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Assessment of the 1978 4VWX Squid (*Illex illecebrosus*) Fishery

by

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INTRODUCTION

Historical assessments for squid populations have employed several different methods varying from embryological through to density methods (Lipinski, 1973) and more recently Cohort (Ikeda & Nagasaki, 1975; Ikeda & Sato, 1976; and Hurley & Waldron, 1978). Ikeda (et al, 1973) prepared a detailed analysis of the neritic squid stocks (*loligo pealei* (Les.) from the east coast of the U.S.A. The fact that the life cycle of loligo is greater than one (1) year allows a more applicable use of current assessment models. Sissenwine (1976) and Hurley & Waldron (1978) have summarized the current methods used to assess squid. It is not the intention to duplicate their efforts here.

Illex illecebrosus is a short lived squid ranging from George's Bank to the Northeast coast of Newfoundland (Squires, 1967, Mercer & Paulmeir, 1974). Despite such a large range, fishing effort is concentrated offshore primarily in ICNAF Division 4VWX and along the coast of Newfoundland. Initial recruitment occurs in April and the squid are available until December, however, the later date is usually determined by weather conditions influencing accessability. Assessment techniques are further hampered because of the life span, illex may obtain a life expectancy from twelve to eighteen months (Squires, 1967). Because of these factors, assessment estimates are only indicative of the stock available during one year, usually after fishing occurs.

A new initiative in illex assessments was presented by Hurley & Waldron, 1978. Employing the techniques of Pope's (1972) Cohort analysis, they determined the exploitation rate of illex in ICNAF Divisions 4VWX to be twice the level recommended by STACRES (Redbook, 1978). With additional inputs, this technique could provide a relatively accurate population estimate.

Data from the 1978 squid fishery in 4VWX was collected at an unprecedented level providing the most reliable catch and effort data to date. Because of the delays in obtaining precise catch and effort data segmented to smaller than monthly values, this paper will present a preliminary analysis of the squid stock in ICNAF 4VWX.

Materials and Methods

Data used for this analysis was obtained from both weekly reported catch and efforts supplied by each Country and the International Observer Program. The latter source of catch and effort figures were used to adjust the weekly reports for those Countries engaged in more than one allocated fishery.

The method of adjustment was to divide the weekly reported country catch by the corresponding observed directed squid catch/effort. A directed squid fishery is defined as one where the squid composition is 80% of any set's total catch. This figure was applied to data used in the 1977 assessments. (Hurley & Waldron, 1978) and was agreed to at the 1978 STACRES meeting (ICNAF Redbook 1978). This concept has been later verified using the Chikuni (1975) method of plotting c/f against % composition and then determining the percentage point at which the catch concentrates (Fig. 1).

The catch and effort data for Canada are preliminary and were obtained from weekly reports supplied to Canada by each vessel operating in conjunction with a Canadian Company. Complete data for both the domestic and foreign fisheries is expected to vary little from that reported here.

Effort used in this analysis was standardized for all countries, to that observed for the USSR vessels over 2000 tons (Table 1). The observed data was classified as either directed or not directed for squid with the 80% level used as a selection criteria. The bi-weekly catch rates for the USSR were then applied to each country inorder to obtain the standardized value.

The catch numbers for squid were calculated by dividing the catch weight with the observed mean weights collected during the International Observer Program.

Results & Discussion

One of the most difficult parts of an assessment and in particular, squid (Illex), is the ability to determine the starting F and constant M. Inorder to estimate these parameters, several methods currently applied to long lived species were attempted. All methods resulted in variable estimates which indicate there is a requirement for detailed information on the life span and more precise knowledge of immigration and emigration.

Estimation of Mortality

1. Catch Curve Method

The use of a catch curve to estimate Z after full recruitment is typically applied to many species. The basic assumption is that F has been stabilized over the time (i.e. ages) under consideration. Effort exerted on the squid population during 1978 increased to a peak on week 40 (Oct. 1) (Fig. 2). The rate of the decline of the fishing effort after week 40 was eased as a direct result of fishing charters arranged between foreign fleets and Canadian companies. This may have artificially kept the effort levels higher than would have normally occurred if these incentives were absent (Table 2). Plotting Ln c/f against time will remove some of the variability associated with either the effort or the catch and allow an avaluation of full recruitment. From this plot, full recruitment has occurred by week 34 (August 20th) (Fig. 3).

