A preliminary stock assessment for *Illex argentinus* in the Falkland Islands Protection Zone in 1985.

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Abstract

A preliminary assessment of the Illex argentinus stock fished from the Falkland Islands Protection Zone in 1985 suggests that recruitment was around 420 million individuals in February 1985; and fishing mortality varied between 0.15 and 0.3 / half month. Total fishing mortality over the whole season is estimated at 1.5/year.

a. Introduction

There is insufficient information available to make an accurate scientific estimation of the size and state of exploitation of the Illex stocks in the FIPZ. This situation is likely to continue whilst there is no generally accepted jurisdiction over the fisheries in the area.

It has however been possible to make a very approximate and unreliable assessment of the Illex stocks from certain information which has become available from various sources. This assessment has been made by relying on a series of approximations and estimations, and is consequently not fully reliable.

b. Available Information

The approach used to calculate the total catch from the FIPZ at any time has been to estimate the number of vessels fishing, to estimate the catch rate of the vessels and to multiply the two to obtain an estimate of the catching rate of the whole fleet. Different classes of fishing vessel have been considered separately.

Information on the number of vessels on the Illex fishing grounds (Fig. 1) was obtained from military surveillance of the area. British military forces monitor shipping within the FIPZ at frequent intervals using ships, helicopters and aeroplanes, recording the names and nationalities of vessels sighted. The coverage of this surveillance is not total on any particular date, so some care is needed in interpreting this information to estimate the total number of vessels present.

Information on the catch rates of jigging vessels was provided by the Kanagawa Squid Jiggers Association, who reported the daily catches of each of their vessels. These figures were taken as representative of all jigging vessels in the area.

Information on the catch rates of trawlers was made available by individual vessel masters from the Polish fishing fleet. Again, these figures were taken as representative of all trawlers in the area, after some corrections had been applied for trawlers of different tonnage classes.

Finally, some information on the catch rates of Spanish trawlers made available by ARVI (Vigo Refrigerated Trawler Owners' Association) has also been included, although this data refers to the 1984 Illex fishing season.

c. Estimates of Vessel Numbers

Ships identified by name were assigned (by reference to Lloyds' Register of Shipping) to one of five classes of fishing vessel:

i. Jigging Vessels
ii. Trawlers < 999 GRT
iii. Trawlers 1000-1999 GRT
iv. Trawlers 2000-2999 GRT
v. Trawlers >3000 GRT

The numbers of vessels of each of the first four such types estimated present on the Illex fishing ground are shown in Figs. 2-5 respectively.

These results are also given in Tables 1-4. The mean number of fishing vessels in each half-month period of the fishery is also calculated and is given in the tables. This information is summarised in Table 5, which also includes some rough estimates of the numbers of trawlers of 3000 to 3999 GRT and of more than 4000 GRT.

A simple check can be made on the accuracy of the estimation. The number of jigging vessels that fished in the South Atlantic in 1985 is known from other sources (such as Customs and Harbour records, personal communications from the fishing fleet managers). The number of vessels in each fleet was:

Japan:	23
Taiwan/Korea:	51
Poland	6
Total:	80

The peak number of jigging vessels recorded fishing in the FIPZ was 73 (on May 1st.). Considering that there will always be a proportion of jigging vessels steaming to and from harbours for transhipping catches, it seems that the correspondence is close enough to lend support to the accuracy of the estimating method. Unfortunately a similar cross-check cannot be applied in the case of the trawlers fleets.

d. Estimates of Catch Rates

As mentioned above, nightly catches of Japanese jigging vessels were made available from 12th. May until the cessation of the fishery in the FIPZ. These are given in Table 6. Regrettably such detailed information was not available prior to this date. Catch rate estimates earlier in the season were calculated from transhipment records from jigging vessels to refrigerated cargo ships in Berkeley Sound and elsewhere (Table 7.)

The catch rates of Korean, Taiwanese and Polish jigging vessels were assumed to be identical to those of the Japanese vessels. This is felt to be justified in that the vessels are of closely similar design and were operated in a similar fashion. More accurate comparisons were not possible due to language difficulties. Polish 'jigging vessels' (eg. "Jasien", "Mielno", "Wigry" etc., actually converted B20 side trawlers) are of different design and probably somewhat less efficient. However there were only 6 of these fishing in the FIPZ, so such an inaccuracy will make minimal difference to the final estimates.

Estimating catch rates of trawlers fishing for Illex in the FIPZ has proved to be much more difficult, with relatively little data being available. Some Polish trawlers of 2000-2999 GRT cooperated in declaring from their log-books their daily catches of Illex; this information is given in Table 8.

No information was available from trawlers of different nationalities fishing in the area (eg. East German, USSR), nor from trawlers of different size-classes than 2000-2999 GRT. Nevertheless estimates of the catch rates of other types of vessel were derived from the Polish data. In order to do this several assumptions were made. Together with the reliance on relatively little Polish data, this constitutes the main weakness of this analysis.

Firstly differences between vessels of different nationalities were ignored, ie. Soviet, Polish and East German vessels of similar sizes were assumed to have similar catch rates. Such vessels seem to be of a similar age, similar design and to have a similar crew size. More importantly these ships are controlled from very similar and closely-linked planning authorities who have similar needs to satisfy and similar resources at their disposal.

Secondly it was assumed that the distribution of catch rates among vessels of different sizes followed the same pattern as among Spanish fishing vessels of different sizes in 1984. This distribution was calculated from the information provided by ARVI (1985). Catch rates of trawlers of smaller size-classes was calculated as a proportion of the catch rate of the 2000-2999 GRT class:

< 999 GRT	35%
1000-1999 GRT	56%
2000-2999 GRT	100%

The Spanish fleet did not include larger vessels, but the corresponding values for such ships were assumed as:

3000-3999 GRT	140%
> 4000 GRT	180%

Errors introduced by this latter assumption are of relatively small importance because of the small number of such ships.

A summary of the estimated catch rates by different classes of ship and different half-month periods in the Illex season is given in Table 9.

e. Estimates of Total Catch.

