Falkland Island Fisheries Department

Fishery Report

Loligo gahi, First Season 2005

Fishery Statistics, Biological Trends and Stock Assessment

SUMMARY

First season (March/1-April/14, 2005) total catch by the *Loligo* fleet was 24605 tons, closer to the highest catches for the same time period of the last 10 years, and total effort was 7292 hours of trawling, the lowest on record. Virtually all the catch was taken from the Beauchene area. Biological trends in proportion of mature individuals and proportion of females were similar to recent seasons. The biological data (as well as the fisheries data) showed the existence of two waves of recruitment, one clearly apparent by the 10th of March and a second comprising the catch from the 21st of March onwards. Stock assessment was undertaken using our implementation of De Lury depletion model. Initial biomass of the first wave of recruits into the Beauchene area was estimated as 23610 tons whereas initial biomass of the second wave was estimated as 93730. This produces the highest biomass estimated for the first season in the last 10 years, even though it does not include the un-exploited biomass of the Central and North areas. A total of 86144 tons were estimated as left in the sea as spawning biomass in the Beauchene area at a fixed spawning date (30th/May). We conclude that the management objective of leaving 10 thousand tons of spawning stock in the sea after the season was amply met.

INTRODUCTION

We have continued applying the improved methods of stock assessment based on DeLury's depletion model as described in previous reports. Apart from the mathematical, statistical and programming changes in the implementation of the model itself –explained in full detail in an internal document of the Fisheries Dpt. (Anon. 2004a)– the most important modifications in relation to previous work by RRAG in London are:

1) the distinction of three major areas (**Fig. 1**) while RRAG pooled the data from all areas inside the Loligo box,
2) the use of a daily time step while RRAG used a weekly step,
3) the unit of effort is vessel-day rather than hours of trawling, and
4) we make no distinction among vessels while RRAG had four fixed GRT categories.

For the analysis of this season's data we introduced a further improvement, related to the value of the natural mortality rate, *M*. The value used so far (M=0.009 day^{-1}) is inconsistent with longevity data collected across many years by reading daily age rings in statoliths. This large database (containing 6184 age readings, both sexes pooled) has been recently presented by Fisheries Department scientists in an analysis of individual growth models in squids (Arkhipkin and Roa-Ureta, In Press). If squids were to die at a rate of 0.009 per day then a cohort would be practically extinct (reduced to 1% of its original magnitude) in ~512 days. Conversely our age database indicates that the oldest squids only lived for 352 days (mean of 368 days and 335 days, males and females respectively). Thus the natural mortality rate should be higher than the previously assumed value. To obtain a new specific value we used Hoenig's (1983) empirical equation based on longevity, as argued in Hewitt and Hoenig (2005), to arrive at M~0.0133. The net effect of this change is to increase the estimate of initial biomass using DeLury's model.

The first season of 2005 started on the 1st of March and lasted until the 14th of April. All our fishery statistics and biological trends cover this period.