The fishery can be divided into three phases: immigration, stabilized fishery, and emigration. The stabilized phase is affected by F and M rather than immigration and/or emigration. Inflections in the catch curve indicate the range of these periods. For the 1978 fishery these can be identified as occurring from the start of the fishery to bi-weekly period 32 (immigration), from periods 34 - 42 (stabilized fishery), and periods 44 - 52 (emigration) (Fig. 3).

Caddy (1979) has presented a yield per recruit model which utilizes these phases in order to calculate immigration and emigration rates based on Z and qf for each bi-weekly period. Since precise estimates of q are difficult to obtain, the simplistic method of estimating the emigration rate would be to subtract $Z_n - Z_{n+1}$.

Regressing Ln c/f (in numbers) against time for periods 34 - 42 and 44 - 52 give high correlations with Z = 0.168 and 0.401 respectively. Subtracting these two rates, results in an estimated bi-weekly emmigration rate of 23% after period 42 (21 October). The last reported catches in the 1978 fishery occurred in the 3rd week of December which corresponds to the total estimated time when all squid would have left the shelf (fishery) area, based upon the above rate (Fig. 3).

2. Natural Mortality when F = 0.

A method of determining the maximum possible M is to set F = 0 in the following equation:

$$\frac{N_t}{N_0} = e^{-Zt} \quad \text{.........................(1)}$$

When F = 0, Z = M then:

$$\frac{N_t}{N_0} = e^{-Mt} \quad \text{..........................(2)}$$

Where t is the time period under consideration.

For the present study, t is assumed to be the life cycle and N_t/N_0 is the survival ratio of the terminal to initial populations.

The 10th special session of STACRES recommended an exploitation rate for Illex of 0.40 while Au (1975) estimates an = E max of 0.65 which results in a mean stock size reduced to 20 - 22% of initial level. Based on these rates, three terminal stock sizes were selected; 60, 35 and 20% of the initial population. Estimates of total and bi-weekly M were calculated for life spans from 6 - 24 months (Table 3).

Selection of the appropriate life span is complicated by the widely varying estimates of the life cycle for squid (Illex illecebrosus) from 12 - 24 months (Lipinski 1973, Mercer 1974, Squires 1967). Since large squid are not present in the spring fishery on the Scotian Shelf it is reasonable to assume that the life cycle does not reach 2 years. Most likely the maximum life cycle is between 15 and 17 months with the majority not surviving 12 - 13 months (Squires 1967). Different spawning rates for sectors of the stock may vary this estimate, however until further data is available this is a reliable estimate of the life span.

Assuming Squires estimate that the majority of squid die after 12 months and Au (1975) hypothesis that for successful recruitment the next year, a minimum spawning stock size of 20% of the initial population is required; the maximum average expected bi-weekly M, at F = 0, would be 0.062.

3. Fishing Mortality

Utilizing a bi-weekly Z = 0.168 and M = 0.062 an initial starting F = 0.106 can be calculated. In order to evaluate the appropriate F, regressions of effort days (f) against F from cohorts at constant M were calculated, (Table 4).

The best regression coefficient was at F = 0.150 however agreement between starting F and r^2 was greatest at F = 0.045. Therefore, the most appropriate combination to be used in a sequential analysis would be M = 0.062 and F = 0.045.

Squid (Illex) Population Estimates - Cohort

Hurley and Waldron (1978) hypothesized that since the weekly sampling data, from the 1977 squid fishery had only a single mode for both males and females, the population could be treated as a single Cohort. Analysis of the 1978 sampling data reaffirms this and again the population can be assumed to consist of a single Cohort.

The sequential analysis (Pope, 1972) at $M = 0.062$ and $F = 0.045$ was calculated from the start of the fishery, period 18 (May 6th), to period 42 (October 21) (Table 5). Iterating the equations below, terminal stock was projected.

$$= F/F+M \; (1 - e^{-(F+M)}) \quad \text{.........................(3)}$$

and

$$N_{t+1} = N_t \; (e^{-(F+M)}) \quad \text{..................................(4)}$$

In this manner it is possible to avoid the obviously erroneous terminal stock size estimated by Hurley and Waldron (1978). It would appear that in fact they may have estimated the available stock left on the shelf rather than the total stock. In this paper the terminal stock of 76,956 metric tons could represent the summation of that part on the shelf as well as that part which is spawning stock off the shelf.

