The Fishery for *Illex argentinus* in the Falkland Islands Protection Zone.

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CONTENTS

1. Abstract

The market, fishery and prospects for the exploited population of Illex argentinus in the Falkland Islands protection zone are briefly discussed. The main market is in Japan, where the price is around US $ 1.0/Kg. Additional markets exist in Spain, Korea, and Taiwan. The total value of the catch is estimated at US $ 70 million. Recruitment to the FIPZ fishery was estimated at 420 million in 1985, and total fishing mortality at 1.6 /year. Fishing in 1985 was too heavy for the stock to be self-sustaining, and recruitment in future years will depend on mixing from other stocks on the Patagonian shelf. A provisional limit on catches of 60 000 tonnes is suggested.

2. Introduction

There are three important directed fisheries around the Falkland Islands. These are for the southern blue whiting *Micromesistius australis*, for the common or inshore squid *Loligo gahi*, and for the Argentine short-finned squid *Illex argentinus*. Although other species may at times make up a valuable by-catch (for example hake, *Merluccius* spp.; kingklip, *Genypterus blacodes*; whiptail hake, *Macruronus magellanicus*; southern cod, *Salilota australis*) they are of comparatively small commercial value.

Of the major fisheries it is that for *Illex* that is the most valuable, is expanding most quickly and seems at greatest risk from overfishing. This report presents some preliminary results of studies on *Illex* in the Falkland Islands Protection Zone. These results are very limited, yet they seem to indicate that the FIPZ *Illex* fishery is being exploited at a level which is not sustainable without recruitment from other stocks.

Given such indications it seems appropriate to suggest what measures might be taken to protect the fishery from exhaustion. Although the scientific evidence is admittedly poor it seems preferable to first protect the stock and later to refine management procedures to optimise yields.

3. The Market for *Illex argentinus*

a. Introduction

By far the major market for *Illex* is in Japan, although small quantities are sold also in Spain, Taiwan and Korea. Japanese people traditionally eat a lot of seafood because of the large population of the country and scarcity of good farmland. There has been a long history of squid fishing in Japanese waters from small boats using hand-lines, but from the 1950s onwards there was a progressive increase in the squid fishery due to postwar recovery and investment. In the 1960s new methods were developed for processing squid that enabled it to be sold in the Japanese market in large quantities.

Fresh squid is an expensive luxury in Japan. Japanese people are very demanding of freshness and quality, and in addition prefer the taste of locally-caught species. New and strange species of squid can best be sold in a highly-processed form that disguises the strange taste and the fact that the squid has been frozen. The form that has found a ready acceptance in the Japanese markets is as processed squid in small ready-to-eat portions in plastic bags containing 50-100g. Typical products are ika-moromi (squid in miso), ika-mirin (in red pepper and soy sauce), yaki-ika (roasted squid in strips), ni-ika (boiled), koji-ika (fermented), shiokara (salted, fermented and with chilli), and many other preparations.

b. Historical Data

Because of the growing acceptance of such products, Japanese consumption of squid has been increasing:

1980	81	82	83	
455	489	559	587	000 tonnes squid consumption in Japan (FAO)

However local catches of similar squid to Illex in the China Sea have been variable but in recent years declining:

1978	79	80	81	82	83	
234	234	379	260	248	227	000 tonnes Todarodes pacificus catch in Japanese waters (FAO).

Peak catches were acheived in 1968 at 774 000 tonnes, so there has been a considerable decline in catches which can be attributed to poor fishery management. This is largely because these squid stocks are shared between South Korean, North Korean, Japanese and USSR waters and there is no overall management strategy. Additionally fishery management within Japan is the responsibility of local "Sea Area Fisheries Adjustment Committees", whose main aim is to keep employment (and therefore fishing effort) high. As there is no unified stock management policy the stock is overfished and catch rates are declining. However squid stocks can be very variable from year to year and catches could still increase for a short time (nb. good year in 1980).

The shortfall between the high and increasing domestic consumption and the declining domestic catch is made good by importing squid from foreign fishing nations and by Japanese vessels fishing in foreign waters. There are three main squid fishing areas outside Japan: There is a fishery in New Zealand waters for Nototodarus gouldi, off Newfoundland for Illex illecebrosus, and also the Patagonian shelf fisheries for Illex argentinus. There is also a stock of Illex illecebrosus in the waters of the USA, but this is not very accessible at the moment to Japanese fishermen due to the very strict fishery licensing regulations. The total catches in recent years from these areas were:

	1978	79	80	81	82	83
Japan	549	600	757	564	608	604
New Zealand	36	42	79	62	70	75
Newfoundland	96	196	111	69	49	38
Patagonia	73	122	30	53	207	202
Total	754	960	977	748	934	919

000 tonnes total squid catches in FAO areas 61, 81, 21 and 41 (FAO).

Imports of squid to Japan from non-Japanese fishermen are restricted by a quota system and by strict demands for quality.

c. The Japanese Squid Import Quota System

Import quotas are designed mostly to maintain a high market value for squid in Japan and to maintain employment in the Japanese fishing industry. The quotas are set twice yearly, and although there is no published procedure for estimating the quota it can in practice be assumed to be calculated as below:

1. Estimate the likely catch of squid from Japanese vessels.
2. Estimate the total capacity of the market to absorb squid.
3. Set import quota to about 60% of the shortfall to maintain prices.
4. When allocating import licences, give preference to companies that have Japanese involvement (This has led to the formation of joint venture companies to fish for squid).

Japanese-owned vessels operating overseas need no import licence to land their catch.

d. Future Prospects for the Illex market

Squid fisheries can fluctuate widely from year to year, and this is reflected in a very unstable price for squid in Japan. It is therefore scarcely possible to predict with any accuracy what will happen in any given fishery and in any given year. However certain long-term trends can be noted. Firstly it seems as if there is an underlying increase in the Japanese demand for consumption of squid (including Illex). However the domestic squid catch is declining and therefore an increasing proportion of the squid will come from far-seas fisheries.

These fisheries are however becoming progressively more restricted. Almost all coastal states with significant fisheries have a 200 mile Exclusive Economic Zone, and manage the fisheries according to their domestic priorities, typically generating revenue from vessel licences and maximising employment.

The situation where a coastal state will grant licenses in preference to domestic fishermen, together with the quota system described above for Japanese imports, often leads to the formation of cooperative and joint venture agreements of a variety of kinds. This trend seems likely to continue.

The Newfoundland and New Zealand stocks of squid are strictly protected and the fisheries for these squid are licensed and restricted. This increases the attractiveness of the unlicensed Patagonian fisheries, so it seems likely that pressure on this stock will increase.

However there are logistic and political difficulties for Japanese fishermen in exploiting this stock, which has meant that in the past non-Japanese distant-water trawlers have mostly been responsible for catching the squid and exporting it to Japan. Recently Japanese fishermen have nevertheless been able to exploit the stock themselves, and it seems very likely that they will continue in this and displace the non-Japanese trawlers from exploiting this fishery by virtue of the import quota system (and technical factors).

In conclusion the likely long-term prospects for the Patagonian stocks of <u>Illex</u> is for an increase in the fishing effort and an increase in the proportion of Japanese fishing vessels.

4. The biology of <u>Illex argentinus</u>: a summary.

<u>Illex argentinus</u> is an annual species. All the adults die after spawning in August and all of the next years' stock are hatched at about the same time. After hatching the young squid are carried in water currents and later migrate over very long distances - some hundreds of miles - during which they feed and grow very quickly. The main foods of <u>Illex</u> are krill and amphipod crustaceans.

When they have grown nearly to full maturity the squid will return to their spawning grounds, lay their eggs and die. The whole cycle takes one year to complete.