Having estimated the number of ships fishing and the average catch rates, the total catches were estimated by multiplying the two quantities. This estimation was performed separately for each size-class of ship and for each half-month period of the fishery. The results are presented in Table 10.

The estimated total catch from the FIPZ by jigging vessels was 50 500 tonnes. This seems a reasonable figure in the light of reports from the Kanagawa Squid Jiggers Association that their total catch was ca. 27 000 tonnes; and from the agents for the

Korean and Taiwanese fleets that "Approximately 50 000 tonnes of squid of squid was caught in the South Atlantic area of which 40 000 was caught within 200 miles of the Falklands." (The FIPZ is, of course a somewhat smaller area than a 200 mile line from the coast would enclose).

This suggests that of some 77 000 tonnes of Illex caught by jiggers in the South Atlantic, ca. 50 000 or 65 % was caught within the FIPZ. This seems a reasonable estimate, and provides some support for the accuracy of the estimating method.

The total catch of Illex by all vessels and during the whole season was estimated at 103 000 tonnes.

g. DeLury Analysis

Stock analysis was carried out in two stages, following the procedure used by Ehrhardt et al. (1983). Firstly the method of DeLury (1947) as modified by Braaten (1968) was used to obtain first estimates of fishing mortality (F), recruitment (No) and catchability (q). The estimate of fishing mortality was then used to refine the estimates using a cohort analysis.

DeLury's model is based on the concept of employing the decrease in catch per unit effort and cumulative effort in order to estimate recruitment (No) and catchability coefficient.

The method depends on assuming that the fishery can be subdivided into several stages:

1. A period of recruitment to the fishery; in this case the period of recruitment seems to have been in late February.

2. A period of maximum availability to the fishery. During this period the observed decline in abundance of squid is assumed to be due exclusively to fishing, and no migration in or out of the fishery is assumed to occur. In this case such a period seems to last from early March until late May.

3. A period of emigration from the fishery, when the squid leave the fishery to breed. In the FIPZ Illex appear to leave the fishery in late May and June- there is clear evidence of a migration out towards the northwest at this time, coupled with a sharp fall in catch rates.

The analysis below rests on the assumption that these phases are discrete and show no overlap. Additional recruitment or early emigration during the period 2. above would introduce large errors.

The DeLury equation as adjusted by Braaten is:

$$\ln (Ci/fi) = \ln (q.No) - q \left(\sum_{j=1}^{j=i-1} fj + fi/2\right)$$

where:
Ci = catch in numbers in the ith time period

fi = fishing effort in the ith time period
q = catchability coefficient
No = initial population size.

Input data required for the model are estimates of the numbers of squid caught in each time period, and estimates of the fishing effort during each time period. Such data can be calculated from the somewhat limited data available.

Firstly the catch-at-time vector can be calculated by dividing the data on catch (in tonnes) by the mean weight of squid in each time period. The former data is from Table 10; the latter is calculated from data in Suzuki (1985).

Defining an indicator of fishing effort is a difficult and complex topic, but it was felt that given the early stage of studies a few simple assumptions would suffice. The indicator of effort used is the mean number of ships within the Illex fishing area, corrected for vessel size. For convenience, trawlers of 2000-2999 GRT were taken as the standard class. Trawlers of other sizes were assumed to contribute to total fishing effort in the same proportion as was assumed for their catch rates. Jigging vessels were assumed to exert a similar effort to a trawler of 2000-2999 GRT, because their mean catch rates over the whole season were closely similar, although it is hard to compare effort by vessels of such dissimilar types. These data and associated calculations for the DeLury estimation are given in Table 11.

The data was analysed using a linear regression of the equation above, such that the slope = q and intercept = ln(q.No). Data from the last time period (June 15-30) were excluded from the analysis because of Caddy's (1983) assertion that information about the fishery during the time of emigration of squid should not be included in such an analysis.

The data points and the fitted regression line are given in Figure 6. The regression shows a surprisingly good fit considering the low quality of the data, with 91% of the variability in ln(CPUE) being explained. The fitted line has slope= -3.19 x 10 ^-3 and intercept =6.916. This leads to the following estimates:

Catchability, q	3.19x10^-3
Recruitment, No	3.16x10^8 individuals
Terminal Fishing Mortality, Ft(=q.f8)	0.22
Seasonal Fishing Mortality, F (=q.Σ f)	1.6

DeLury's model does however suffer from many oversimplifications, such as the assumption that catchability remains constant; that natural mortality is small during the time periods; and that the population is closed. It is therefore useful to refine these estimates further using a cohort analysis.

h. Cohort Analysis

Cohort analysis is a standard technique (due to Pope, 1972) for analysing exploited fish populations and their state of exploitation from catch-at-age data. Given certain input parameters the fishing mortality (F) can be estimated, and from

this the severity of the impact of fishing on the fish stock can be assessed. Cohort analyses are normally carried out on yearly data. However in this case catch-at-age data from half-monthly periods was used. This was because the squid grow extremely fast compared with fish, and (in this case) all fishing takes place during a very short period of time (peak fishing from March-May).

There is barely sufficient data to warrant the application of a cohort analysis to the catch data calculated above. However it may be instructive to attempt the application of a model of this kind as long as the limitations of the data are constantly borne in mind and the results treated with due caution.

Input data required for cohort analysis are:

1. Catch-at-age data, as for the DeLury estimation.

2. Natural mortality. This was estimated by the method of Pauly (1984). He recommended the use of the predictive relationship:

$$\log M = -0.2107 - 0.0824 \log W_{oo} + 0.6757 \log K + 0.4627 \log T$$

where
M - exponential rate of natural mortality
K and Woo are the same constants as in the normal von Bertalanffy growth function
T - Mean annual water temperature in C.

Woo and K were taken from Anon. (1983) [FAO]. T was taken as 7.0 C, from data from a Japanese trawler in July and from a Spanish trawler in October.

