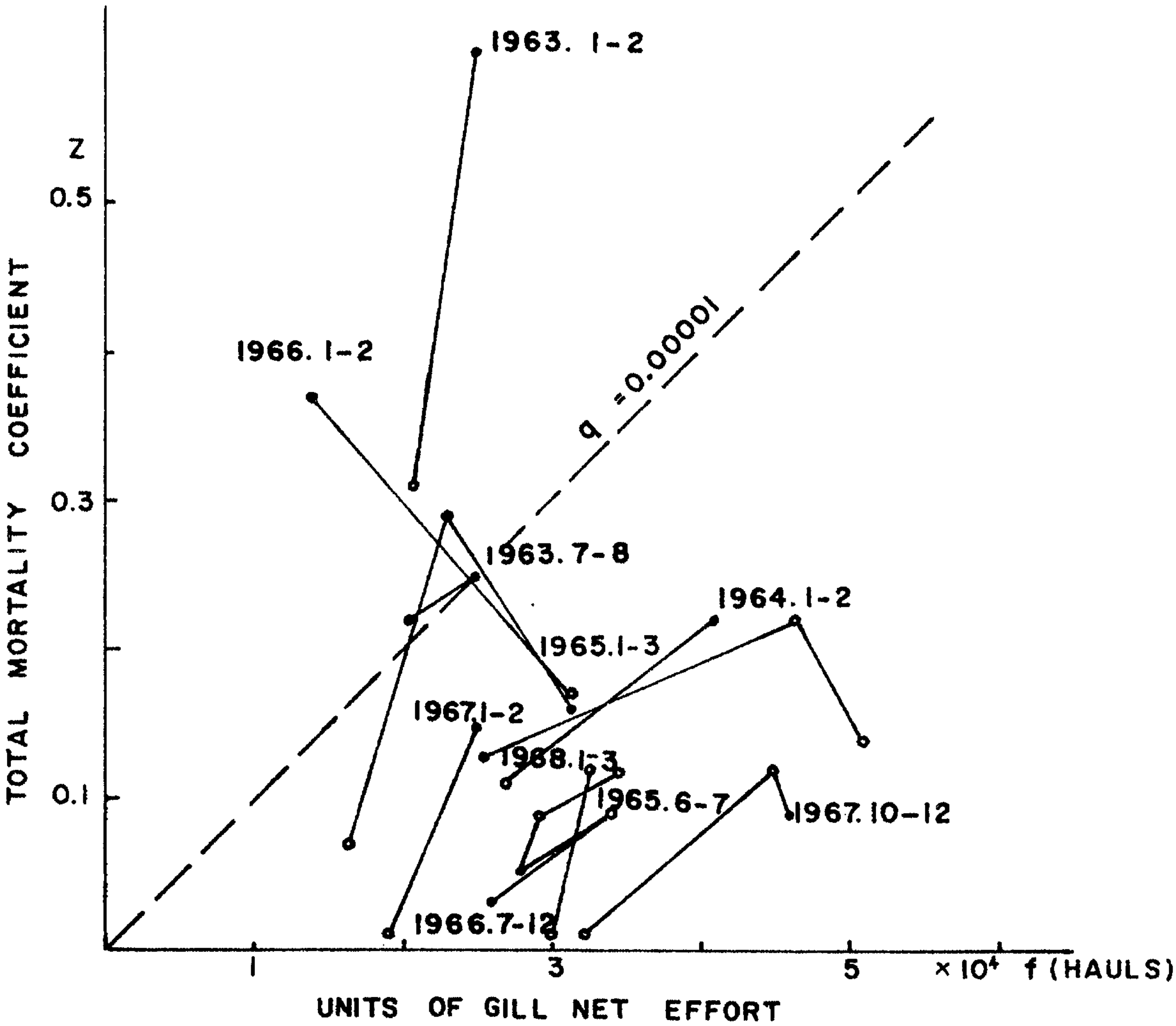

Figure 8. The regression of the total mortality coefficient on the units of gill net effort in the western coastal area (Area III) and in the inner Gulf (Area II).