The evidence so far available suggests that there is a spawning ground in deep water over 200 miles east of Mar del Plata. There may be other spawning grounds but their location is unknown.

<u>Illex</u> are to be found over nearly the whole Patagonian shelf at different times of the year. It is not known whether they constitute one large stock or several independent stocks. Other taxonomically similar squid have been found to have separate substocks associated with different ocean currents, but with a high degree of mixing between the substocks. Studies of migration are very difficult on squid because they have a high mortality after tagging.

This type of life cycle makes fishery management and prediction very difficult as conventional methods are not applicable. The size of the spawning stock will have an influence on the number of squid available to the next years' fishery, but other factors such as climatic changes, fluctuations in ocean currents and availability of food also have a very strong influence.

Beddington (1985) quoting Caddy (1981) suggested maintaining a breeding reserve of about 40% of the unexploited stock size to ensure a sufficient stock to maintain recruitment in subsequent years. This seems an eminently sensible management objective.

5. The South Atlantic fisheries for *Illex*

a. Introduction

As noted above, the *Illex* stocks are distributed right across the Patagonian shelf, and much of the stocks lie in waters claimed by Argentina. Greatest fishing intensity takes place just outside the limit of Argentine jurisdiction, which can be subdivided for convenience into an area more than 200 miles from the Argentine coast (and so not claimed by Argentina) and the area from which Argentine military vessels are excluded by British military activities (The Falkland Islands Protection Zone, a circle of 150 n.m. radius centred on position 51°40' S 59°30' W).

In addition to the Argentine domestic fisheries, there are three separate fishing areas available to distant-water fishermen for *Illex*. These are considered in turn below.

The first is a deep-water ground at 42°S 58 W, where small *Illex* can be caught in January. These squid are of about 19cm mantle length, and have poor commercial value. They may be sold for food or for bait for the tuna fisheries. Between February and May little is caught on this ground, but in June large quantities of much larger *Illex*, of about 30cm mantle length are caught: this is the most productive grounds for the large trawlers. However jigging vessels cannot exploit this ground because at some 600m depth their fishing method is ineffective. The pattern of the fishery on this ground suggests that it is close to a deep-water spawning ground, young squid being caught as they leave the deep water for the rich feeding grounds of the continental shelf, and mature squid being caught on their way to spawn.

Another fishing area lies at 46°S and 60-61° W. This is an area where the continental shelf extends beyond the Argentine 200 mile limit. The *Illex* fishery at this area starts somewhat later than that at 42°S, perhaps in February, and continues until early July.

The *Illex* fishery to the North of the Falklands and within the FIPZ starts in early March, and continues until late June, when the squid appear to migrate to the north-west and into Argentine jurisdiction. Female *Illex* grow from ca. 23-36 cm mantle length during this period.

This somewhat complex pattern might suggest that the Patagonian shelf *Illex* is all one stock, spawning east of the fishing ground at 42°S, recruiting to the whole shelf area to feed, and returning to the same spawning ground to spawn. However there is not sufficient evidence about this topic to make any firm conclusions.

b. Trawling fleet

Trawling vessels have been fishing in this area for the longest time and are responsible, for the bulk of the catches. The fleet consists mostly of large stern trawlers of approx. 2500 GRT, with some smaller trawlers and a few larger ones. The trawlers started the 1985 season working the Illex grounds at 42° S, then later fished to the North of the Falklands. They were however displaced from here by the Japanese, Korean and Taiwanese jigging vessels. These fish by drifting slowly in a large group spread over a wide area. A large freezer-trawler cannot fish in the same area partly because of risk of collision but also because the jiggers attract the squid upwards in the water column and around their own vessels. Most of the trawlers are registered in Poland, USSR, Spain, East Germany or Korea.

After mid-April most trawlers either fished for the small squid Loligo gahi to the south of the Falklands, or returned to the northern Illex fishing grounds.

c. Jigging Vessels.

These are much smaller vessels of some 300 to 500 GRT and have a quite different fishing method, which depends on the attraction of squid by light. These boats have rows of powerful lights suspended above the deck, as much as 150KW. They fish at night, the boat held steady in the water with a sea anchor, and squid are attracted from over a wide area by the lights. The squid gather in a shoal below the boat and are caught from there. Rows of automatic machines on either side of the boat repeatedly drop and retreive weighted lines with sets of plastic lures bearing hooks. The line is wound in over an elliptical drum so that the lures move jerkily up through the water. Squid which have been attracted by the lights attack the lures and are impaled on the hooks. The hooks are barbless, so when the lures are wound inboard and turned upside down the squid fall off. An arrangement of chutes and watercourses leads the squid to the processing deck where they are packed neatly and frozen in blocks.

The jigging vessels make shorter trips than the trawlers and are less self-reliant than the trawlers. Their fish holds contain on average some 300 tonnes of squid, so they can only make short trips.

6. A Stock Assessment for Illex argentinus in the FIPZ.

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. Nevertheless in the subsequent analysis such assumptions are pointed out where they are made, and the consequences of error are explored as far as possible. Finally stock size estimations from different methods have been made to allow cross-checking of results.

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

As mentioned above, the coverage of the military surveillance of the FIPZ is more complete on some days than others, which generates problems in interpreting the reports of shipping sighted. Additional problems occur because ship names are not always clearly visible, or in some cases insufficient time is available for the identification of individual ships, and the number of radar contacts only is recorded. Such problems are at their worst during the Illex season because of the large number of ships in the area, and the difficulty of identifying oriental jigging vessels, which do not have very clearly-marked names.

The problem of incomplete coverage has been countered by only using for the purpose of estimating vessel numbers data from those days when the surveillance of the Illex fishing area was complete or very nearly so, and by linear interpolation between such dates.

The secondary problem of unidentified ship sightings was countered by assuming that such unidentified ships had the same distribution of type and size as did all ships identified within the same half-month period.

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 Berkely 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.

f. The Value of the Total Catch

The price of Illex is hard to assess as it can vary greatly according to where it is being sold, how good the quality is, and who is selling it (because of the quota systems). Some prices in different markets are discussed below. In each case it is the price which the vessel operator receives which is being considered.

The Illex price in Spain is fairly stable at US $ 2.1/Kg (150 ptas.) for gutted squid (termed 'tubes'), equivalent to about US $ 1.0/Kg of whole squid. The price in Japan was similar but fell dramatically in the course of the 1985 Illex season, from US $ 1.4 to 0.4/Kg for whole squid. Taiwanese owners sold squid from Montevideo for US $ 0.68 to 0.73/Kg; and from Berkeley Sound (Falkland Islands) for US $ 0.5/Kg for market destinations other than Taiwan.

It is therefore difficult to estimate an overall average price for Illex without a better knowledge of the market. Depending on the assumed value of the squid, the value of the total catch might lie between US $ 124 million (for a price of US $ 1.2/Kg) and US $ 41 million (for a price of US $ 0.4/Kg). If Japanese-caught Illex is valued at US $ 1.0 /Kg and other catches valued at US $ 0.65 /Kg, this leads to an estimated value for the FIPZ Illex catch of some US $ 70 million, or approx. £ 50 million.

f. Possible License Revenue to the Falkland Islands

It does not seem likely that the Illex stocks will be able to support the 1985 level of fishing effort for many years (see below). However it is perhaps useful to consider what the revenue to the Falklands Islands Government would have been had the fishery been licensed in 1985. Only gross return is calculated here- the cost of enforcing policing is not considered.

Licensing schemes often aim to levy a fee of some 5 to 10% of the value of the catch at the surface of the sea. Had this practice been followed in 1985 the Falkland Islands Government might have received a revenue of between US $ 2 million (pessimistic assumption of 5% levy and US $ 40 million total value) and US $ 12.4 million (optimistic assumption of 10% levy and US $ 124 million total value).