Exploitation Rate and Stock Size

An exploitation rate, assuming a Ricker type 11 fishery, was calculated from period ending May 6 to October 21. At $M = 0.062$, the $M = 0.806$ and $F = 0.447$. Employing Baranov's catch equation, $= F(1-e^{-Z})Z = 0.255$. This exploitation rate is lower than that recommended in the literature (Au, 1975). The preferable range should be from 0.40 to 0.50.

An approximate estimate of stock size at $= 0.255$ would be four times the total catch of area 4 (53, 118 MT) which would be 212, 472 MT.

Conclusion

The Illex fishery is probably more sensitive to influence from their abiotic environment than the fishery. In other words, the squid fishery will become self limiting through lack of availability to the fleets as a result of changes in the environment and emigration. An alteration in the environment facts (i.e. temperature), or onset of immigration could have the squid populations more accessable and thus over fishing could ensue.

Squid pass through the fishery only once and that fishery is intensely prosecuted for a brief period of time. Increasing fishing effort within this time frame could seriously affect the fishery by substantially decreasing the population numbers at one particular time. Since for each bi-weekly period the catch is dependent upon the number available at the end of the last period x an increase in weight (growth), management by quota and attempting to increase effort could have adverse consequences in this fishery. It is undesirable to increase effort at this time until more of the dynamics of this population are understood.

Future analysis should concentrate on the stock recruitment relationships, aging and quantifying emmigration and immigration.

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Table 1. Reported catch,effort(days) and adjusted effort for the 4vwx squid fishery in 1978.

Wk.	CANADA Mt.	CANADA Report Days	CANADA Obser. Adj.	CANADA Total Adj.	BULGARIA Mt.	BULGARIA Report Days	BULGARIA Obser. Adj.	BULGARIA Total Adj.	CUBA Mt.	CUBA Report Days	CUBA Obser. Adj.	CUBA Total Adj.	FRANCE Mt.	FRANCE Report Days	FRANCE Obser. Adj.	FRANCE Total Adj.
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	0.4	-	3	0.1	-	-	-	-
22	-	-	-	-	-	-	-	-	2.5	-	6	0.6	-	-	-	-
24	-	-	-	-	-	-	-	-	0.8	-	1	0.2	-	-	-	-
26	-	-	-	-	28.0	-	2	4	14.2	-	3	2	-	-	-	-
28	-	-	-	-	41.0	-	5	3	9.2	-	2	1	-	-	-	-
30	135.2	3	-	5	417.0	9	13	16	1014.9	50	46	39	-	-	-	-
32	392.2	24	-	36	268.2	19	15	23	283.6	33	32	28	172.0	7	-	16
34	1316.7	51	-	33	-	-	-	-	18.4	7	1	0.5	205.0	14	-	5
36	3207.8	142	-	202	-	-	-	-	124.7	15	11	8	376.0	21	40	24
38	5304.5	235	-	306	-	-	-	-	527.8	23	36	30	760.0	34	34	44
40	5768.3	233	-	534	-	-	-	-	81.9	6	-	8	461.0	20	17	43
42	2641.4	186	-	219	-	-	-	-	73.0	11	-	6	-	-	-	-
44	4747.7	154	-	247	-	-	-	-	449.5	19	-	23	-	-	-	-
46	667.6	88	-	195	-	-	-	-	115.5	5	-	34	-	-	-	-
48	104.8	34	-	24	-	-	-	-	-	-	-	-	-	-	-	-
50	29.0	12	-	12	-	-	-	-	-	-	-	-	-	-	-	-
52	0.5	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	24315.6	1143	-	1814	734.2	28	35	46	2716.4	169	141	178.4	1974	96	91	132