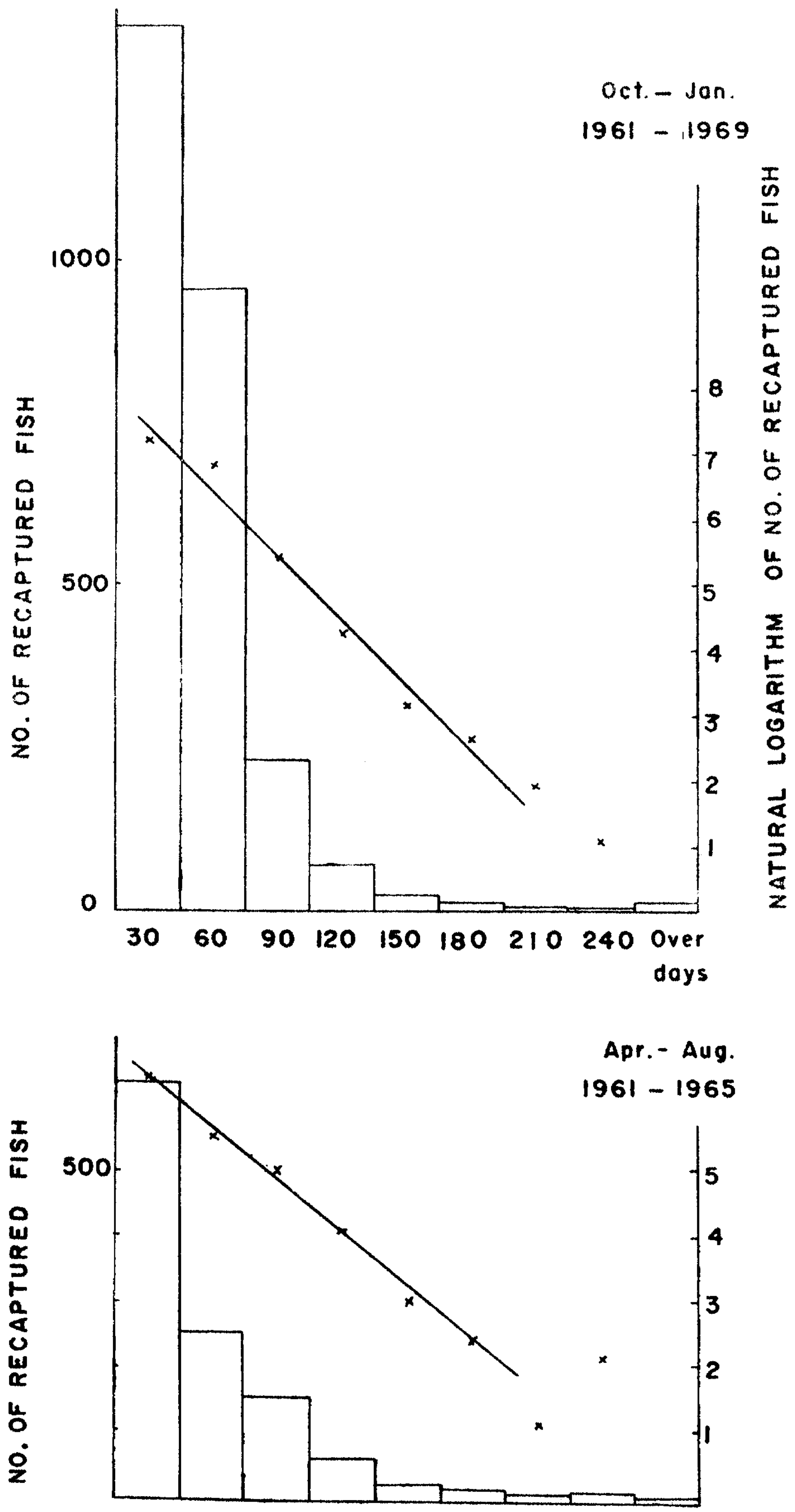

Figure 9. The number of tagged fish recaptured during successive months after liberation.