If US $ 70 million is taken as the total value of the catch, the income should have been between US $ 3.5 to 7.0.

A useful guide to the value of the catch is that the New Zealand fishery for Todarodes was licensed at the rate of US $ 0.085/Kg. If applied to a total catch of some 103 000 tonnes, this would have generated a revenue of US $ 8.8 million to FIG. However this squid has a somewhat higher market value than Illex, and the FIPZ Illex fishery has the disadvantage of being close to fishing grounds which look likely to remain unlicensed (at 46 degrees S).

In conclusion therefore it seems reasonable to take US $ 7.0 million as the maximum revenue that FIG could possibly have obtained from licensing the FIPZ Illex fishery in 1985.

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 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.$\sum$ 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:

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

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	$W=4.29L^{3.31} \times 10^{-6}$	$W=5.65L^{3.24} \times 10^{-6}$
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

i. Usefulness and reliability

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 1.6/ year.

ii. Estimate of state of exploitation of the stocks.

Beddington (1985) quoting Caddy (1981) recommended maintaining a spawning reserve of some 40% of the unexploited stock size to maintain a spawning reserve (ICNAF policy when managing Illex illecebrosus stocks in the northwest atlantic is to maintain a reserve of some 60%; Caddy (1983) was of the opinion that this was overcautious). Although it is difficult to state exactly what level of stock depletion is harmful, it seems very likely that removing anything over 60% of the stock size must be detrimental.

Illex have a relatively low fecundity with a high energetic investment in egg production: this suggests that the stock-recruitment relationship in this species is likely to be fairly strong, and that heavy overfishing in one year will quickly cause recruitment overfishing. This is of course conjectural.

Using the population parameters derived above, it is fairly simple to calculate the proportion of stock remaining at June 15th. as a proportion of the estimated unexploited stock size at this date. (ie as ((EXP(-Z)/EXP(-M))*100)). This proportion in 1985 was estimated at 23%. If FIPZ Illex is considered as a unit stock, then it seems clear that this stock must have been overexploited in 1985, and that recruitment in 1986 may well be affected.

iii. A Validation of the Analysis.

The input data for the models are little more than back-of-envelope notes. Consequently there must be serious doubts about any conclusions drawn from the models. A simple check can be made on the overall performance of the models to see whether they generate plausible results. Unfortunately only a rough check is possible, but at least it allows some independent comparison.

Otero et al.(1981) describes the results of some demersal trawl surveys on the Patagonian shelf, including the Illex fishing area described in this study. Unfortunately the results are not reported in detail by separate areas. However from Fig. 7 the total demersal stock was estimated (very approximately) as below:

Surface area (Sq. mi.)	Mean density (t/sq. mi.)	Weight (t)
450	60	27 000
7200	9.5	68 400
11250	2.0	22 500
Total Weight (Tonnes)		117 900
Estimated No. (x10^6)		198

This survey was carried out in May and June of 1978 and 1979, ie after a season of fishing of unknown intensity. Consequently little can be said about the comparison of the estimates, except to note that they are not wildly disparate, and hopefully indicate that no extremely serious errors were made in this assessment.

It is at least some comfort that the DeLury analysis and the cohort analysis give similar results, but because results from one are used as input data from the other, the comparison is not fully valid.

7. Suggested Management Objectives

Assuming (1) the above analysis is essentially correct, (2) that 40% of unexploited stock size should remain on 15th June, and that (3) recruitment remains constant at 1985 levels, a maximum yield that would still safeguard a breeding stock of FIPZ Illex can be calculated. The third assumption is not realistic, but nevertheless a catch limit so calculated gives some indication of the value that this parameter should take.

Because the Illex grow so quickly during the period of the fishery, the timing of the fishery might be important. A catch of 10 000 tonnes in February will have a much greater impact on the stock than the same weight caught in June (some 38 million squid compared with some 14 million squid). Consequently any consideration of yield should include some thought as to when the fishery starts. It might prove to be beneficial to delay the start of the fishery in order to maximise yields.

Three calculations have been carried out to estimate a yield that would leave about 40% of the stock as a breeding reserve, for three possible start dates for the fishery. These calculations are given in Tables 13, 14 and 15. The quality of the data does not warrant a full yield per recruit analysis, especially where recruitment is likely to be so variable.

The first calculation assumes constant fishing from 14th. February, and results in a yield of some 80 000 tonnes. The second assumes a start date of 16 March, and results in a yield of 73 000 tonnes. The third calculation, for a start date of 16th. April, results in a yield of some 72 000 tonnes. There seems therefore no advantage in declaring a closed season before the start of the fishery (start date has a similar importance to mesh size in other fisheries). More detailed modelling of this topic may be useful later.

As a tentative recommendation therefore it is suggested that a safe level of catches of FIPZ Illex would be around 80 000 tonnes. This quantity would be the maximum safe level of catch assuming that recruitment remains constant. As Caddy (1983) suggests, catch rates early in the season should be monitored to assess trends in recruitment, and the safe level of catches should be adjusted accordingly.

In practical terms it would scarcely be possible to reduce the number of vessels licensed to fish once licences had been issued. It would therefore be necessary to set a conservative catch limit before the season starts - possibly 60 000 tonnes - and to issue an additional number of licences in mid-season according to the estimated recruitment.

Until better fisheries data become available for this stock, it is suggested therefore that a limit on catches of 60 000 tonnes be imposed, but that this limit be reviewed in mid-season and increased according to yearly recruitment.

8. Enforcing Management Measures

Regulating the fishery directly by enforcing a catch quota system around the Falklands would be extremely difficult because of manpower and logistic difficulties. The simplest way to regulate the fishery would be to regulate the number of ships by issuing fishing licences. Licences would be priced according to the catching capacity of the ships.

The number of licences issued would be set by attempting to match the catching capacity of the licensed fleet to the required yield discussed above. The licences would be priced according to the estimated value of the catch of a licensed ship.

As an approximate example, jigging vessels (with catch rates averaging some 13 t/day) and fishing from 1 March until the end of the season (say 100 days approx.) might be expected to catch around 1300 tonnes of squid. A reasonable figure for a fishing licence for such a ship for one season might be around US $ 65 000 (calculated at 5% of the value of the catch in Japan). Unfortunately because of the proximity of other, 'free' fishing grounds at 42°S and 46°S, a somewhat lower fee would probably have to be charged, perhaps around US $ 40 000. Issuing licenses to 46 jigging vessels would ensure a catch somewhere in the region of 60 000 tonnes for the whole season, but in practice a mixture of vessel types might be licensed.

Using the above assumptions about catch rates and catching efficiency might lead to a table of licence fees as below, calculated at ca. 3% of the value of the catch.

Vessel Type	Licence fee US $	Licences Issued	Likely Catch/t
Jigging Vessels	40 000	21	27300
Trawlers <999 GRT	14 000	5	2450
Trawlers 1000-1999 GRT	25 600	6	5400
Trawlers 2000-2999 GRT	40 000	14	19600
Trawlers 3000-3999 GRT	56 000	1	1960
Trawlers >4000 GRT	72 000	1	2500

Such a scheme might yield a revenue of some US $ 1.7 million, which would hopefully be a long-term sustainable revenue.

Setting the levels of licence fees is of course a fertile ground for much acrimonious debate. The fees listed above are only illustrative.

In addition to paying a fee, licensed vessels might be required to carry government observers who would provide information allowing more reliable management of the fishery. In particular they would monitor catch rates early in the season so that the number of licences could be adjusted in mid-season to allow for variation in recruitment.

9. Consequences of Continued Free Fishing

As previously noted, the FIPZ *Illex* were overexploited in 1985. Consequently recruitment in 1986 may be severely affected. Whether or not this occurs will depend on how much mixing takes place between the squid stocks on the Patagonian shelf.

