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Considerations on the Management of the International Squid (*Illex*) Fishery in ICNAF Subarea 4

by

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A yield per recruit model for the Illex fishery in ICNAF Subarea 4 was developed based on catch statistics from the 1977 International fishery. An optimal fishing rate for 1978 was derived using this model.

Introduction

In recent years the fishery for squid has developed rapidly. In 1977 the International fishery off Nova Scotia caught about 40,000 mt of squid compared to 33,000 mt of silver hake, the other important species to the International fishery. To this point the fishery has been managed on a quota basis. However, STACRES at its special meeting on Illex in Cuba (ICNAF Summ. Doc. 78/VI/3) recommended an effort regulation on the fishery.

In the present paper a first attempt is made at estimating the effective fishing effort for squid during 1977. The relation between fishing effort and fishing mortality rate could then be calculated.

A yield per recruit model to determine the fishing mortality rate which gave a maximum yield was undertaken. The effect of varying the date of onset of fishing on the yield per recruit was also investigated.

An optimal exploitation rate of 0.4 was assumed based on other mathematical simulations (Au, 1975; Sissenwine and Tibbetts, 1976) for a population with a moderate stock recruitment relationship. Using this value and the yield per recruit model, an optimal fishing rate was derived for the 1978 fishing season.

Modal Analysis

Before undertaking a study of the 1977 squid fishery the number of cohorts or generations in the fishery must be established. Various authors have suggested life-cycles for Illex ranging from 9-18 months (Mesnil, 1976; Paulmier, 1974; Squires, 1967) and have given evidence of more than one cohort being present in the catch. They noted relatively small Illex in the catch in the late fall. If there was more than one generation in the catch of the International fishery in 1977 an examination of the length frequencies throughout the fishing season should show at least two distinct size classes of squid.

Amaratunga et al (1978) published bi-weekly length frequencies from samples taken of the catch in 1977. Preliminary examination of the length frequencies during the first 2-week period beginning April 4, show a few relatively large squid in the sample. These may be adult Illex or they may be misidentified Loligo. Mercer (1970) stated that the northern limit of the range of Loligo is off the coast of Nova Scotia. Also, Squires (1957) found a few mature Illex in May off Newfoundland.

A computer program NORMSEP (Abramson, 1971) was used to separate different cohorts statistically. For the final 2-week period of the fishing season beginning on November 13, two distinct size-modes were identified. These modes correspon to the modal sizes of the males and females in the sample. The analysis was run again for a 2-week period earlier in the season beginning on May 30 when the length frequencies were not separated into male and female groups. As in the 13 November samples only 2 modes were identified. Since the two modes differed by only 20 mm in length, the modes do not represent two generations of squid but more probably are the result of the difference in growth rates between males and females.

We may conclude that there was a single cohort making up the catch, based on the sampling done in 1977 of the International fishery.

Growth Rate

The general characteristics of the growth of Illex in 1977 are given in Amaratunga et al (1978 a,b). Growth data is summarized for consecutive bi-weekly intervals throughout the fishing season except for a few periods late in the season when no sampling was done. In order to estimate the growth level for these periods and to provide complete growth information for the yield per recruit model a mathematical model using the von Bertalanffy (1934, 1938) equation was fitted to the average lengths for each bi-weekly interval. The equation of this curve (Fig. 1) is:

$$\ell_t = L_\infty \, (1-e^{-K(T-To)}) \qquad (1)$$

$$= 254.6 \, (1-e^{-0.164(T+3.2)})$$

where ℓ_t = length at time t

L_∞ = mean asymptotic length

K = rate of decrease of length

T_o = time at which fish has 0 length

The growth of Illex is very similar to that described by Squires (1957) using the same model.

Table 1 lists the mean lengths used to derive equation (1). The mean lengths calculated using equation (1) for periods when no sampling was done are also noted. Using the sex ratios given in Amaratunga et al (1978 b) and the length-weight relationships for males and females given in Amaratunga et al (1978 a) the mean weight per animal was calculated for each bi-weekly interval from the mean lengths.