The following values were used to estimate M separately for males and for females:

	Males	Females
Loo	268.5mm	363.0mm
L-Wt. relation	W=4.29L^3.31 x10^-6	W=5.65L^3.24 x10^-6
Woo	470g	1112g
K (/year)	2.88	1.8
Calculated M (/year)	1.864	1.2642

Mean M for both sexes: 1.564 (/year)

0.0652 (/half month)

This manner of estimating M is very approximate one. It is based on the assumption that M for this squid is likely to be similar to that for a typical fish of similar size and growth rate and living in water at a similar temperature. It is little more than a rough guess, but it provides a useful and reasonable first estimate for this parameter. For comparison, other authors have estimated M for Illex illecebrosus in the Northwest Atlantic as below:

Author	Estimate of M
Lange and Sissenwine (1983)	0.762 (Males)
"	1.12 (Females)
Au (1975)	2.13

3. Terminal fishing mortality (Ft). This parameter was taken from the DeLury estimation above, by multiplying the terminal fishing effort by the catchability coefficient. This is only an approximation of course, but fortunately cohort analysis is fairly robust to the choice of Ft.

i. Results from Cohort Analysis

Although the procedures used above are reasonably well-proven and reliable, they can only be as good as the input data will allow. In this case therefore the results produced by these models should be treated with some caution. They are only preliminary findings which it is hoped to refine considerably for the 1986 season. Nevertheless some conclusions may be drawn, if somewhat tentatively, from the analysis in Table 12.

1. Recruitment is estimated at about 420 million squid in late February.

2. Fishing mortality was highest in the period 16 March to 15 April, at about 0.3/ half month.

3. Fishing mortality was somewhat lower later in the season, at about 0.15 to 0.2/ half month.

4. Total fishing mortality over the whole season is estimated at 1.5/ year.

There is good agreement between the results of the two analyses on total fishing mortality, at 1.6 and 1.5 from the DeLury and the cohort analyses. However the estimate of recruitment by the DeLury method at 319 million squid was somewhat lower than the estimate from the cohort analysis, which was 420 million squid; this is not unexpected as the DeLury method ignores natural mortality.

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Table 1. Estimates of numbers of jigging vessels within the *Illex* fishing area at different dates in 1985.

	February		March		April		May		June	
DATE	Number	Mean	Number	Mean	Number	Mean	Number	Mean	Number	Mean
1			4		62		71		47	
2			4		60		68		51	
3			4		57		55		55	
4			4		55		54		58	
5			5		52		52		60	
6			7		49		50		63	
7			7		46		48		65	
8			7	5.9	44	44.9	46	43.6	67	63.3
9			7		41		44		70	
10			7		40		37		71	
11			7		37		33		70	
12			7		35		28		69	
13			7		33		26		68	
14	0		8		32		22		68	
15	0		8		31		21		67	
16	0		8		31		20		66	
17	0		9		31		18		65	
18	1		10		32		17		60	
19	2		12		32		19		49	
20	3		13		32		21		40	
21	4		16		33		23		32	
22	3		23		33		26		24	
23	3	2.1	27	33.2	33	37.5	28	27.3	16	24.1
24	3		33		34		30		8	
25	3		39		35		30		1	
26	3		43		36		30		0	
27	3		50		38		30		0	
28	3		55		41		30		0	
29			62		48		33		0	
30			67		73		39		0	
31			64				43		0	

Table 2. Estimates of numbers of trawlers <999 GRT within the *Illex* fishing area at different dates in 1985.

	February		March		April		May		June	
DATE	Number	Mean	Number	Mean	Number	Mean	Number	Mean	Number	Mean
1			0		15		1		1	
2			0		13		1		1	
3			0		13		1		1	
4			0		12		1		2	
5			0		12		1		2	
6			5		12		1		2	
7			11		11		1		2	
8			10	5.2	11	10.7	1	1	3	2.3
9			9		11		1		3	
10			8		11		1		3	
11			7		10		1		3	
12			7		9		1		3	
13			7		7		1		3	
14	0		7		7		1		3	
15	0		7		7		1		3	
16	0		8		4		1		5	
17	0		8		1		1		7	
18	0		8		1		0		8	
19	0		8		1		0		11	
20	0		7		1		0		10	
21	0		7		1		0		8	
22	0		7		1		0		6	
23	0	0	7	10.4	2	1.5	0	.2	0	3.7
24	0		8		2		0		6	
25	0		10		2		0		0	
26	0		11		2		0		0	
27	0		13		1		0		0	
28	0		16		1		0		0	
29			17		1		0		0	
30			17		1		0		0	
31			15				1			

Table 3. Estimates of numbers of trawlers 1000-1999 GRT within the *Illex* fishing area at different dates in 1985.

	February		March		April		May		June	
DATE	Number	Mean	Number	Mean	Number	Mean	Number	Mean	Number	Mean
1			0		17		2		0	
2			0		13		2		0	
3			4		13		2		0	
4			5		12		2		0	
5			5		12		2		0	
6			5		11		2		0	
7			6		11		2		0	
8			5	4.4	10	10.4	2	2.2	0	0
9			5		10		2		0	
10			5		9		1		0	
11			4		8		1		0	
12			4		8		1		0	
13			5		7		1		0	
14	0		6		7		4		0	
15	0		7		8		7		0	
16	0		8		9		11		0	
17	0		9		10		10		2	
18	1		10		10		10		3	
19	2		12		10		9		3	
20	0		12		10		10		3	
21	0		11		10		11		3	
22	0		11		10		12		2	
23	0	.2	11	16.9	10	9.3	13	10.3	0	1.5
24	0		15		10		14		6	
25	0		18		10		13		0	
26	0		22		10		13		0	
27	0		25		10		13		0	
28	0		27		8		12		0	
29			30		7		8		0	
30			27		5		4		0	
31			22				1			

Table 4. Estimates of numbers of trawlers 2000-2999 GRT within the Illex fishing area at different dates in 1985.