Oriental jigging vessels plan a massive increase in fishing effort in 1986, with some 97 vessels from Japan, 30 from South Korea and 40 from Taiwan. These vessels will fish mainly in the FIPZ. These are mostly vessels that would otherwise have fished in New Zealand waters, but essentially see no reason to continue paying licence fees when the FIPZ fishery is unregulated. Some vessels continue to fish in New Zealand only because they paid their licence fees in advance.

These vessels plan to come to the FIPZ from late January onwards. 167 jigging vessels will fish from about February onwards, compared with 46 vessels suggested above. This is in addition to a substantial fleet of trawlers from various countries. Although some fishing will take place on the fishing area at 46 degrees S, it still seems clear that in 1986 the FIPZ fishery will be very heavily overexploited. It will depend entirely for its continuation on mixing with squid stocks from other areas.

The total catch of *Illex* from the Patagonian shelf may not increase by a very great deal in 1986 over 1985. The reason for this is that by virtue of their privileged market access the squid jiggers can displace the trawler fleets, who will have to compete for a smaller import quota for *Illex* into Japan. However the proportion of *Illex* that is caught within the FIPZ is likely to increase dramatically because the jigging vessels are restricted to fishing in shallower water. Additionally Japanese vessels will base their operations in the Falklands, transhipping their catches in Berkeley Sound and in Port William. This provides an additional incentive to fish in the FIPZ.

Trawler fleets will probably be largely displaced from the FIPZ by jiggers in 1986, and will need to fish further north or to concentrate on Loligo stocks.

The long-term future of the fishery depends almost entirely on the amount of recruitment that occurs from other stocks, as the FIPZ Illex will not be self-sustaining. If it was a unit stock with little recruitment from other populations it seems likely that recruitment in 1986 will be much lower than in 1985, and the very heavy fishing pressure in 1986 might drive the stock virtually to extinction.

Reduced catch rates in the later part of the fishing season coupled with a fall in the market price of Illex may be sufficient to bankrupt some vessels operators.

10. Summary and Conclusions

There exist on the Patagonian Shelf large stocks of Illex argentinus which could support substantial fisheries over a long time. Otero (1983) estimated the size of these stocks at some 467 000 tonnes mean annual standing stock in 1978/9.

As fishing in the FIPZ is so intensive it seems likely that the continuation of the fishery will depend on how much mixing occurs between the population that recruits to the FIPZ fishery and the remainder of the Patagonian Illex. If all the squid constitutes one stock on the whole shelf, the FIPZ fishery will not be affected by local overfishing. Studies on the stock separation of Illex in the South Atlantic are therefore vital to any management measures that are introduced.

However proper management measures cannot be taken for the FIPZ in isolation, but should be taken in cooperation with Argentina, because this stock migrates between the FIPZ and Argentine waters. This holds true if the FIPZ Illex is a separate stock, but such cooperation is even more necessary if the FIPZ Illex is a small part of a Patagonian shelf stock. Managementof the fisheries at 46° S and 42° S should also be considered in conjunction with that of the Argentine and FIPZ Illex populations.

A preliminary suggestion for the management of the the FIPZ Illex is to limit fishing effort so that around 60 000 tonnes of squid can be caught, with a relaxation of the limitation in mid-season according to yearly recruitment.

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

DATE	February Number	February Mean	March Number	March Mean	April Number	April Mean	May Number	May Mean	June Number	June 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 <u>Illex</u> 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.

DATE	February Number	February Mean	March Number	March Mean	April Number	April Mean	May Number	May Mean	June Number	June 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		10		2		0	
9			5	4.4	10	10.4	2	2.2	0	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.

DATE	February Number	February Mean	March Number	March Mean	April Number	April Mean	May Number	May Mean	June Number	June 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 6. Nightly captures of <u>Illex argentinus</u> by Japanese jigging vessels. (Numbers of blocks of 8.5 Kg frozen each night)

SHIP NAME	MAY 12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Yuko Maru 8	500	500	1100	800											
Yuko Maru 18	2000	3600	1500	4500	2000	2500	2500	2500	3000	2000	2000				
Yuko Maru 28	2000	4200	3000	3400	4600	3800									3000
Yuko Maru 38	2500	1000	1600	2000	1600	1800								1500	1500
Yuko Maru 58	1000	1500	1500		1900	3100	3600			3800	3500	1300	2000	1500	3000
Sanko Maru 1	600	900	700	2200								1200	1000	100	1300
Sanko Maru 18	500	3300	3000	2500	3700	1900	2100	500	5500	1200	3100	400	2500	1000	2200
Sumiyoshi Maru 181	700	1500	4000	2000	3800	2300	3000	500	2300	1500					
Ootori Maru 38	1000	1500	1300	3000	2000	1500	2000	500	1000	1800	2000	100	1000		
Hosei Maru 13	1500	2300													
Hosei Maru 23								200	1200	3000	5000	1500	4500	2000	3500
Kannon Maru 35	700	1000	1000	2200	3500	3300	3400							700	1500
Kannon Maru 55	6000	3400	4000					200	800	2000	3500	1500	3500	2000	2400
Fuki Maru 51													1000	1000	4000
Fuki Maru 55	1000	500	800												
Kaneshige Maru									1500	4000	3000	3000	3000	1000	2500
Hide Maru 1									2000	2300	2200	2500	2000	2000	3000
Nikko Maru 21	500	2000	1500	2000	3500	2500	3800	1800	1600	1500	2000				
Kinpo Maru 28	800	800	1600	2100	1700	1800	1500	300	1000	500					
Koyo Maru 1	2400	200	1800	2300	1500	2300	1700	1000	2000	2000	1300	1200	800	1500	800
Shosei Maru	2000	2200	500											1500	1000
Mean all vessels: Blocks	1512	1788	1806	2417	2710	2436	2622	833	1991	2133	2760	1411	2130	1317	2285
Tonnes	12.9	15.2	15.4	20.5	23.0	20.7	22.3	7.08	16.9	18.1	23.5	12.0	18.1	11.2	19.4

Table 6. Nightly captures of <u>Illex argentinus</u> by Japanese jigging vessels. (Continued)

	MAY					JUNE									
SHIP NAME	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10
Yuko Maru 8	400	1500		1500		1400		1000	800	500	1000	1500	2000	3000	3000
Yuko Maru 18				1000				1200	800	1200	800	2000	3000	3200	2000
Yuko Maru 28	3000	3500		2000		6100								2000	2500
Yuko Maru 38	2860	2400		1000		3700		1600	600	800	1800	2700	1000	600	4200
Yuko Maru 58										300	1400	2200	3100	2660	1700
Sanko Maru 1	1800	1000		800		5200		100	200	300	400	200	500	800	400
Sanko Maru 18								200	500	400	1300	700			500
Sumiyoshi Maru 181				1300		1300		2000	600	400	200	300	1000	500	800
Ootori Maru 38						310		100	100	100	1500			1200	600
Hosei Maru 13	2500	3500						100	500	100	1000			500	1100
Hosei Maru 23	1000	4000		1100		6400		1600	800	500	1500	1000			
Kannon Maru 35	2500	2000		1000		3300		2500	1000	1000					
Kannon Maru 55	3000													1800	2000
Fuki Maru 51	2000	2000		2000		4000		800	300	100					
Fuki Maru 55		1500		1500				1400	500	100	1500	1200			600
Kaneshige Maru	3000	3500		1000		5200								1500	1500
Hide Maru 1	1300	1000		1300		5000		500	200						
Nikko Maru 21										1000	3000	600	2700	2000	
Kinpo Maru 28	700	800		300		1100		500	500	500	1400	1000	300	900	500
Koyo Maru 1				500				200	200	500	500	700	1000	500	
Shosei Maru	2500	3500		1000		900		1500	100	1000					600
Mean all vessels: Blocks	2043	2323		1153	1688	1688		956	481	518	1236	1175	1622	1511	1467
Tonnes	17.4	19.7		9.80	14.3	14.3		8.13	4.09	4.40	10.5	9.99	13.8	12.8	12.5