Wk.	FRG Mt.	FRG Report Days	FRG Obser. Adj.	FRG Total Adj.	ITALY Mt.	ITALY Report Days	ITALY Obser. Adj.	ITALY Total Adj.	JAPAN Mt.	JAPAN Report Days	JAPAN Obser. Adj.	JAPAN Total Adj.
18	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	4.1	-	-	1
26	-	-	-	-	-	-	-	-	13.5	7	-	2
28	-	-	-	-	-	-	-	-	132.6	34	37	9
30	-	-	-	-	-	-	-	-	834.1	62	75	32
32	-	-	-	-	-	-	-	-	356.6	33	37	32
34	-	-	-	-	-	-	-	-	322.7	18	22	8
36	-	-	-	-	-	-	-	-	202.7	18	14	13
38	435.0	14	-	25	405.2	61	53	23	342.7	26	-	20
40	141.0	14	-	13	594.9	77	68	56	258.8	12	-	24
42	244.0	11	10	20	55.0	15	12	5	239.2	14	-	20
44	-	-	-	-	-	-	-	-	902.3	41	-	47
46	-	-	-	-	-	-	-	-	260.8	21	-	76
48	-	-	-	-	-	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	820.0	39	16	58	1055.1	153	133	84	3870.1	286	185	284

Wk.	POLAND Mt.	POLAND Report Days	POLAND Obser. Adj.	POLAND Total Adj.	PORTUGAL Mt	PORTUGAL Report Days	PORTUGAL Obser. Adj.	PORTUGAL Total Aj.	ROMANIA Mt.	ROMANIA Report Days	ROMANIA Obser. Adj.	ROMANIA Total Adj.
18	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-
28	90.2	10	-	6	-	-	-	-	14.0	1	-	1
30	999.8	43	-	39	-	-	-	-	895.0	24	-	39
32	212.9	14	-	19	-	-	-	-	71.0	4	-	6
34	384.0	27	13	12	-	-	-	-	-	-	-	-
36	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	138.5	11	-	13	-	-	-	-
42	-	-	-	-	102.0	14	10	8	-	-	-	-
44	-	-	-	-	220.0	14	-	11	-	-	-	-
46	-	-	-	-	110.0	11	-	32	-	-	-	-
48	-	-	-	-	8.0	3	-	2	-	-	-	-
50	-	-	-	-	-	-	-	-	-	-	-	-
52	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	1686.9	84	13	74	578.5	53	10	66	980	29	-	47

Wk.	SPAIN Mt.	SPAIN Report Days	SPAIN Obser. Adj.	SPAIN Total Adj.	USSR Mt.	USSR Report Days	USSR Obser. Adj.	USSR Total Adj.	TOTAL INTERNATIONAL Mt.	TOTAL INTERNATIONAL Sum. Adj.	TOTAL INTERNATIONAL c/f	TOTAL FISHERY Mt.	TOTAL FISHERY Sum Adj.	TOTAL FISHERY c/f
18	-	-	-	-	7.2	-	1.36	-	7.2	1	7	7.2	1	7
20	-	-	-	-	52.8	-	14	-	53.2	14	4	53.2	14	4
22	-	-	-	-	54.4	-	14		56.9	15	4	56.9	15	4
24	-	-	-	-	62.5	-	17	-	67.4	18	4	67.4	18	4
26	5.6	6	-	1	214.7	227	32	-	276.0	41	7	276.0	41	7
28	50.3	20	-	3	235.1	367	16	-	572.4	39	15	572.4	39	15
30	427.7	81	72	17	5853.6	368	237	-	10442.1	415	25	10577.3	420	25
32	516.0	79	68	47	1083.1	240	98	-	2943.4	267	11	3335.6	303	11
34	454.7	88	-	11	997.2	98	25	-	2382.0	60	40	3698.7	93	40
36	599.7	82	-	38	948.8	60	60	-	2251.9	143	16	5459.7	345	16
38	228.1	29	-	13	Charter	c/f	17.314	-	2698.3	155	17	8002.8	461	17
40	220.3	24	-	20	-	-	10.8	-	1896.6	177	11	7664.8	711	11
42	427.8	50	-	35	-	-	12.07	-	1141.0	94	12	3782.4	313	12
44	153.0	12	-	8	-	-	19.23	-	1723.8	89	19	6471.5	336	19
46	-	-	-	-	-	-	3.43	-	486.3	142	3	1153.9	337	3
48	-	-	-	-	-	-	4.3	-	8.0	2	4	112.8	26	4
50	-	-	-	-	-	-	-	-	-	-	-	29.0	12	2
52	-	-	-	-	-	-	-	-	-	-	-	0.5	1	1
TOTAL	3082.2	471	140	193	9509.4	1360	581.5	-	27006.5	1672	199	51322.1	3486	207