	February		March		April		May		June	
DATE	Number	Mean	Number	Mean	Number	Mean	Number	Mean	Number	Mean
1			0		69		37		5	
2			0		67		36		5	
3			0		62		33		4	
4			5		56		29		4	
5			9		54		27		4	
6			13		53		26		4	
7			17		50		25		4	
8			17	12.5	48	49.1	24	23.1	5	4.9
9			17		47		22		9	
10			17		47		20		7	
11			18		44		18		6	
12			18		41		16		4	
13			19		36		14		4	
14	0		19		33		11		4	
15	0		19		29		8		3	
16	0		20		25		5		3	
17	1		21		20		5		3	
18	0		23		20		4		2	
19	0		26		20		4		2	
20	0		28		21		5		3	
21	0		31		21		6		3	
22	0		34		21		7		3	
23	0	.07	37	43.1	21	22.7	7	6.2	2	1.6
24	0		40		22		8		2	
25	0		44		22		8		1	
26	0		49		23		8		0	
27	0		56		24		7		0	
28	0		64		25		7		0	
29			70		25		6		0	
30			75		31		6		0	
31			72				6		0	

Table 5. Summary of estimated mean numbers of fishing vessels within the Illex fishing area in half-month periods in 1985.

	Jiggers	Trawlers (GRT)				
		<999	1000-1999	2000-2999	3000-4000	>4000
Feb. 14-28	2.1	0	0.20	0.07	0	0
Mar. 1-15	5.9	5.2	4.4	12.5	0	0
Mar. 16-30	33.2	10.4	16.9	43.1	4	6
Apr. 1-15	44.9	10.7	10.4	49.1	4	5
Apr. 16-30	37.5	1.5	9.3	22.7	2	0
May 1-15	43.6	1	2.2	23.1	1	0
May 16-31	27.3	0.2	10.3	6.2	3	0
June 1-15	63.3	2.3	0	4.9	0	0
June 16-30	24.1	3.7	1.5	1.6	0	0

Table 8. Reports of daily catch rates by Polish trawlers of 2000-2999 GRT fishing in the *Illex* fishing area to the North of the Falkland (Tonnes of whole *Illex* caught per days' fishing)

March 1-15	March 16-31	April 1-15	April 16-30	May 1-15	May 16-31
21.8	8	13.3	5	5.2	.9
5.2	0	23.3	5	15	.9
37.5	9	13.3		3	20
51.9	14.5	16.7		1.5	.9
40.7	12	10		1.5	0
14.8	9.2	8.8		2.4	20
16.4	23	4.7		1.5	26
25.5	14	4.5		1.5	.9
11.9	13.8	12.2		.93	20
39	12.5	16.3		1.35	12.8
30	23	13.9		.3	0
19.5	39	0		.9	0
9.3	6	10.8		1.5	
7.92	27	5.5		11.5	
	28	32.3		2.7	
	64	27.96		4.6	
	13.4	0		1.6	
	10	2.88		1.7	
	10	2.7		10.2	
	16.8	19.02		21.2	
	10	10.62		20.1	
	30	29		20.9	
	43.4	13		0	
	0	9		12.78	
	20			6.06	
	20			.6	
	46.4			3.6	
	41.6				
	21				
	0				
	23.76				
	24				
	11.1				
	14.1				
	24.24				
	26.88				
	30.9				
	20.82				
	37.62				
	6.54				
	10.86				
	26.7				
MEAN: 23.67	20.07	12.49	5	5.71	8.53

Table 9. Summary of catch rate estimates (Tonnes of whole squid per ship and per day).

	Trawler size classes (GRT)					Jigging Vessels
	<999	1000-1999	2000-2999	3000-3999	>4000	
Feb. 16-28	8.3	15.2	23.7 *	33.2	42.7	14.9
Mar. 1-15	8.3	15.2	23.7	33.2	42.7	14.9
Mar. 16-31	7.0	12.9	20.1	28.1	36.2	15.0
Apr. 1-15	4.4	8.0	12.5	17.5	31.5	16.6
Apr. 16-30	1.8	3.2	5.0	7.0	12.6	13.7
May 1-15	2.0	3.6	5.7	8.0	14.4	11.3
May 16-31	3.0	5.4	8.5	11.9	21.4	16.9
June 1-15	2.1	3.8	6.0 *	8.4	15.1	9.0
June 16-30	2.1	3.8	6.0 *	8.4	15.1	2.8
Relative rate:	35%	64%	100 %	140 % *	180 % *	

* denotes assumed rates

Table 11. Data for DeLury Analyses.

Time Period	Catch (x10^3)	Effort (vessels)	CPUE	ln(CPUE)	Cumulative effort *
Feb. 14-28	2115	2.3	920	6.824	1.15
Mar. 1-15	24707	23	1074	6.979	13.8
Mar. 16-31	90433	107.1	844	6.738	78.9
Apr. 1-15	66374	119	558	6.324	191.8
Apr. 16-30	22048	69.5	317	5.759	286.1
May 1-15	19581	69.92	280	5.635	355.8
May 16-31	16762	44.4	377	5.932	412.9
June 1-15	14656	69	212	5.357	469.6
June 16-30 +	1811	28	65	4.17	518.1

* Calculated as: $\sum_{j=1}^{j=i-1} fj + fi/2$

\+ Plotted in Figure 6 but not included in regression.

Table 12. Cohort analysis using calculated catch data for FIPZ *Illex* in 1985. Natural mortality is taken as 0.065/ half month, and terminal fishing mortality is taken = 0.22. (F= fishing mortality, C= Catch, N= number in sea)

Time Period i	Catch (Tonnes)	Mean Wt (grammes)	Catch Ci (x10^3)	Ciexp M/2	Ni (x10^3)	Ni exp M	Fi
June 1-15	9058	618	14656	15140.14	76561.59	81703.39	.22
May 16-31	9235	552	16762	17315.71	99019.10	105669.1	.1922173
May 1-15	9634	492	19581	20227.84	125897.0	134352.1	.1751511
Apr. 16-30	9591	435	22048	22776.33	157128.4	167681.0	.1565996
Apr. 1-15	25753	388	66374	68566.59	236247.6	252113.8	.3428170
Mar. 16-31	30928	342	90433	93420.35	345534.1	368739.8	.3152110
Mar. 1-15	7412	300	24707	25523.17	394263.0	420741.3	.0669269
Feb. 14-28	552	261	2115	2184.867	422926.2	451329.5	.0051795