Table 6. Nightly captures of *Illex argentinus* by Japanese jigging vessels. (Continued)

SHIP NAME		JUNE									
		11	12	13	14	15	16	17	18	19	20	21
Yuko Maru 8		1500	1300	1800	2000							
Yuko Maru 18		1500	1000	2500	1600			1600		1400	300	200
Yuko Maru 28		300	400	1300	1900	2800		500		200	200	100
Yuko Maru 38					500	400		800		800	300	100
Yuko Maru 58		500	400			300		100		300	200	100
Sanko Maru 1		1500				300		300		300	300	100
Sanko Maru 18		100	800	300	200	300		200		400	100	
Sumiyoshi Maru 181		300	1000			100		100		400	500	300
Ootori Maru 38		700	300	800	1400	700		200		600	100	400
Hosei Maru 13		1200	1100	900	1000	700		1000		200	300	100
Hosei Maru 23				700	600	1000		200		100	100	0
Kannon Maru 35		600	300	200	200	700		200		300	200	300
Kannon Maru 55		2000	1200	2000	1700	1000		1000		800	900	400
Fuki Maru 51		600	500	800	500	600						
Fuki Maru 55		400	200	300	200	300		200		200	300	300
Kaneshige Maru		1000	1000	1000	1500	1000		500		1200	300	0
Hide Maru 1		100	100	500	1000	1100		300		500	300	100
Nikko Maru 21			1000	1400	1000	2400		100		200	200	0
Kinpo Maru 28		600	400			300		400		300	100	0
Koyo Maru 1		500	700	600	1000	1000		500		300	200	100
Shosei Maru		800	100	300	800	500		800		100	100	0
Mean all vessels:	Blocks	789	656	963	1006	816		474		453	263	144
	Tonnes	6.71	5.58	8.19	8.55	6.94		4.03		3.85	2.24	1.22

able 7. Fishing trips by Japanese jigging vessels, their total catches and calculated catch rates.

essel	Date of Start	Date of Finish	Days Fsd	Catch/t	C.rate
osei Maru 23	12/03	08/04	27	430	15.94
	13/04	09/05	26	467	18
annon Maru 55	12/03	04/04	24	436	18.2
	11/04	03/05	21	455	21.7
	09/09	30/05	22	449	20.4
osei Maru 13	10/03	31/03	20	334	16.7
	06/04	19/04	13	302	23.2
	22/04	23/05	31	302	9.7
uki Maru 51	10/03	31/03	20	278	13.9
	04/04	18/04	14	273	19.5
	19/04	20/05	31	273	8.8
annon Maru 35	12/03	30/03	18	215	12
	01/04	17/04	16	271	16.9
	19/04	21/05	33	274	8.3
ide Maru 1	07/03	27/03	20	279	13.4
	01/04	19/04	18	249	13.8
	21/04	13/05	24	211	8.8
aneshige Maru 15	28/02	27/03	27	360	13.4
	01/04	17/04	17	269	15.8
	19/04	16/05	28	305	10.9
otori Maru 38	27/02	22/03	23	342	14.9
	29/03	19/04	22	297	13.5
	22/04	26/05	35	334	9.5
uko Maru 8	27/02	18/03	19	305	16.1
	26/03	17/04	20	341	17
	19/04	23/05	33	420	12.7
anko Maru 1	27/02	17/03	19	252	13.2
	27/03	13/04	17	215	12.6
	16/04	17/05	31	268	8.6
umiyoshi Maru 181	21/02	13/03	20	295	14.8
	19/03	14/04	25	301	12
	16/04	24/05	38	392	10.3
anko Maru 18	22/02	13/03	18	317	17.6
	19/03	10/04	21	345	16.4
	13/04	04/03	22	356	16.2
	08/05	29/05	19	346	18.2
uki Maru 55	23/04	24/04	32	336	10.5

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 10. Estimates of total catch of _Illex_ from within the FIPZ in 1985.

	Trawler size classes (GRT)					Jigging Vessels	Total
	< 999	1000-1999	2000-2999	3000-3999	> 4000		
Feb. 14-28	0	52.44	34.13	0	0	465	552
Mar. 1-15	647.4	1003.	4444.	0	0	1318	7412
Mar. 16-31	1165.	3488.	13861	1686	3258	7470	30928
Apr. 1-15	706.2	1248	9206.	1050	2363.	11180	25753
Apr. 16-30	40.5	446.4	1703.	210	0	7192	9591
May 1-15	30	118.8	1975.	120	0	7390	9634
May 16-31	9.6	889.9	843.2	571.2	0	6921	9235
June 1-15	72.45	0	441	0	0	8545	9058
June 16-30	116.6	85.5	144	0	0	945	1291

							103454

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

Table 13. Calculation of Total Yield for fishing beginning at 14th. February.

INPUTS

M = .065 /half month
F = .114 /half month
No = 420000 Thousands

Time	Number	Catch	Mean wt.	Yield/t
Feb 14-28	420000	45251.66	261	11810.68
Mar 1-15	351164.5	37835.18	300	11350.55
Mar 16-31	293610.7	31634.22	342	10818.90
Apr 1-15	245489.6	26449.55	388	10262.43
Apr 16-30	205255.3	22114.63	435	9619.863
May 1-15	171615.2	18490.17	492	9097.164
May 16-31	143488.5	15459.74	552	8533.777
Jun 1-15	119971.6	12925.98	618	7988.256
		Total Yield		79481.63

Table 14. Calculation of Total Yield for fishing beginning at 16th. March.

INPUTS

M = .065 /half month
F = .152 /half month
No = 420000 Thousands

Time	Number	Catch	Mean wt.	Yield/t
Feb 14-28	420000	0	261	0
Mar 1-15	393568.3	0	300	0
Mar 16-31	316794.9	44671.80	342	15277.76
Apr 1-15	254997.7	35957.67	388	13951.58
Apr 16-30	205255.3	28943.41	435	12590.38
May 1-15	165216.2	23297.42	492	11462.33
May 16-31	132987.4	18752.79	552	10351.54
Jun 1-15	107045.6	15094.68	618	9328.513
		Total Yield		72962.09

Table 15. Calculation of Total Yield for fishing beginning at 16th. April

INPUTS

M = .065 /half month
F = .228 /half month
No = 420000 Thousands

Time	Number	Catch	Mean wt.	Yield/t
Feb 14-28	420000	0	261	0
Mar 1-15	393568.3	0	300	0
Mar 16-31	368800.1	0	342	0
Apr 1-15	345590.6	0	388	0
Apr 16-30	257818.2	52562.88	435	22864.85
May 1-15	192338.1	39213.07	492	19292.83
May 16-31	143488.5	29253.82	552	16148.11
Jun 1-15	107045.6	21824.00	618	13487.23
		Total Yield		71793.02