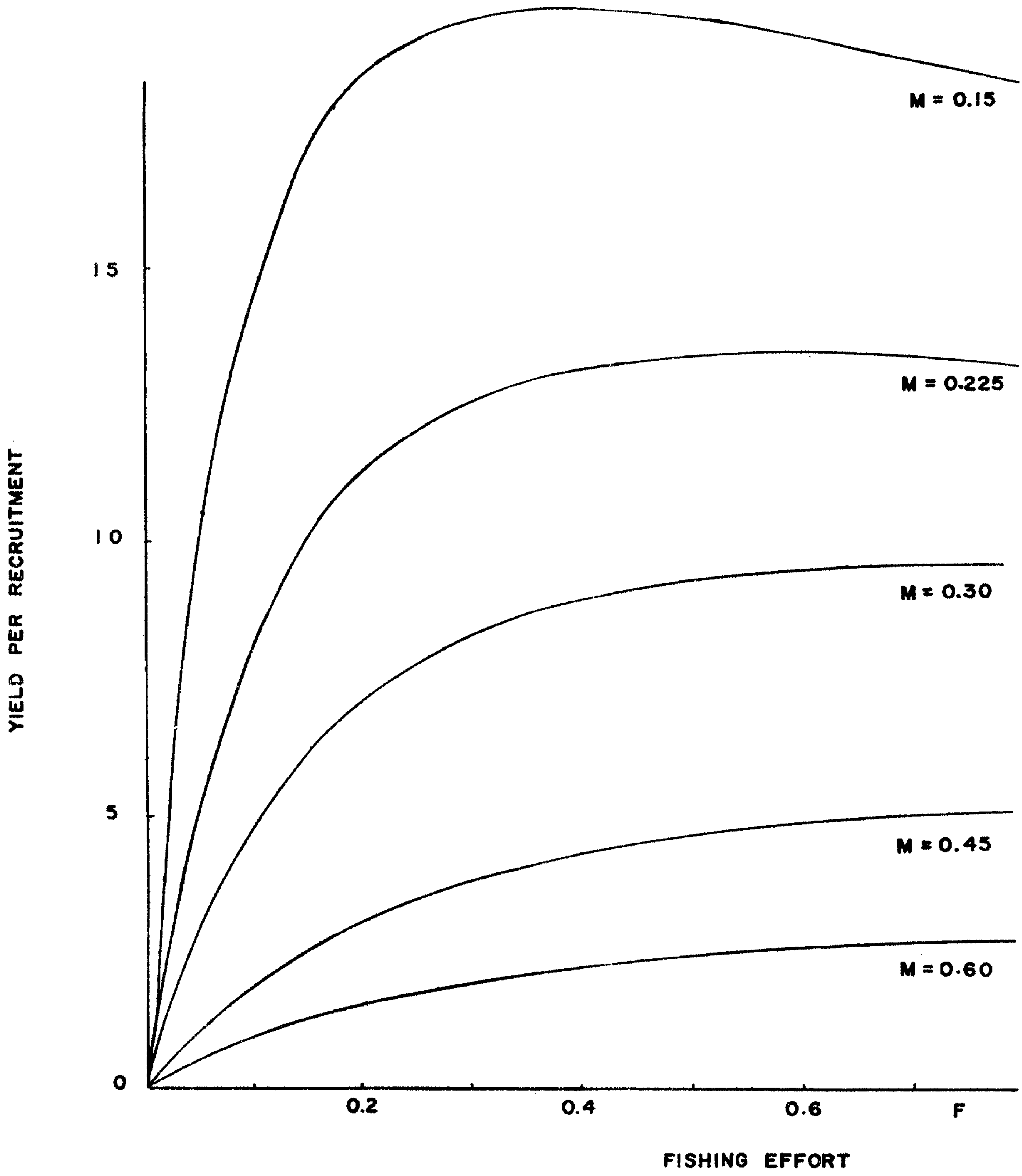

Figure 10. Variations in the yield per recruit of the indo-pacific mackerel stock with fishing mortality under equilibrium condition computed for different values of natural mortality (c = 0.60, K = 0.30).