Total fishing mortality: 1.474102

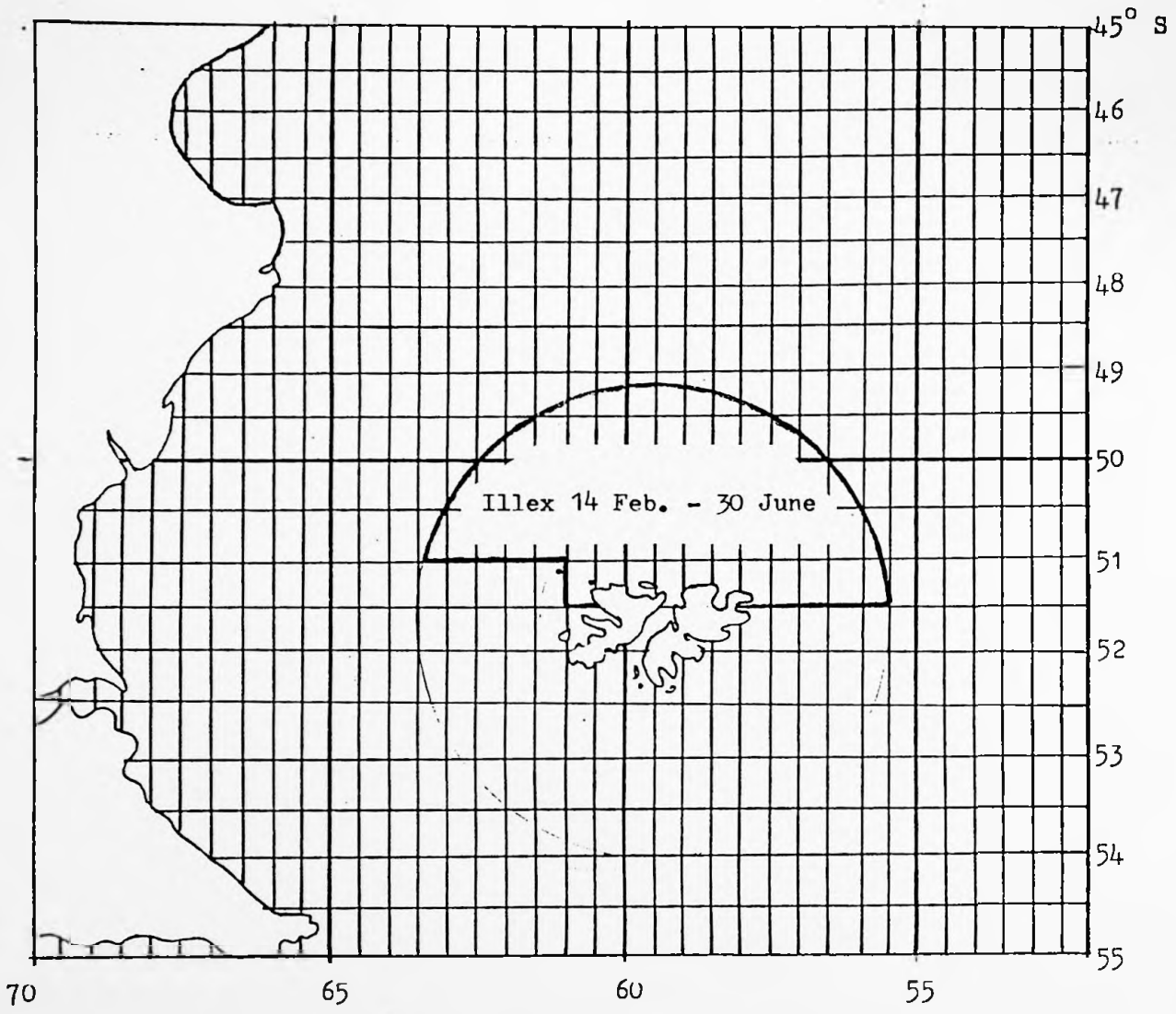
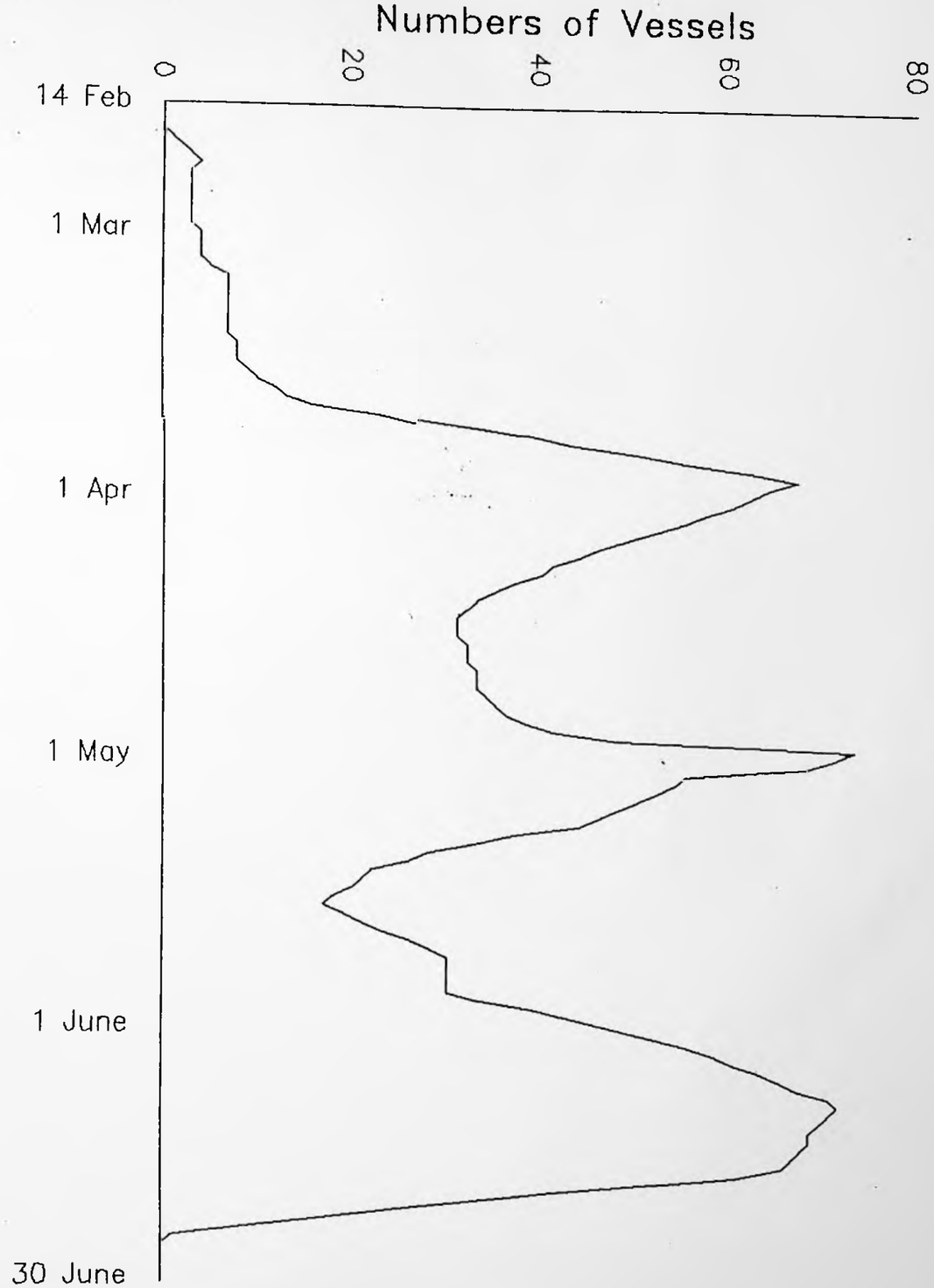