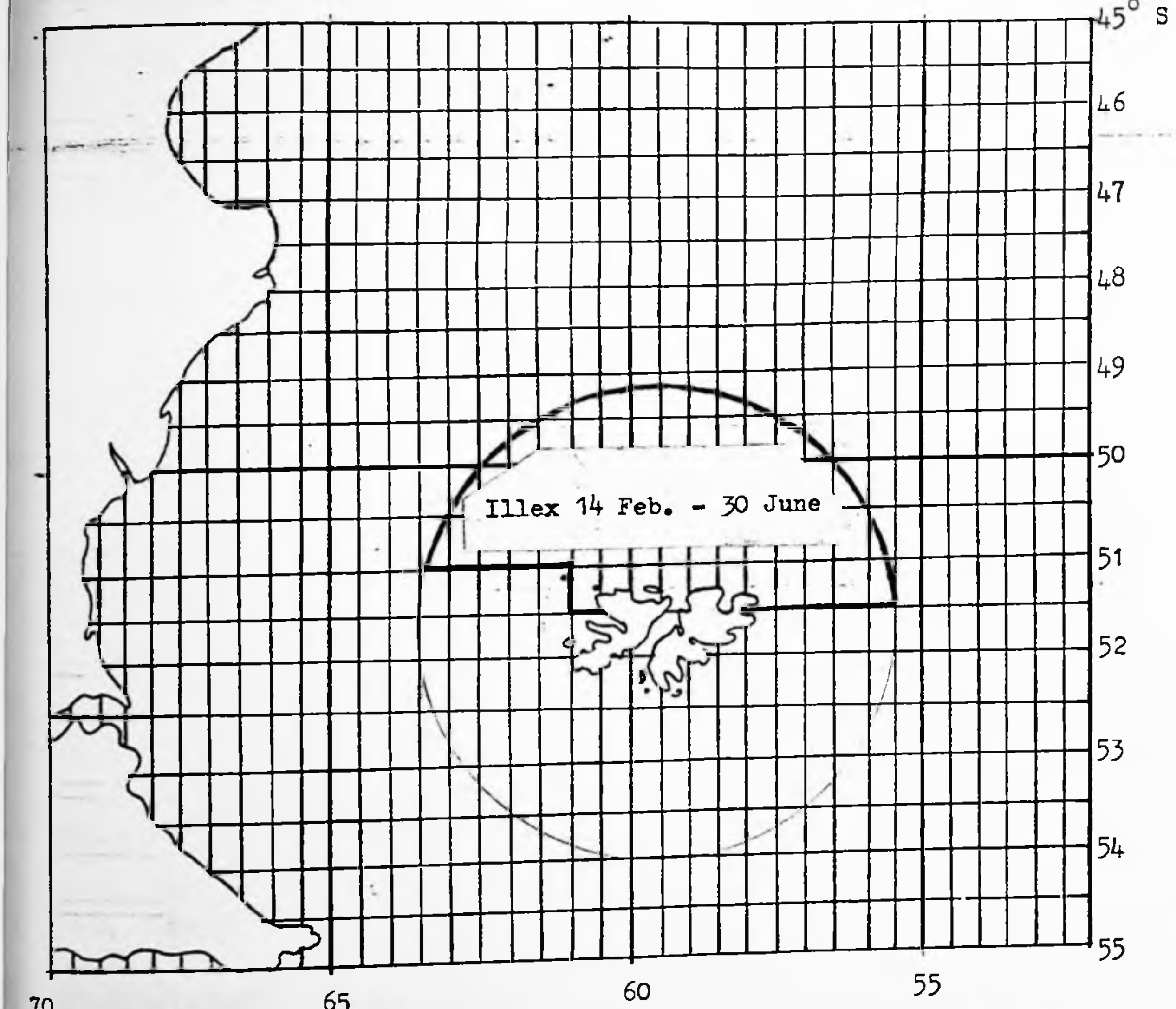


Fig. 1. The fishing area and time period considered in this analysis.

Figure 2. Estimates of numbers of jigging vessels within the <u>Illex</u> fishing area.

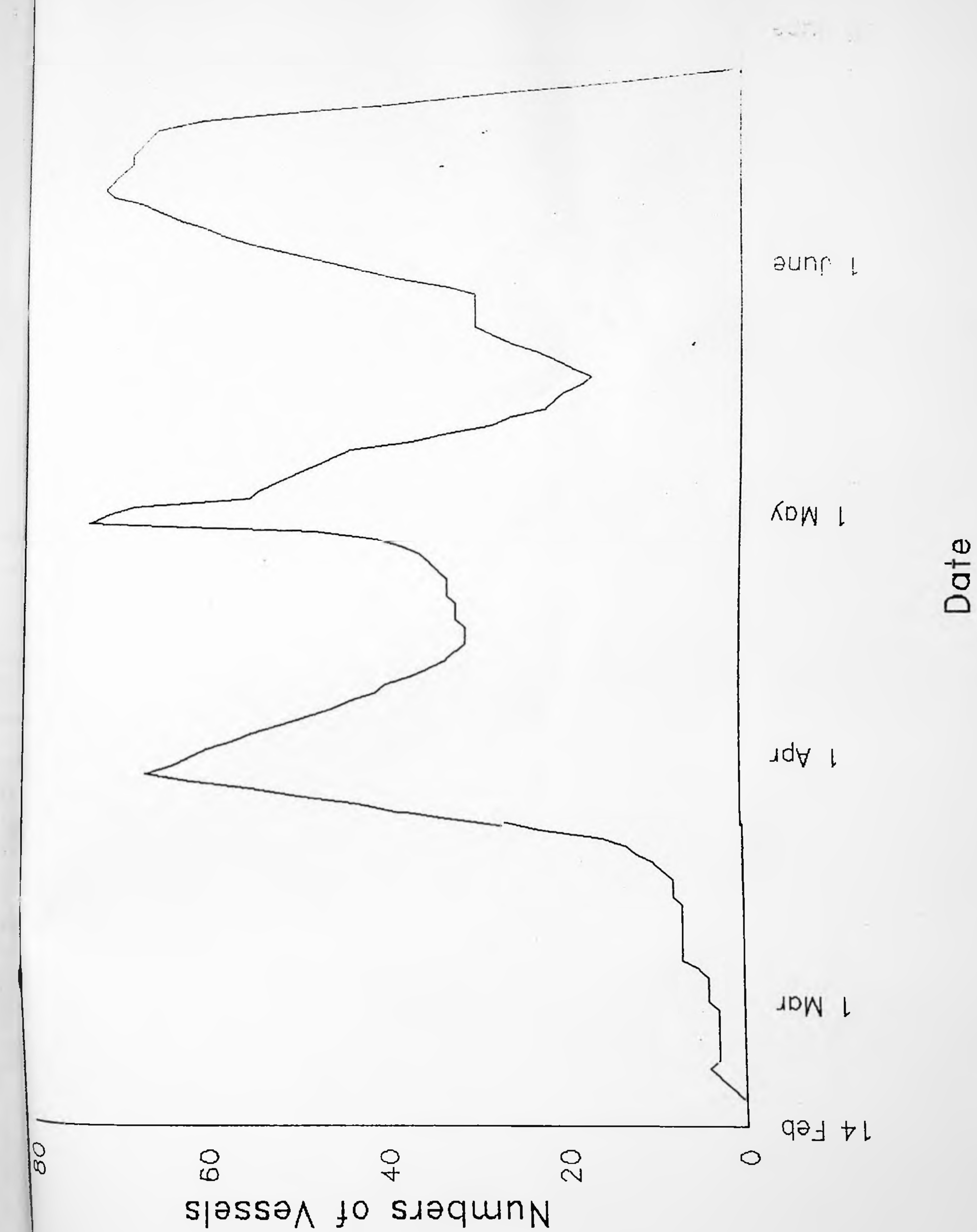


Figure 3. Estimates of numbers of trawlers smaller than 999 GRT within the Illex fishing area.