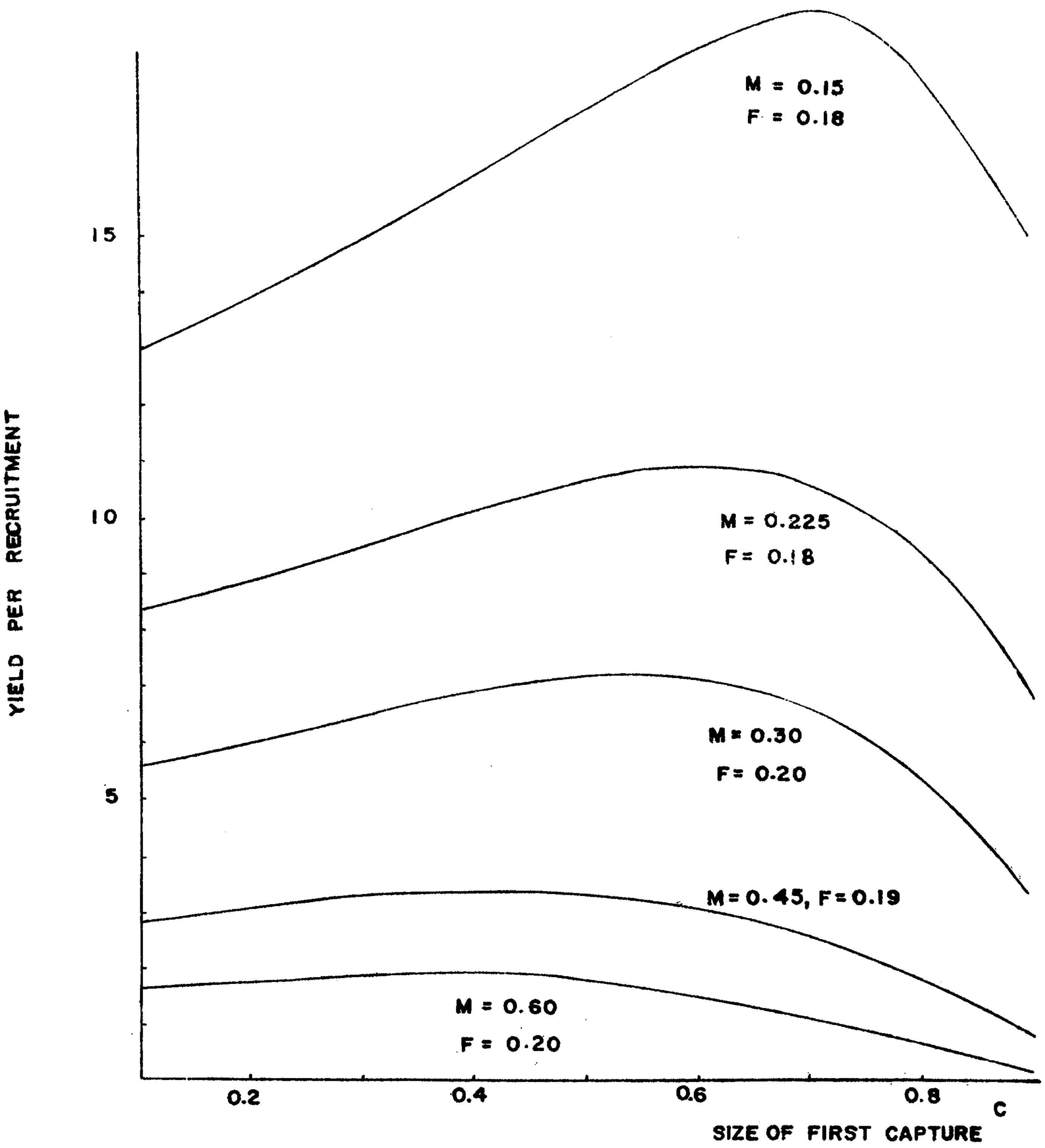

Figure 11. Variations in the yield per recruit of the stock of Indo-Pacific mackerel under study with the size at first capture computed at five levels of natural mortality (K = 0.30, F = 0.20).