Table 2. Calculations for the 1978 Canadian and Non-Canadian Squid (Illex) Fisheries in ICNAF Division 4VWX

Bi Week	Canadian[1] Catch (m.t.)	Non-Canadian Catch (m.t.)	Total Catch (m.t.)	X wt. (kg)	Total Catch numbers	f (days)	C/f (no/day)
18	-	7.2	7.2	0.090	80000	1	80000
20	-	53.2	53.2	0.073	728767	14	52055
22	-	56.9	46.9	0.088	646591	15	43106
24	-	67.4	67.4	0.090	748889	18	41605
26	-	276.0	276.0	0.100	2760000	41	67317
28	-	572.4	572.4	0.138	4.47826	39	106355
30	135.2	10442.1	10577.3	0.147	61954422	420	171320
32	392.2	2943.4	3335.6	0.148	22537838	303	74382
34	1316.7	2382.0	2698.7	0.191	19364921	93	208225
36	3207.8	2251.9	5459.7	0.222	24593243	345	71285
38	5304.5	2698.3	8002.8	0.221	36211765	461	78550
40	5768.2	1896.6	7664.8	0.235	32616170	711	45874
42	2641.4	1141.0	3782.4	0.250	15129500	313	48337
44	4747.7	1723.8	6471.5	0.261	24795019	336	73795
46	667.6	486.3	1153.9	0.272	4242279	337	12588
48	104.8	8.0	112.8	0.283	398587	26	15330
50	29.0	-	29.0	0.293	98976	12	8248
52	0.5	-	0.5	0.303	1650	1	1650
TOTAL	24315.6	27006.5	51322.1		261056443		

Table 3. Estimated M for Squid (Illex illecebrosus) assuming various spawning stock sizes remaining.

Life Span (months)	No Bi-weekly Periods	Estimated Life Span M[1]			Estimated Bi-weekly M		
		0.60	0.35	0.20	0.60	0.35	0.20
6	13.0	0.085	0.175	0.268	0.034	0.081	0.124
7	15.2	0.073	0.150	0.230	0.034	0.069	0.106
8	17.3	0.064	0.131	0.201	0.029	0.061	0.093
9	19.5	0.057	0.117	0.179	0.026	0.054	0.083
10	21.7	0.051	0.105	0.161	0.024	0.048	0.074
11	23.8	0.046	0.095	0.146	0.021	0.044	0.068
12	26.0	0.043	0.087	0.134	0.020	0.040	0.062
13	28.2	0.039	0.081	0.124	0.018	0.037	0.057
14	30.3	0.036	0.075	0.115	0.017	0.035	0.053
15	32.5	0.034	0.070	0.107	0.016	0.032	0.050
16	34.7	0.032	0.066	0.101	0.015	0.030	0.046
17	36.8	0.030	0.062	0.095	0.014	0.028	0.044
18	39.0	0.028	0.058	0.089	0.013	0.027	0.041
19	41.2	0.027	0.055	0.085	0.012	0.025	0.039
20	43.3.	0.026	0.052	0.080	0.012	0.024	0.037
21	45.5	0.024	0.050	0.077	0.011	0.023	0.035
22	47.7	0.023	0.048	0.073	0.011	0.022	0.034
23	49.8	0.022	0.046	0.070	0.010	0.021	0.032
24	52.0	0.021	0.044	0.067	0.010	0.020	0.031

Table 4. Calculated f and effort values with regression and expected F values (M = 0.062).

Period	f (days)	F = 0.005	F = 0.045	F = 0.10	F = 0.150	F = 0.3	F = 0.5	F = 0.75
18	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	14	0.000	0.001	0.001	0.001	0.002	0.002	0.002
22	15	0.000	0.001	0.001	0.001	0.002	0.002	0.002
24	18	0.000	0.001	0.001	0.002	0.002	0.002	0.002
26	41	0.001	0.003	0.005	0.006	0.007	0.008	0.009
28	39	0.001	0.005	0.008	0.010	0.012	0.013	0.014
30	420	0.016	0.103	0.167	0.201	0.252	0.281	0.297
32	303	0.005	0.037	0.062	0.077	0.100	0.114	0.123
34	93	0.005	0.035	0.061	0.076	0.102	0.117	0.127
36	345	0.007	0.049	0.088	0.113	0.156	0.184	0.202
38	461	0.010	0.082	0.156	0.208	0.307	0.381	0.432
40	711	0.010	0.085	0.176	0.250	0.423	0.587	0.729
42	313	0.005	0.045	0.100	0.151	0.300	0.500	0.750
r^2 =		0.72	0.834	0.901	0.924	0.901	0.817	0.703
a =		0.001	0.003	0.003	0.002	0.002	-0.006	-0.006
b =		1.8×10^{-5}	1.4×10^{-4}	2.8×10^{-4}	3.8×10^{-4}	0.001	0.001	0.001
expected F from regression		0.006	0.049	0.088	0.119	0.313	0.313	0.313