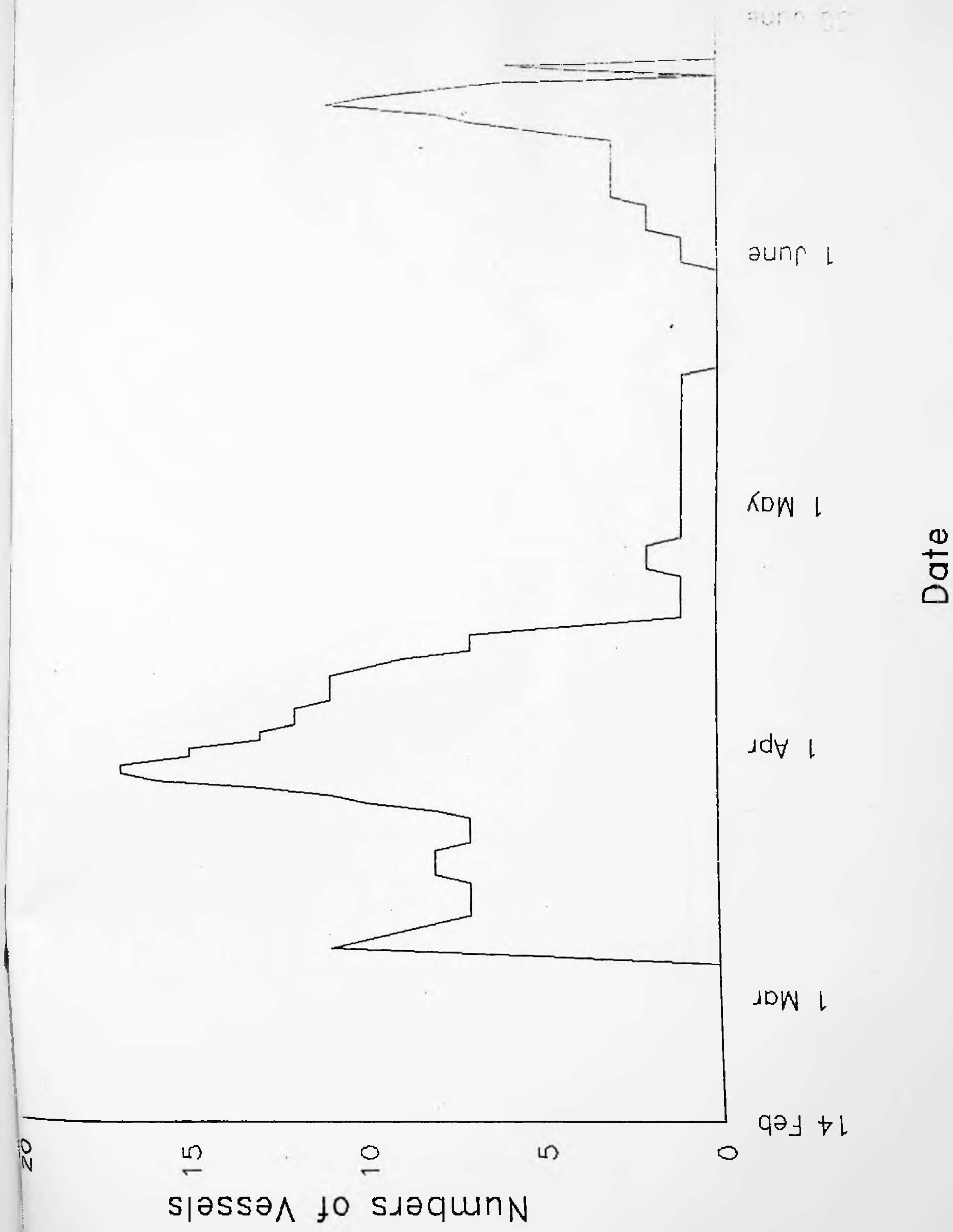


Figure 4. Estimates of number of trawlers of between 1000 and 1999 GRT within the *Illex* fishing area.

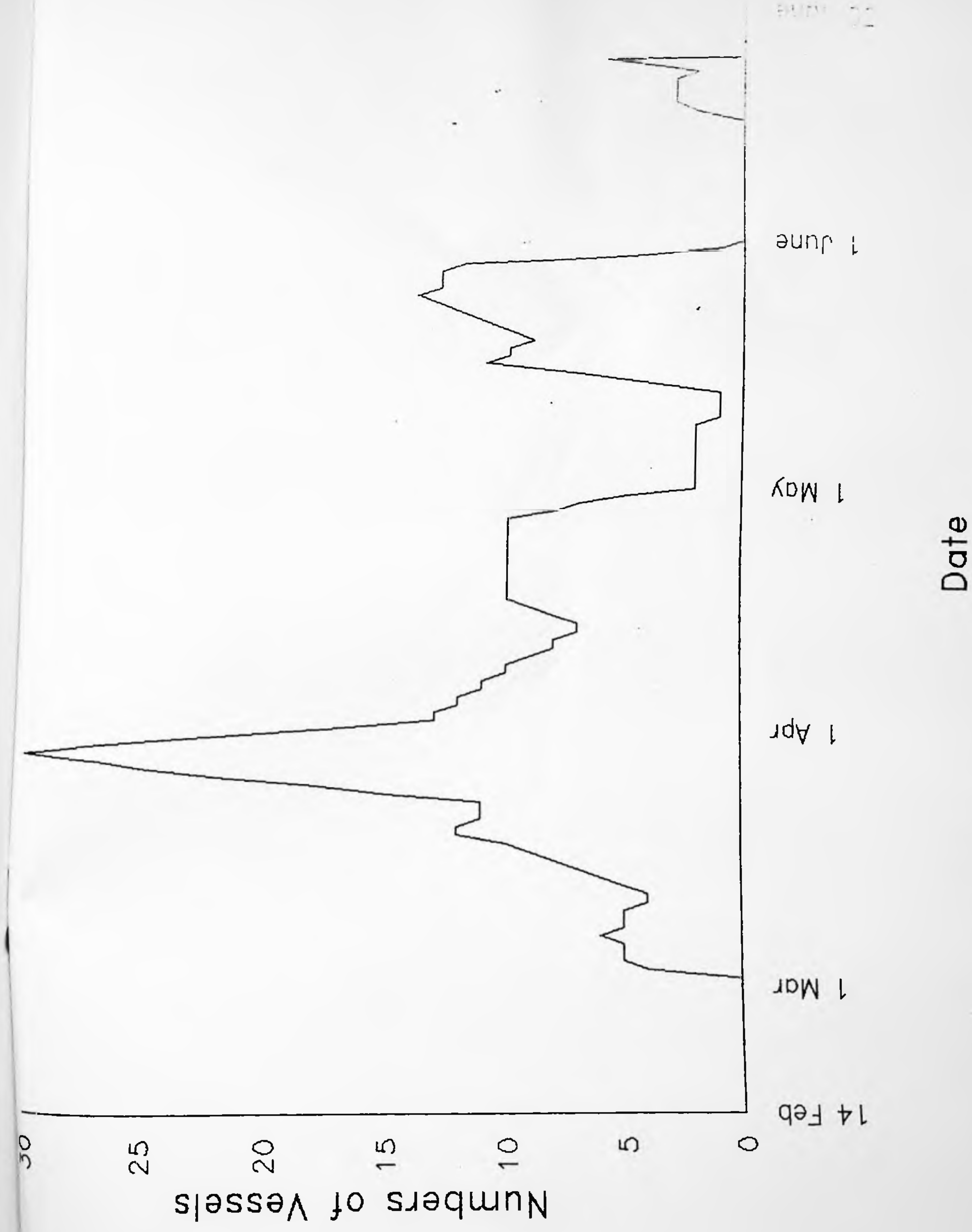
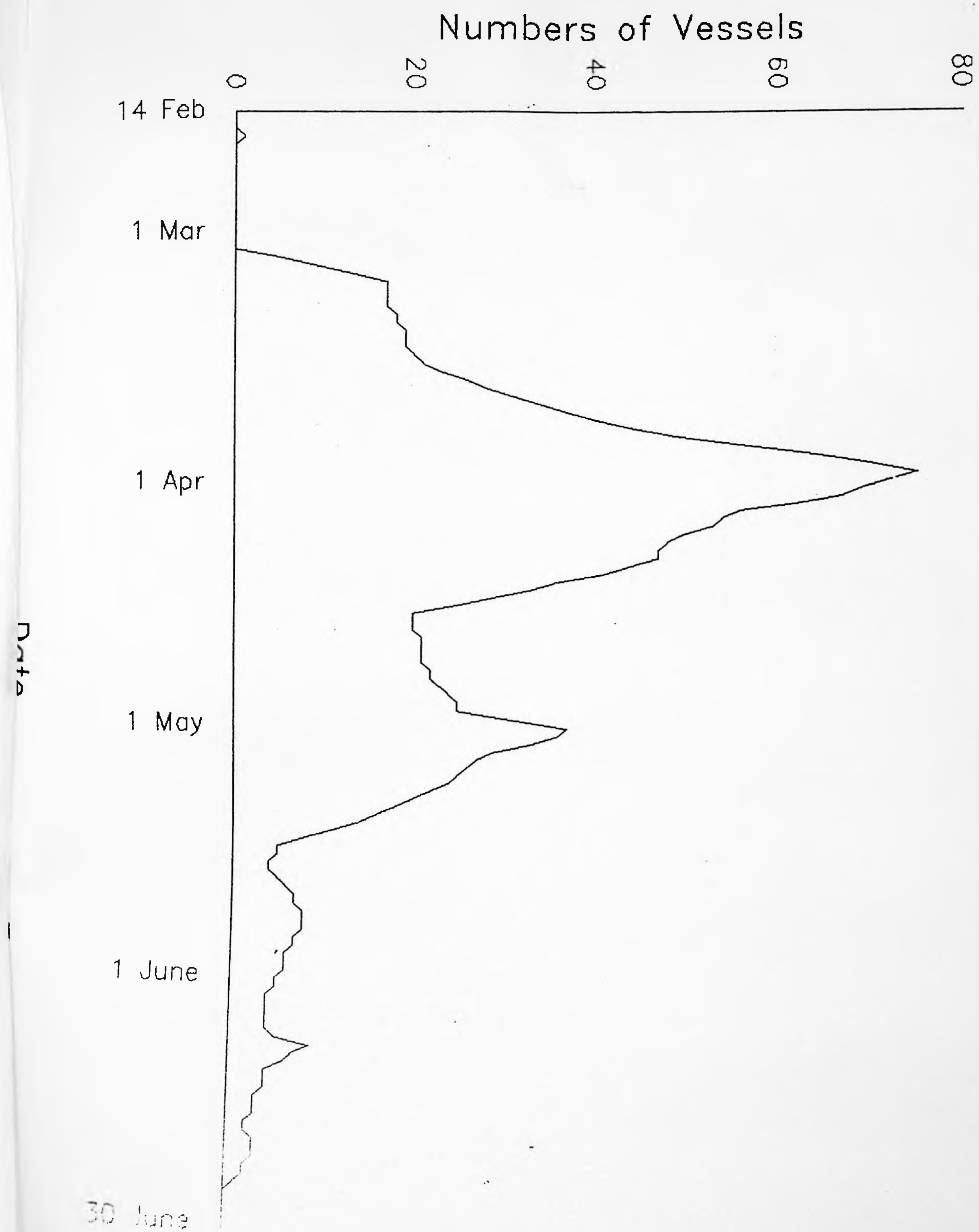