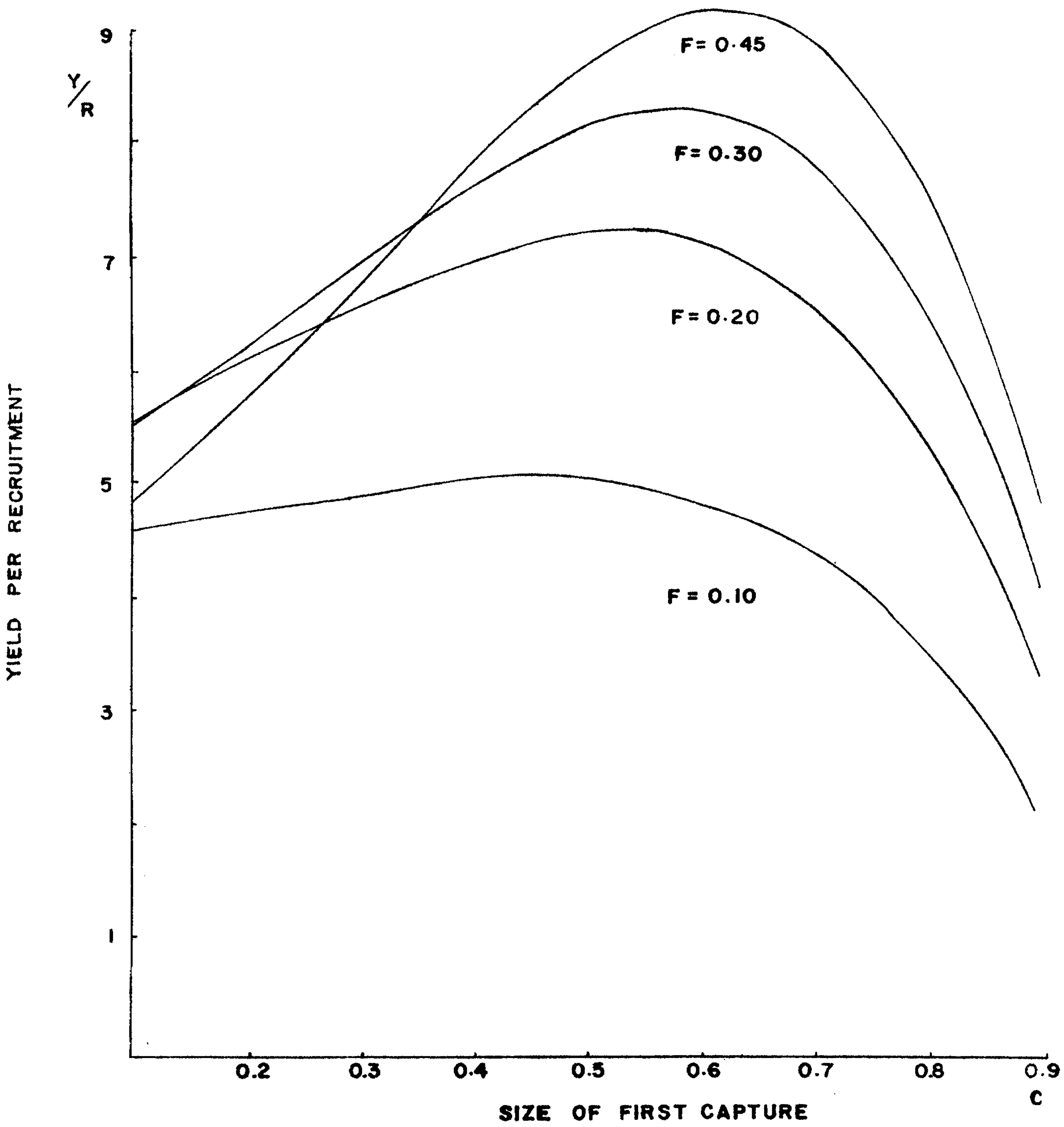

Figure 12. Variations in the yield per recruit of the stock of the Indo-Pacific mackerel with the size at first capture computed at four levels of fishing effort (M = 0.30, K = 0.30)