Fig. 1. The fishing area and time period considered in this analysis.

Figure 2. Estimates of numbers of jigging vessels within the Illex fishing area.



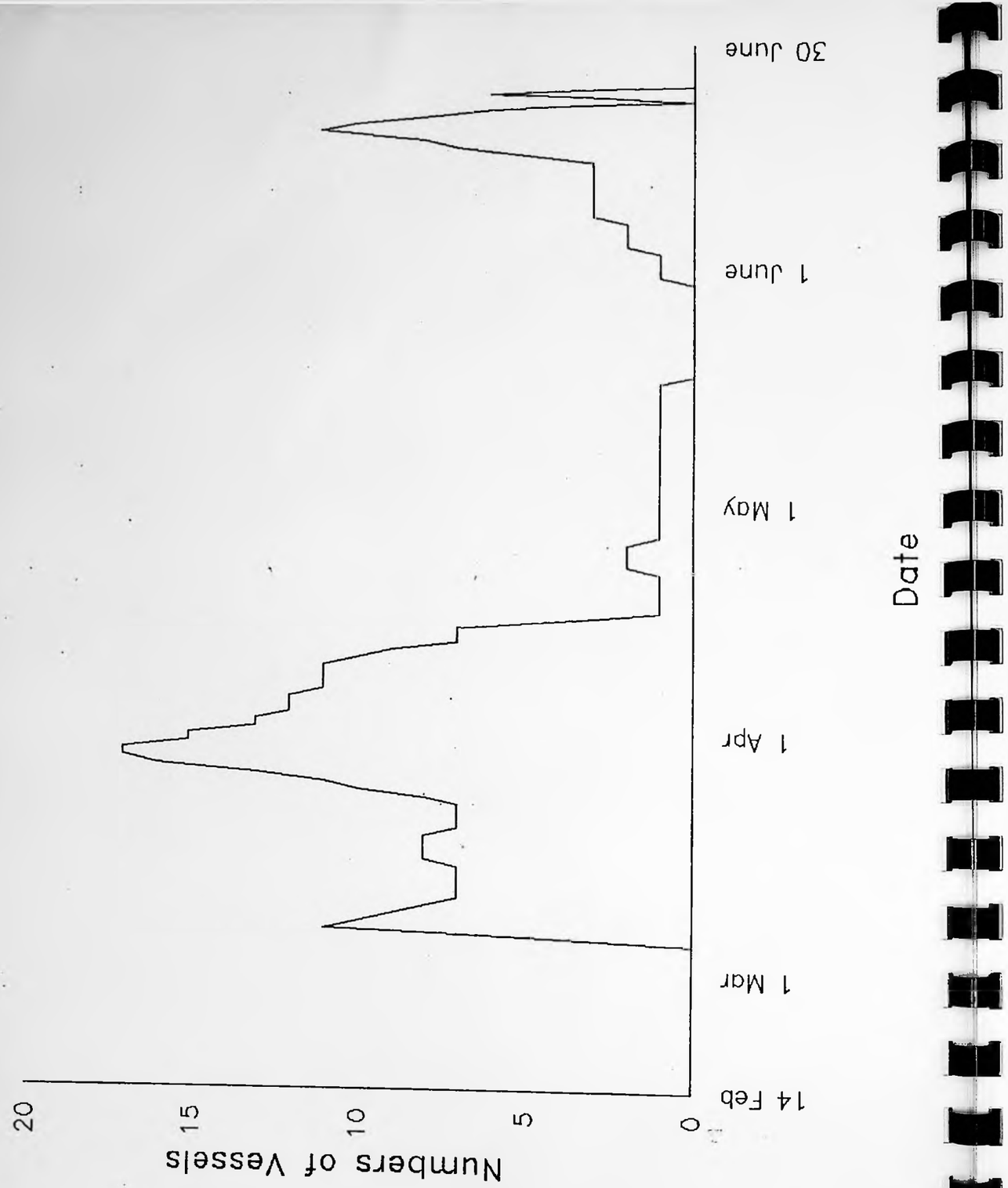


Figure 3. Estimates of numbers of trawlers smaller than 999 GRT within the Illex fishing area.