Mortality Rates

The yield per recruit model requires not only information on growth rate but also estimates of mortality rates. Following the method of Au (1975) values of natural mortality were estimated based on the life expectancy of the species as reported by various authors. Squires (1967) reported a life cycle of 1-1.5 years (M = 0.03 for 2-week period) while

Table 1. Growth of Illex in 1977. Bi-weekly mean mantle lengths and mean weights are listed.

Period Beginning	Mean Mantle Length (MM)	Percentage Males	Mean Weight (GM) Females	Mean Weight (GM) Males	Mean Weight (GM) Sexes Combined
April 18	130	)	35.6	38.8	37
May 2	147	) Unsexed	53.7	58.3	56
May 16	157	) estimate at) 57.0%.	67.0	72.6	70
May 30	175	)	96.4	104.1	101
June 13	186	)	118.2	127.4	123
June 27	203	)	158.2	170.4	165
July 11	211	64.0	180.4	193.7	189
July 25	214	59.0	189.1	203.0	197
Aug 8	219	56.0	204.3	219.2	213
Aug 22	227	56.0	230.4	246.9	240
Sept 5	230	57.0	240.7	257.9	251
Sept 19	234)	57.0	255.1	273.1	265
Oct 3	237) *	57.0	266.2	284.9	278
Oct 17	240)	57.0	277.7	297.1	289
Nov 1	244	43.5) **	293.5	313.8	305
Nov 13	240	43.5)	277.7	297.1	286

* Lengths calculated from equation (1).

** Subarea 5.

Mesnil (1976) reported a 1-2 year life-cycle (M = 0.02 for a 2-week period). Au (1975) suggested that the life cycle was 12 months or less ($M \geq 0.04$ for 2-week period), assuming M is constant throughout the life span. Efanov and Puzhakov (1975) estimated a monthly M value of 0.1 (2-week value M = 0.05).

To derive an estimate of the total mortality rate (Z) a plot was made of log C/E (catch per unit effort) over the duration of the fishing season at two-week intervals (Fig. 2). The values for the catch are expressed as the number of animals calculated by Hurley and Waldron (1978).

The effort used was from the Canadian FLASH reporting system. However, this effort cannot be considered effective squid effort since nearly half the reported catch from the international fishery was caught in mixed fisheries along with other species. During the 1977 fishing season, the Canadian International Observer Program placed observers on fishing vessels of those nations which carried on mixed fisheries. The observer coverage of these vessels was considered representative of the fishing activities of each nation (Waldron, 1978). From data collected by the International Observer Program from May 2-September 19, 1977, it was possible to correct the FLASH effort for effective squid effort. Effective squid effort was arbitrarily defined as a day on which squid represented the major species caught by weight in the catch. Original FLASH effort, effective squid effort weighting factors and the corrected effective squid effort are given in Table 2 for each 2-week period from May 2 to September 19.

Table 2. F-values and FLASH effort adjusted to effective squid effort. (see text)

Period Beginning	F-value	% Squid Days	Weighting Factor	FLASH Effort	Effective Squid Effort
May 2	.002	10	0.11	83	9
May 16	.025	31	0.33	139	46
May 30	.106	27	0.29	184	53
June 13	.203	71	0.76	245	186
June 27	.211	63	0.67	319	214
July 11	.220	43	0.46	463	213
July 25	.370	61	0.65	397	258
Aug 8	.272	46	0.49	312	153
Aug 22	.339	42	0.45	244	110
Sept 5	.509	89	0.95	254	241
Sept 19	.329	94	1.00	246	246

A geometric mean regression (Ricker, 1973) was calculated and the resulting line of best fit is shown in Fig. 2. Data for the month of May was not used in fitting the regression line. Squid caught in May are relatively small (Amaratunga et al 1978b) and there may be a considerable number of animals that pass through the nets. This would result in a catch rate of this period that is lower than the true catch rate. The slope of the regression line gives an estimate of the total mortality rate (Z) (Ricker 1975 p.8). The equation for the G.M. regression is:

$$y = 6.64 - 0.32\ X \qquad (2)$$

Therefore, the estimate of the total mortality rate (Z) = slope of the line = 0.32. An average value for the fishing mortality rate (F) for this period can be calculated from the F-values generated by a cohort analysis given in Hurley and Waldron (1978) (Table 2). The average F-value for the same time period = 0.28.