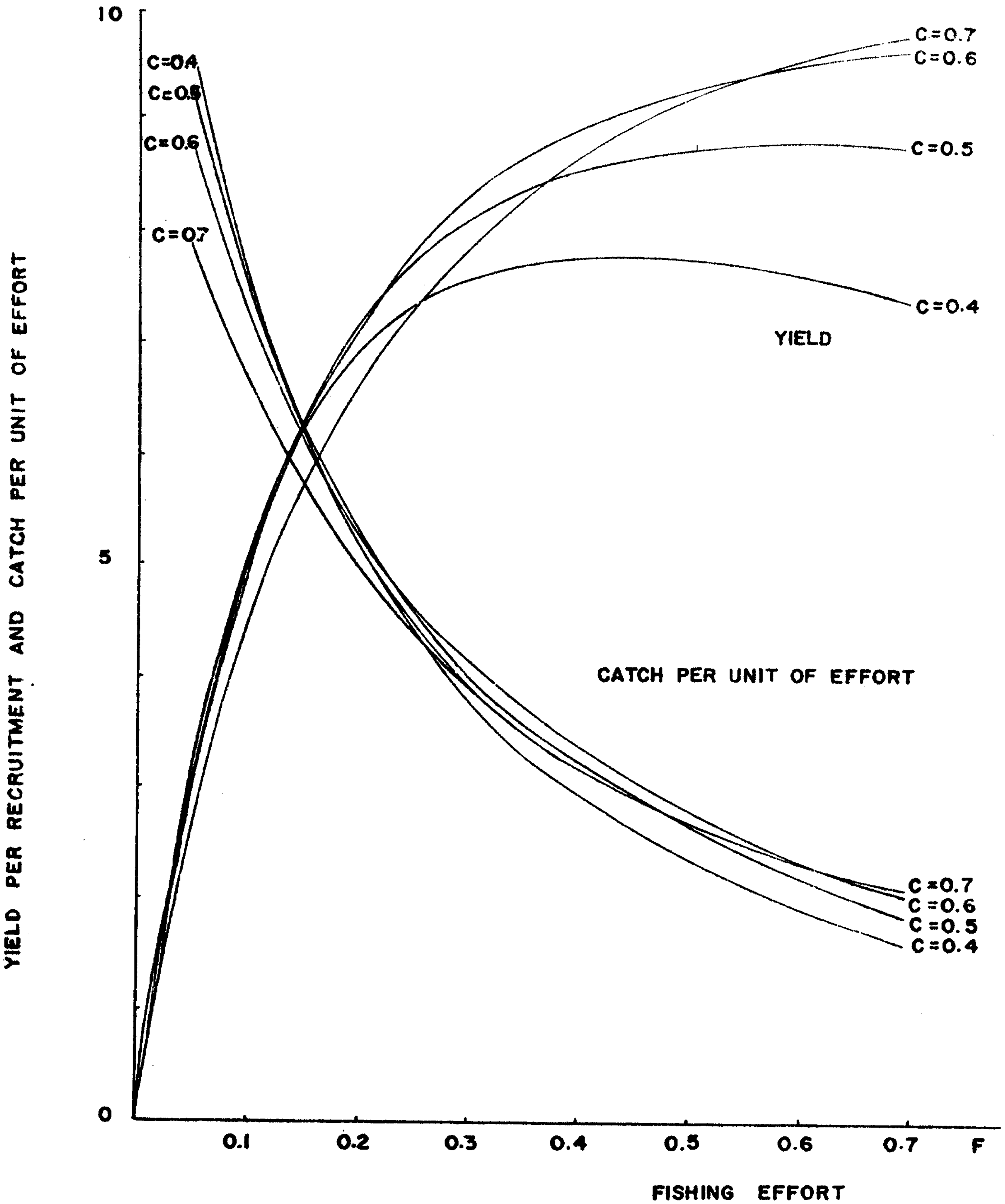

Figure 13 Variations in the yield per recruit and catch per unit of effort with the fishing effort, computed at four size at first capture (M = 0.30 and K = 0.30).