Figure 5. Estimates of the number of trawlers of between 2000 and 2999 GRT within the Illex fishing area.



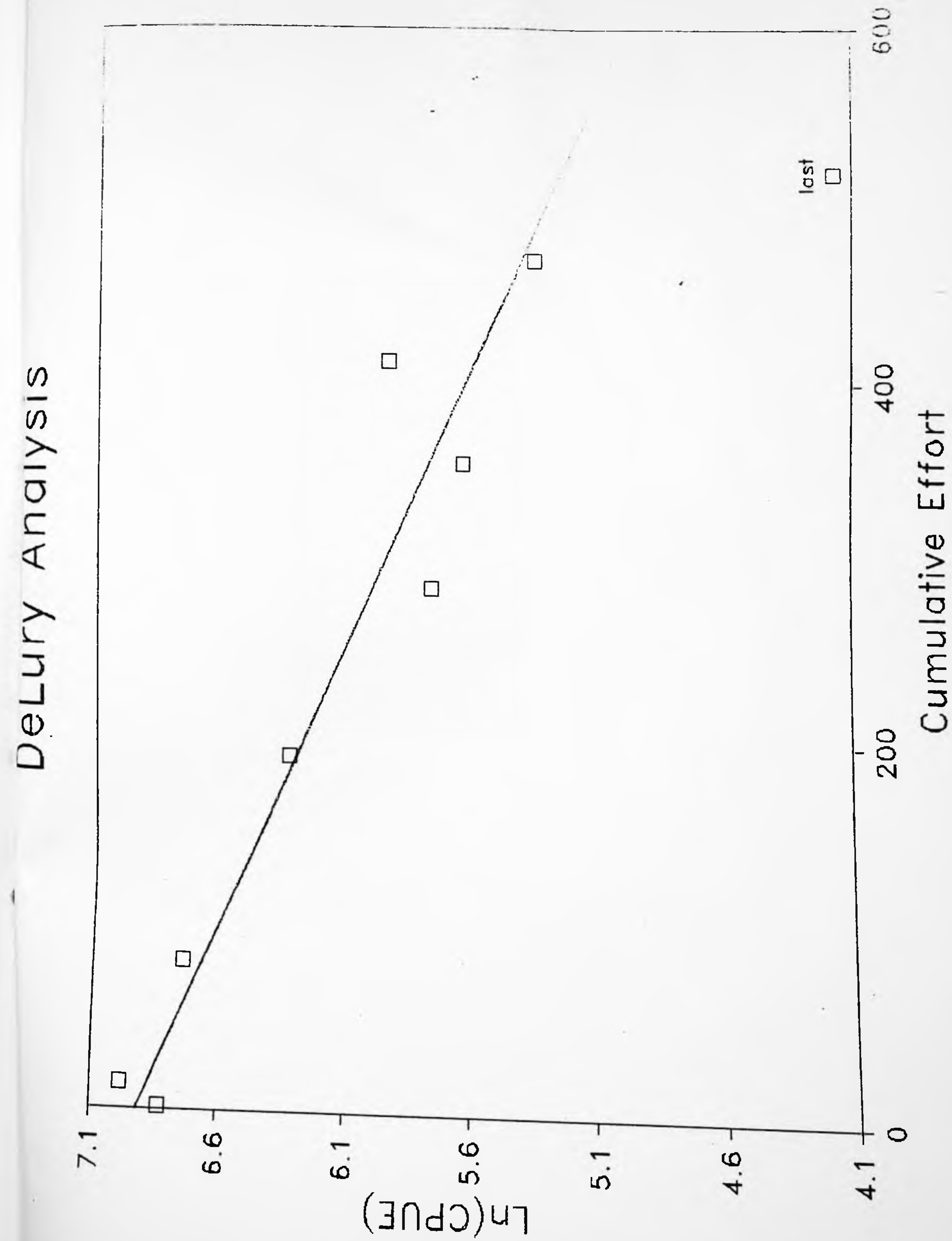


Figure 6. Data points and fitted regression line for the DeLury analysis. Data from Table 11 are plotted, and the regression line fitted to all data points except for that for the last half month of the fishing season. The fitted line has slope = -3.19x10^3 and intercept = 6.916.

Figure 7. Distribution and abundance of Illex argentinus on the Patagonian shelf in 1978/79. From Otero et al. (1983).