Since $Z = F + M$
therefore by subtraction

$$M = Z - F$$

$$= 0.32 - 0.28$$

$$= 0.04 \qquad (3)$$

This value for M falls within the range of values listed in the discussion above based on proposed life cycles of Illex.

Yield-per-recruit

With the above information on the growth rate, fishing and mortality rates for the International fishery in a 1977 a yield-per-recruit model was developed based on the method of Ricker (1975). The model was run for two values of M (M = 0.03 and M = 0.05). The value M = 0.04 derived from Fig. 2 falls between these two values. The growth rate was determined from the von Bertalanffy model (Fig. 1). The bi-weekly fishing mortality rates (F) tested in the model ranged from 0.1 to 0.4 which covered the range of most of the derived values of F in 1977 (Table 2).

The analyses producing the yields given in Tables 3 and 4 were calculated starting with an arbitrary 1000 Kg starting biomass. A more diagramatic representation of the yield per recruit model is shown in Fig. 3.

The model produced yields based on the same fishing period in 1977 for which data was available for calculating the growth rate i.e. from April 18 to the 2-week period beginning Nov. 13, (Table 2).

Not only were the values for F and M varied in the model but also the time of onset of fishing. Highest yield assuming M = 0.05 is achieved when fishing begins on August 8 at F = 0.4. Assuming M = 0.03 the highest yield is achieved again at F = 0.4 when fishing begins 2 weeks later on August 22, the last date considered in the analysis.

In 1978 the legal opening day for the squid fishery is June 15. Figure 4 shows a detailed graph of the relation between yield and F-values when fishing commences in mid-June. The maximum yield occurs at F = 0.3 when M = 0.03.

Table 3. Yields produced by yield per recruitment model starting with 1000 kg. A value of M = 0.03 is assumed.

Onset Of Fishing	FISHING MORTALITY RATE (F)			
Period Beginning	0.1	0.2	0.3	0.4
April 18	2723 (kg)	2747	2418	2128
May 16	3016	3416	3275	3066
June 13	3158	3939	4050	3990
June 27	3139	4073	4303	4319
July 25	2926	4063	4481	4615
Aug 22	2572	3841	4462	4761

Table 4. Yields produced yield per recruit model starting with 1000 kg. A value of M = 0.05 is assumed.

Onset Of Fishing	FISHING MORTALITY RATE (F)			
Period Beginning	0.1	0.2	0.3	0.4
April 18	2343 (kg)	2442	2206	1980
May 16	2558	2975	2912	2770
June 13	2631	3348	3500	3492
June 27	2586	3415	3661	3717
July 25	2353	3307	3686	3829
Aug 22	2020	3039	3555	3817

Relation of F and Effort

In order to manage the fishery on a practical basis the fishing mortality rate must be related to the fishing effort. This is normally done using the equation:

$$F = qf$$

where F = the fishing mortality rate
q = the catchability coefficient
f = fishing effort

A more complete discussion of this relation may be found in Gulland (1977).

Figure 5 shows the relation between F and effort(f). The bi-weekly F-values are the same as listed in Table 2. The bi-weekly effort values are the effective squid effort values discussed above as listed in Table 2. The equation for the GM regression is:

$$y = -0.04 + .0017\ X \tag{4}$$

The correlation coefficient for the relation is $r = 0.8$. ($t = 4.0$, significant 1% level)

Discussion

The exploitation rate of the 1977 international fishery was 0.75 according to Hurley and Waldron (1978). This corresponded to an average bi-weekly F value of 0.28 or to an average bi-weekly effort of 160 effective squid days (Fig. 5).