Table 5. Sequential analysis from 6 May to 21 October for the F = 0.045 and M = 0.062 for the 1978 Div. 4VWX squid (*Illex illecebrosus*) fishery.

Period ending		Catch (numbers)	Numbers	F	Weight (metric tons)
May 6	(18)	80,000	1,114,720,564	0.000	100,325
May 20	(20)	728,767	1,047,629,223	0.001	76,477
June 3	(22)	646,591	983,942,256	0.001	86,587
June 17	(24)	748,889	924,163,633	0.001	83,175
July 1	(26)	2,760,000	867,879,554	0.003	86,788
July 15	(28)	4,147,826	813,029,388	0.005	112,198
July 30	(30)	71,954,422	760,131,192	0.103	111,739
Aug 12	(32)	22,537,838	644,676,244	0.037	95,412
Aug 26	(34)	19,364,921	584,070,286	0.035	111,557
Sept 9	(36)	24,593,243	530,183,848	0.049	117,701
Sept 23	(38)	36,211,765	474,468,177	0.082	104,857
Oct 7	(40)	32,616,170	410,838,100	0.085	96,547
Oct 21	(42)	15,129,500	354,519,118	0.045	88,630
Nov 4	(44)	2,495,019	330,882,151	0.010	86,360
Nov 18	(46)	4,242,279	307,119,773	0.013	83,537
Dec 2	(48)	398,587	288,377,002	0.001	81,611
Dec 16	(50)	98,976	270,228,706	0.0003	79,177
Dec 31	(52)	1,650	253,981,786	0.000006	76,956