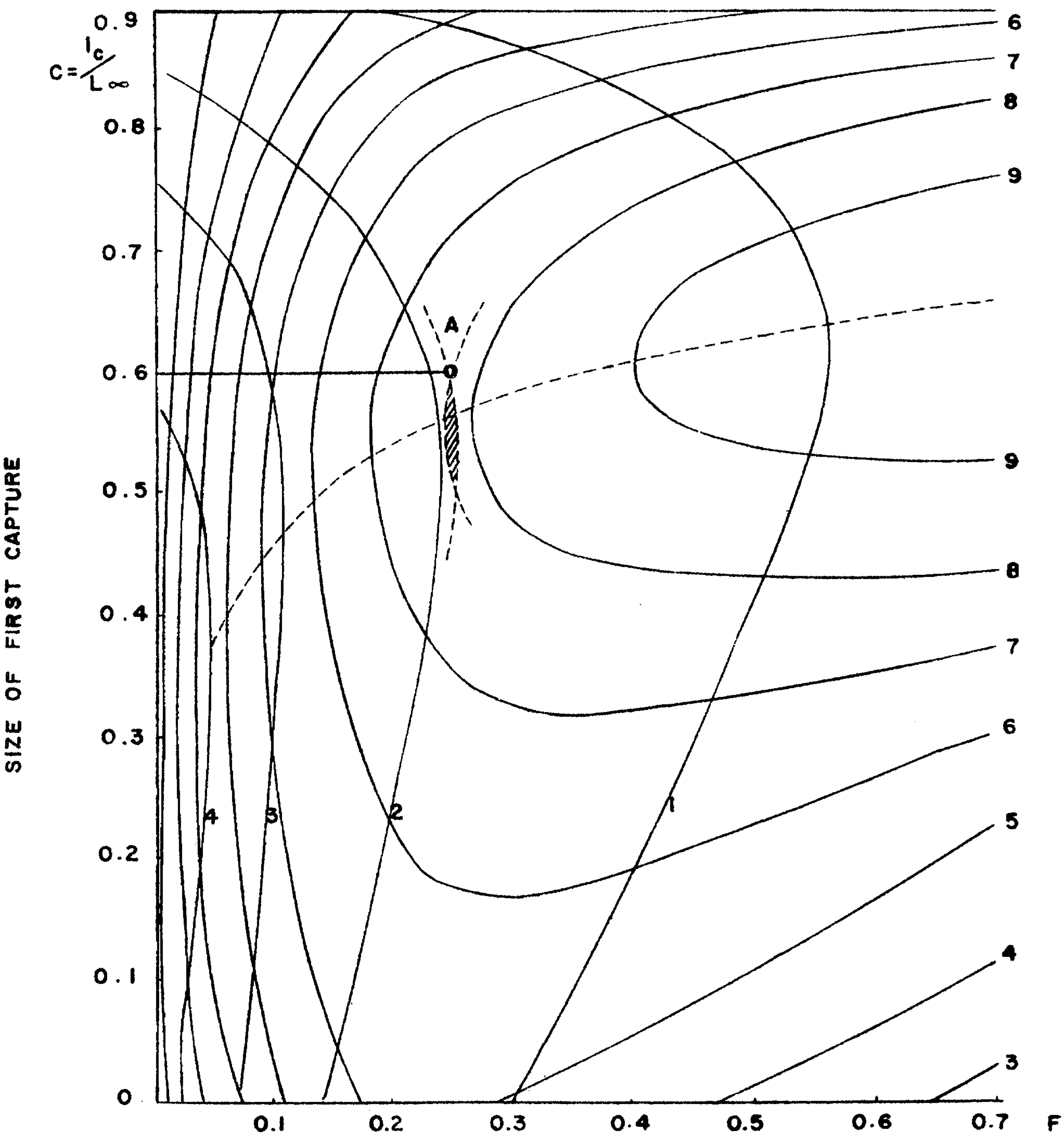

Figure 14. The isopleth diagrams of yield and of catch per unit of effort of the Indo-pacific mackerel obtained from combination of F and l_c using M = 0.30 and K = 0.30. Contours are drawn at 1 unit interval.
Thick lines represent contour lines of yield.
Fine lines represent contour lines of catch per unit of effort.
Dotted line represent the eumetric fishing curve.
A.= the probable level of fishery at present.