The optimal exploitation rate for Illex suggested in the special STACRES meeting in Cuba, Febraury 1978 (ICNAF Summ. Doc. 78/VI/3) and by Sissenwine and Tibbetts (1976) for a population which is moderately dependent on spawning stock size is 0.4. If we can accept this figure ($u = 0.4$) as an optimal exploitation rate then using the Baranov equation, the corresponding optimal F value can be calculated.

$$\text{Since } C = \frac{FAN}{Z} = uN \tag{5}$$

$$\text{then } u = \frac{FA}{Z} = \frac{F\left(1-e^{-(F+M)}\right)}{F+M}$$

Substituting $u = 0.4$ and $M = 0.44$ (M is the summed bi-weekly value for the period May 2 to September 19 over which most fishing occurs and assumes a constant bi-weekly value of $M = 0.04$) and solving iteratively, the summed F value = 0.7 and the optimal bi-weekly F value = 0.06. This corresponds to an effective squid effort of 60 days (Fig. 5).

In 1977 the international squid fishery commenced in late April. As previously pointed out, the legal opening day in 1978 will be June 15. From the yield per recruit model (Tables 3 and 4) for both $M = 0.03$ and 0.05, it is noted that by delaying the onset of fishing from mid-April to mid-June, the fishing rate should be increased from 0.2 to 0.3, a factor of 1.5, to achieve the maximum yield. It follows from equation (4) that an increase in the fishing rate should result in a corresponding linear increase in the effective squid effort.

Therefore the optimal effective squid effort for 1978 should be equal to:

1977 optimal effort x 1.5

= 60 x 1.5

= 90 days

Actual allocations of days on ground for each nation would depend on the number of nations participating in the overall fishery, the historic fishing effort expended by each nation on the Scotian Shelf and the particular attitude of a country's fishery. The latter criterion refers to whether squid are caught in a directed fishery or in a mixed fishery along with other species.

REFERENCES

Abramson, N.J. 1971. Computer programs for fish stock assessment. FAO Fish. Tech. Pap. No. 101. FAO/UN.

Amaratunga, T., R.D. Durward, M. Roberge and L. Wood. 1978a. Population structure of Illex illecebrosus in the Scotian Shelf fishing areas in 1977. ICNAF Res. Doc. 78/II/2.

, M. Roberge and L. Wood. 1978b. A study of the 1977 international catch statisitcs for the squid, Illex illecebrosus fishery in ICNAF Subareas 3 and 4. ICNAF Res. Doc. 78/II/3.

Au, David. 1975. Considerations on squid population analysis and recommendations for rational exploitation. ICNAF Res. Doc. 75/61.

von Bertalanffy, L. 1934. Untersuchungen uber die Gesetzlichkeit des Wachstums. I. Roux' Archiv 131: 613.

1938. A quantitative theory of organic growth. Hum. Biol. 10: 181-213.

Efanov, V.N. and N.P. Puzhakov. 1975. Size composition, growth, maturity rate, and condition of the shortfin squid (Illex illecebrosus) stocks in the west Atlantic. ICNAF Res. Doc. 75/58.

Gulland, J.A. 1977. Fish Population Dynamics. John Wiley and Sons, Toronto. 372 p.

Hurley, G.V. and D.E. Waldron. 1978. 1977 Population estimates for squid (Illex illecebrosus) in ICNAF Subarea 4 from the International fishery in 1977. ICNAF Res. Doc. 78/61.

Mercer, M.C. 1970. Sur la limite septentrionale du calmar Loligo pealei. Le Sueur. Nat. Can. (Que.) 97: 823-824.

Mesnil, B. 1976. Growth and life cycle of squid, Loligo pealie and Illex illecebrosus from the northwest Atlantic. ICNAF Res. Doc. 76/65.