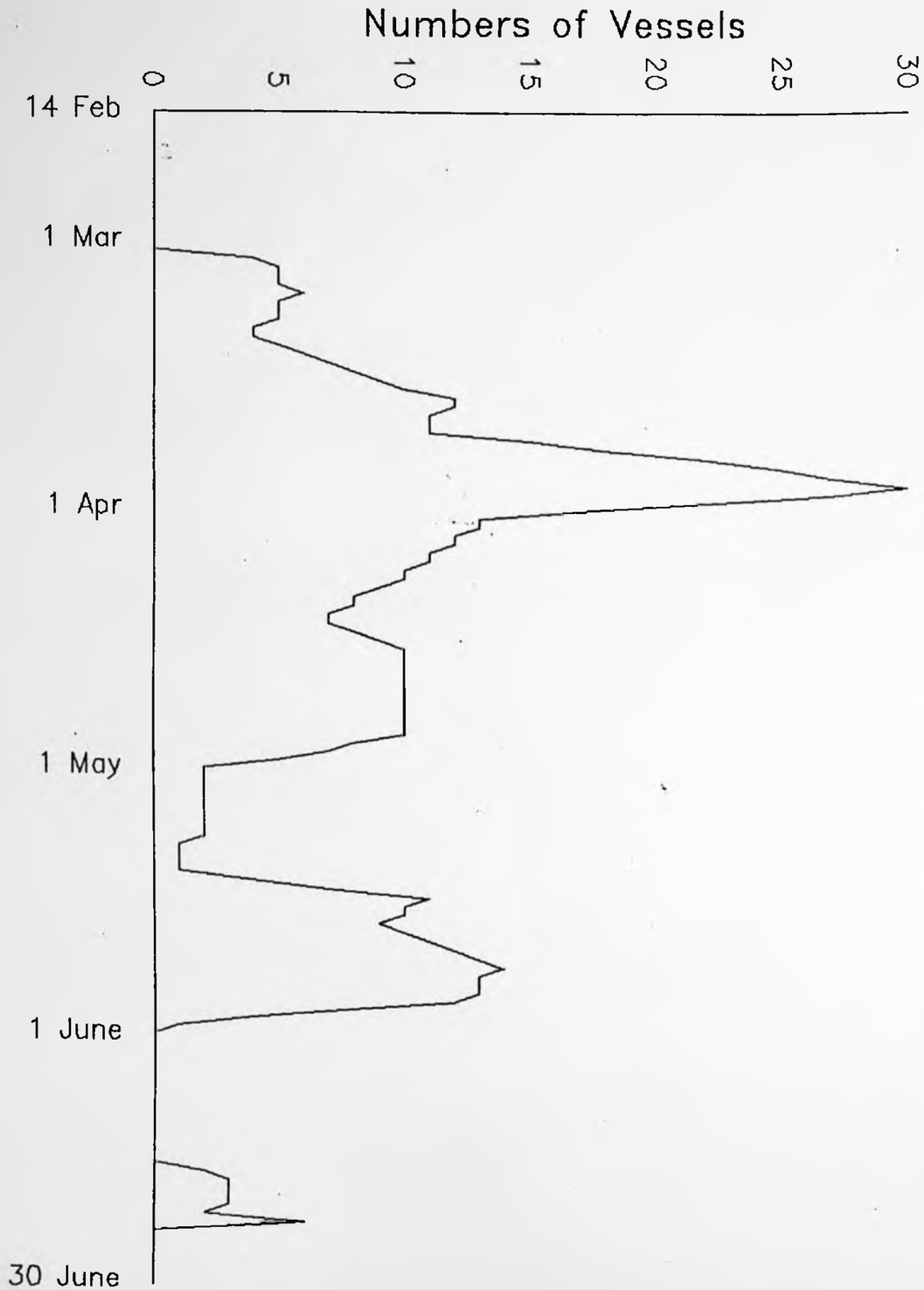


Figure 4. Estimates of number of trawlers of between 1000 and 1999 GRT within the Illex fishing area.