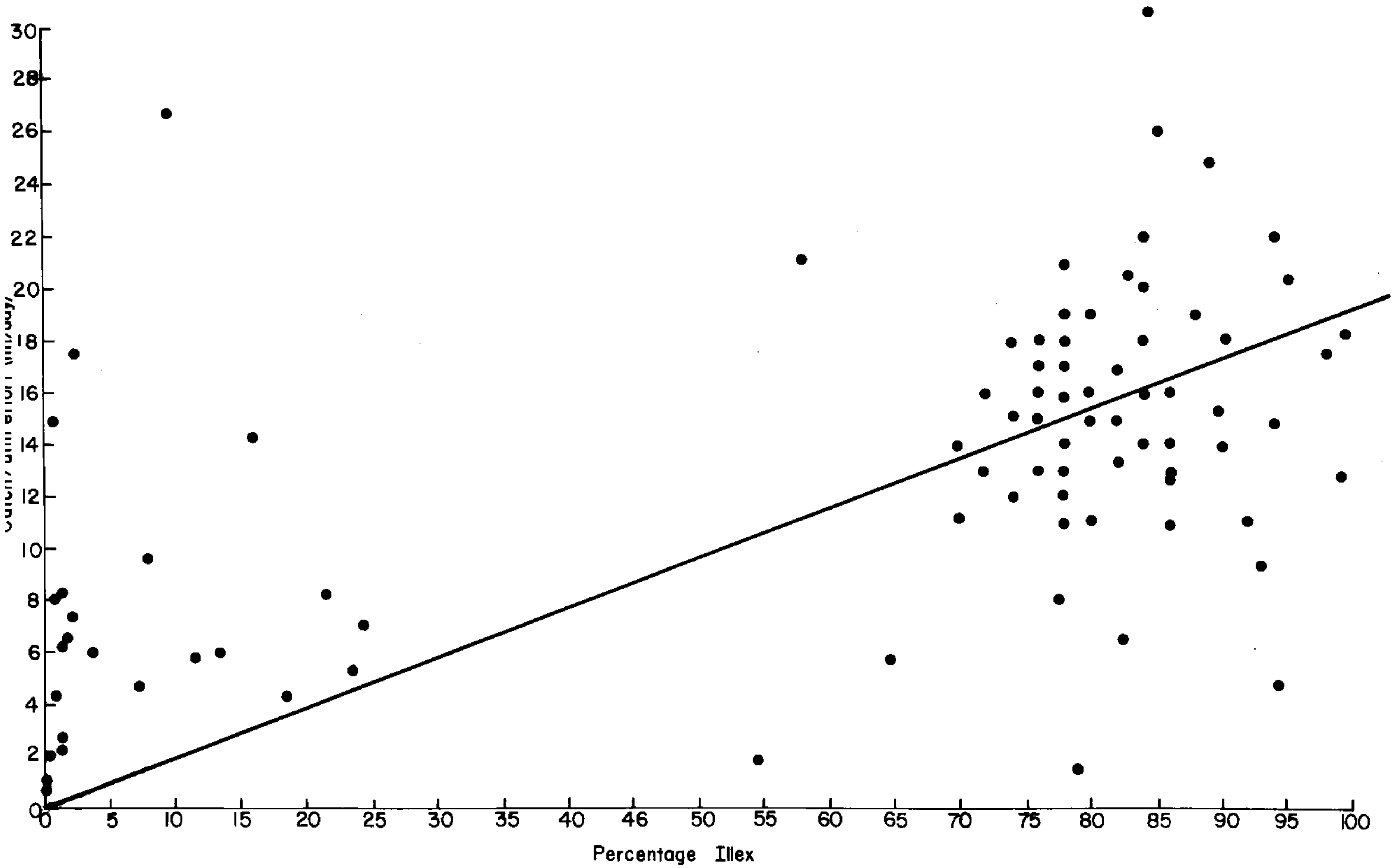

Fig. 1. Plot of c/f against % Illex in observed sets.