Paulmier, G. 1974. Preliminary observations on commercial squid (Loligo pealei Le Sueur and Illex illecebrosus Le Sueur) on Georges Bank - R/V Cryos Cruise September-October 1973. ICNAF Res. Doc. 74/50.

Ricker, W.E. 1973. Linear regressions in fishery research. J. Fish. Res. Board Can. 30: 409-434.

1975. Compilation and interpretation of biological statistics of fish populations. Bull 191. Fish. Res. Board Canada. 382 p.

Sissenwine, M.P. and Anne M. Tibbets. 1976. Simulating the effect of fishing on squid populations of the northeastern United States. ICNAF Res. Doc. 76/30.

Squires, H.J. 1957. Squid, Illex illecebrosus (Le Sueur) in the Newfoundland fishing area. J. Fish. Res. Board Can. 14: 693-728.

1967. Growth and hypothetical age of the Newfoundland bait squid, Illex illecebrosus. J. Fish. Res. Board Can. 24: 1209-1217.

Waldron, D.E. 1978. Catch composition during the 1977 Scotian Shelf International fishery with emphasis on the silver hake and squid (Illex) fisheries. ICNAF Res. Doc. 78/9.

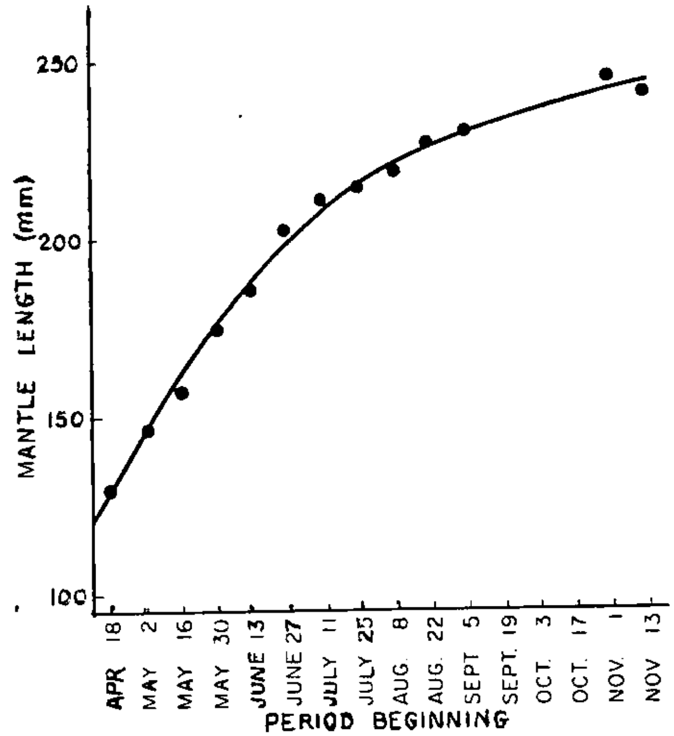

Fig. 1. Growth of Illex in 1977. Curve represents the von Bertalanffy equation fitted to the mean mantle lengths for bi-weekly periods.