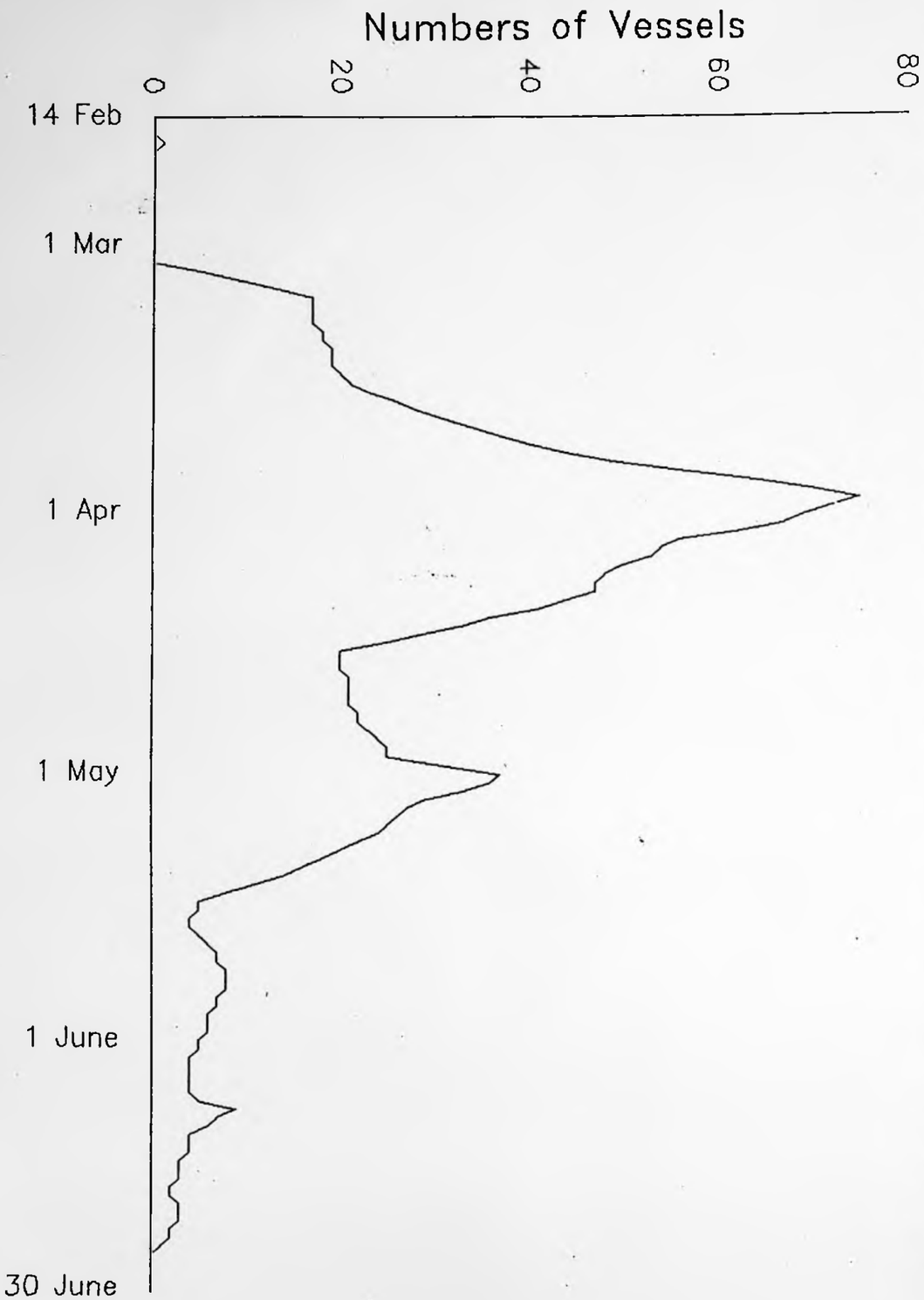


Figure 5. Estimates of the number of trawlers of between 2000 and 2999 GRT within the Illex fishing area.

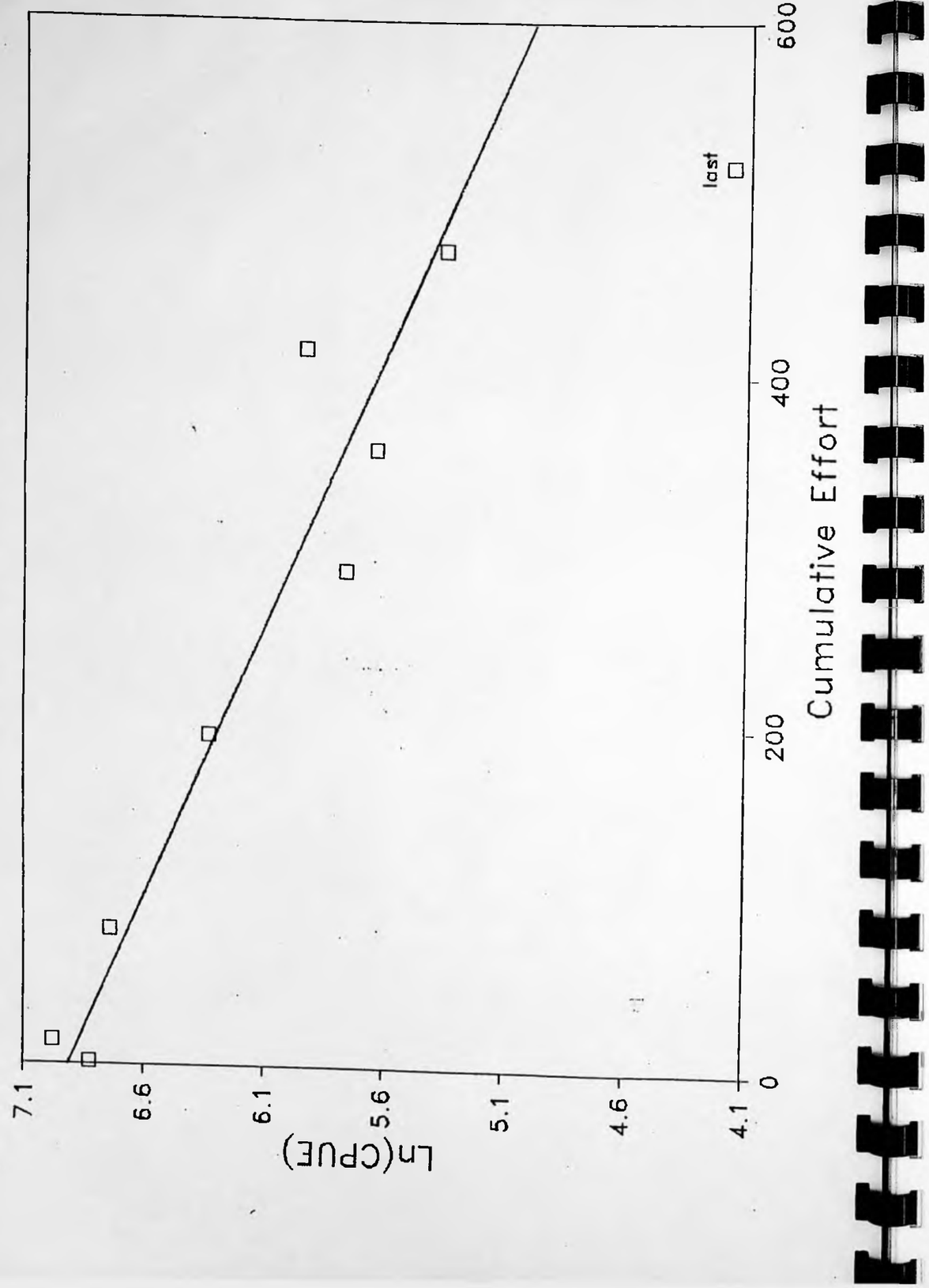


Figure 6. Data points and fitted regression line for the DeLury analysis. Data from Table 11 are plotted, and the regression line fitted to all data points except for that for the last half month of the fishing season. The fitted line has slope = -3.19x10^3 and intercept = 6.916.