F 11

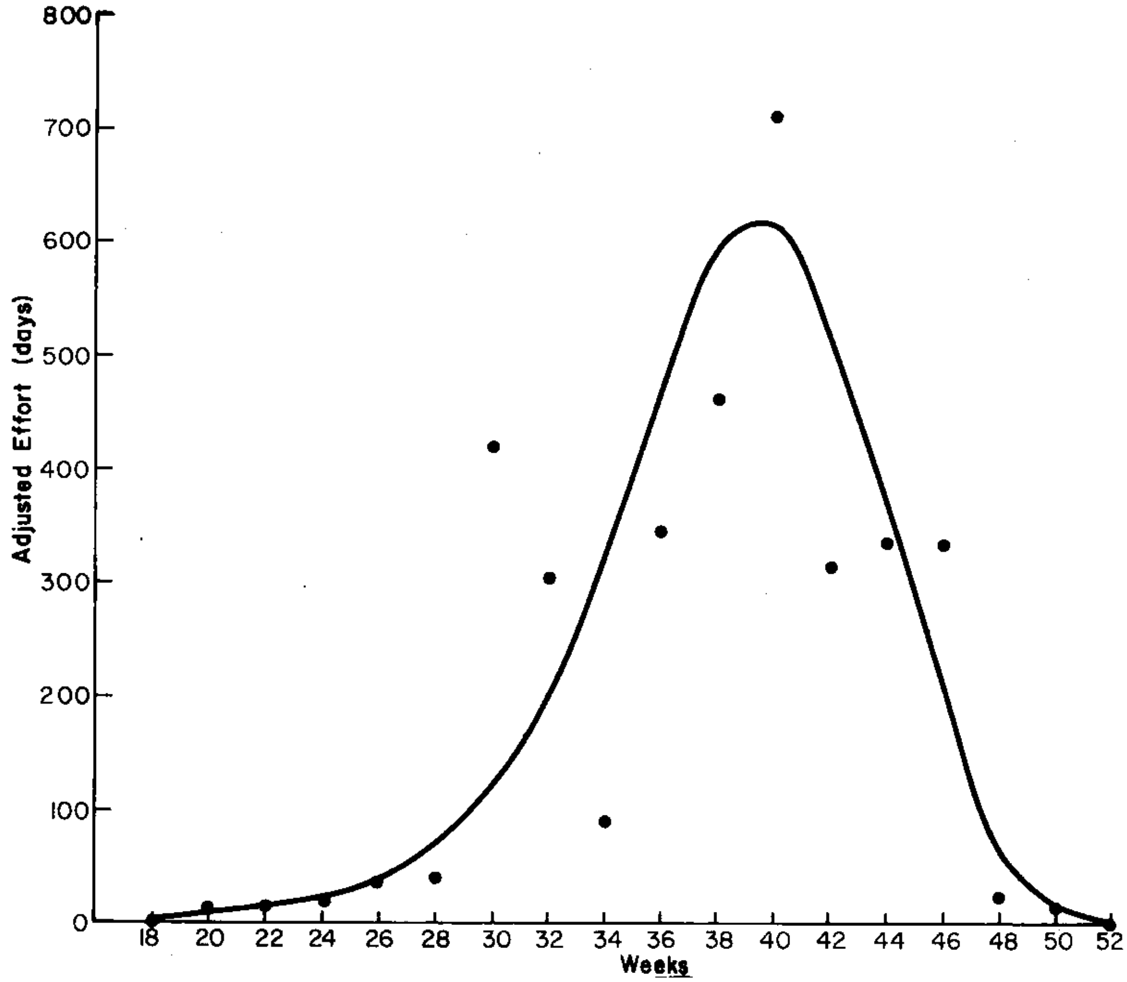

Fig. 2. Plot of adjusted effort days against weeks for the 1978 4VWX squid fishery.

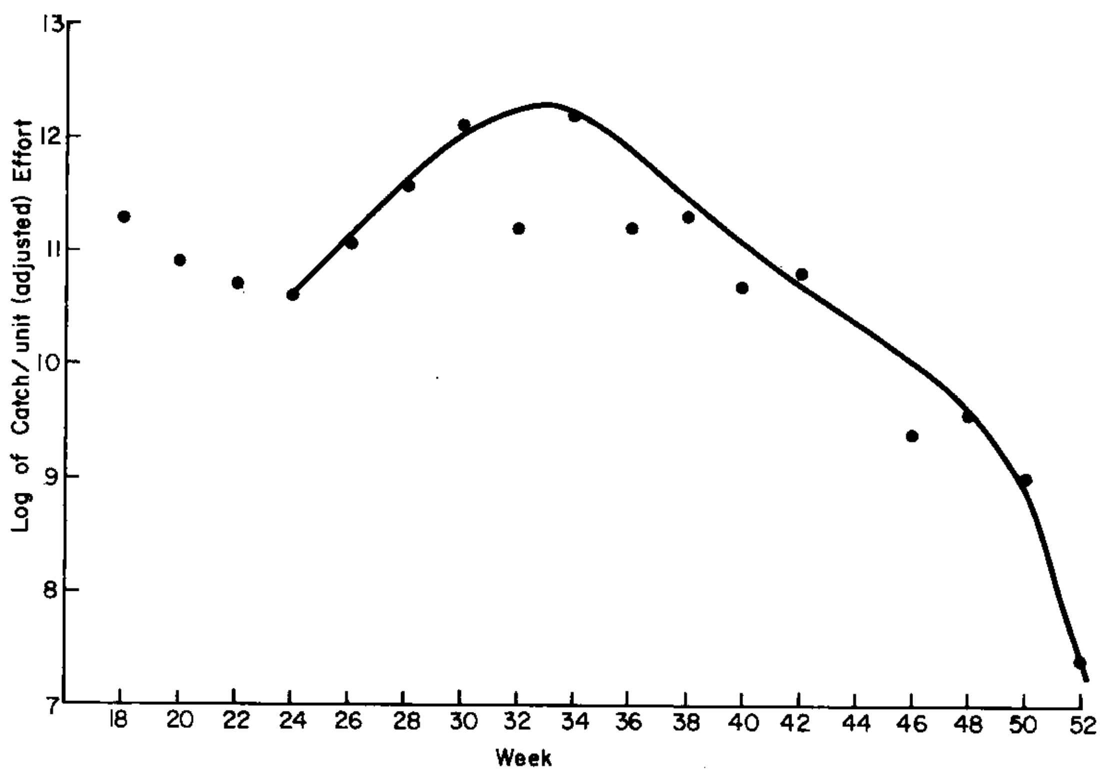

Fig. 3. Plot of ln c/f against weeks for the 1978 4VWX squid fishery.