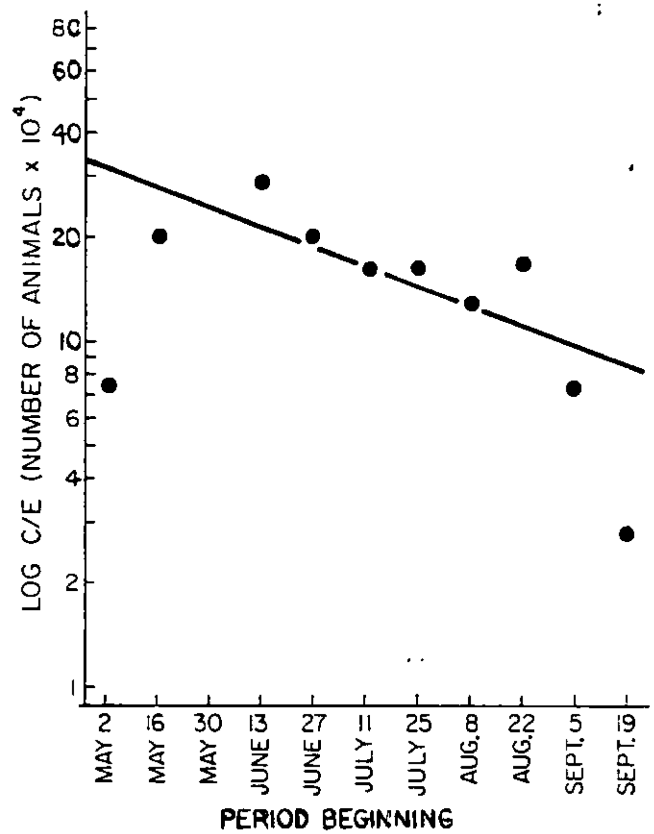

Fig. 2. Graph of log C/E - catch per unit effort - (number of animals) versus time during 1977 fishing season. Effort is effective squid effort (see text).

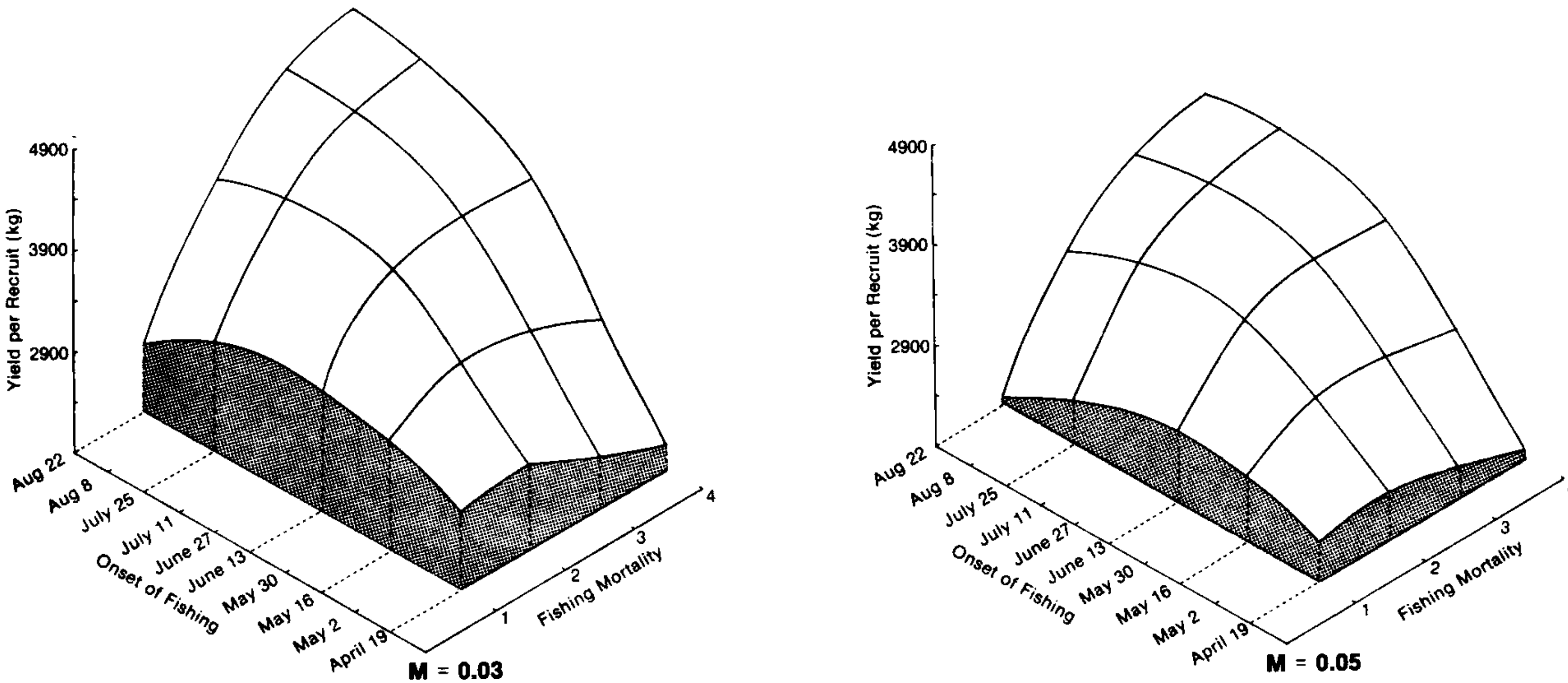

Fig. 3. Diagrammatic representation of yield per recruit model for 2 levels of natural mortality rate ($M = 0.03$ and $M = 0.05$).

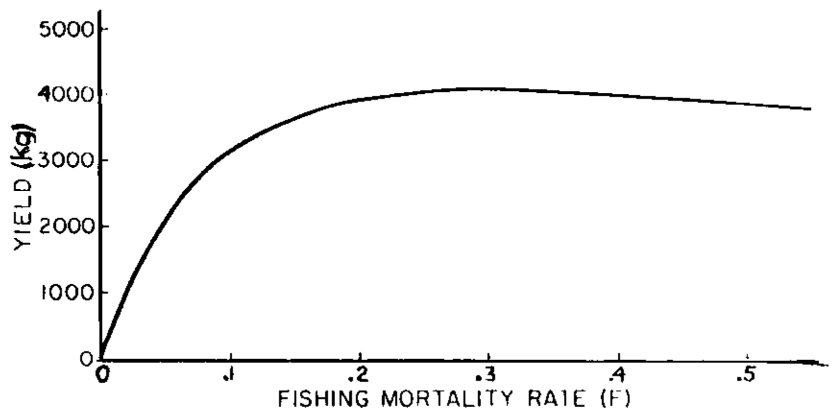

Fig. 4. Relation between yield and F-values when fishing commences June 13 (M = 0.03).

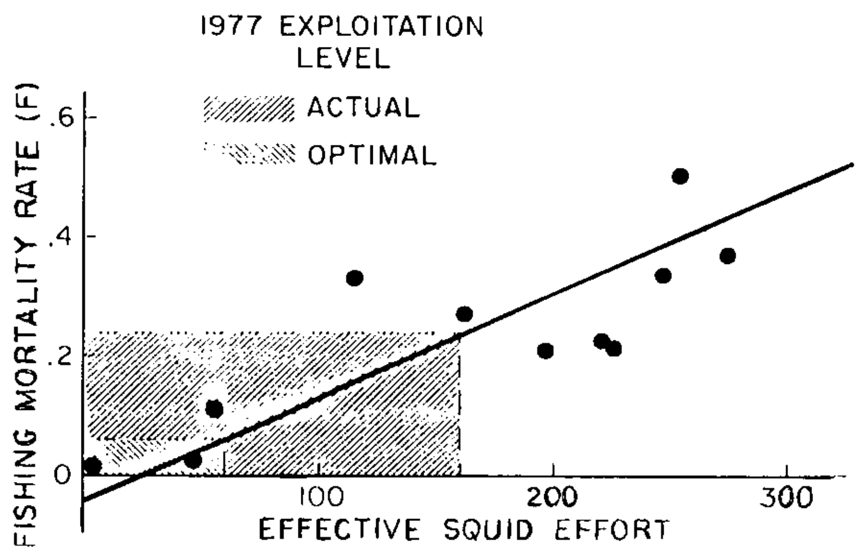

Fig. 5. The relation between bi-weekly F-values and effective squid effort for the International fishery in 1977 (see text). The 1977 actual exploitation level and calculated optimal exploitation are indicated on the graph.