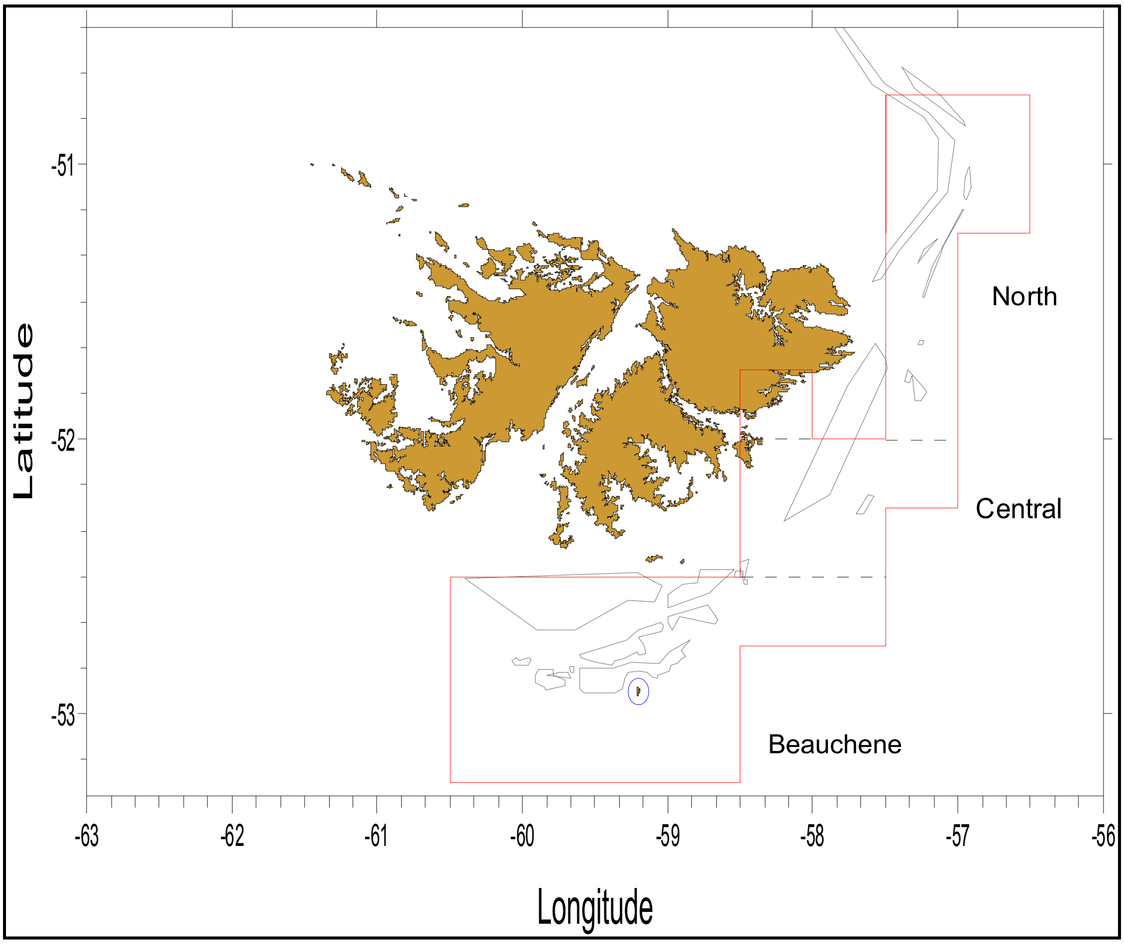

Fig. 1.- Fishing grounds and rocky bottom around the Falkland Islands. In red, the *Loligo* box, and in blue, the three-nm exclusion area around Beauchene Island.

PART 1 – FISHERY STATISTICS

Total Catch and Total Effort in Historical Perspective

Total catch was closer to the highest values of the last 10 years whereas total effort in hours trawled was the lowest on record (**Table 1**). The biomass of the stock at the start of the season was about five times larger than the catch. It is not possible to compare the current biomass estimate with previous seasons' estimates because the stock assessment methodology has changed significantly. It is necessary to undertake a re-analysis of the old data with the new methodologies.

Catch and Effort per Fishing Ground and Cumulative Catch

Virtually all fishing was carried out in the Beauchene area (**Table 2**). Only a small amount of squid was caught in Central area and nothing in North area. The daily cumulative catch was closer to the best than to the worst first season on record (**Fig. 2**).

Table 1.- Fishery statistics and initial biomass for the known history of the *Loligo gahi* fishery of the Falkland Islands. RRAG is the Renewable Resource Assessment Group of the Imperial College, London. FIFD is the Falkland Islands Fisheries Department. 'Failure' indicates that De Lury depletion model could not produce a reasonable estimate of initial biomass. Latest figures in bold font.

	Season 1			Season 2			Year Total	
Year	Catch (ton)	Effort (h)	Biomass (ton)	Catch (ton)	Effort (h)	Biomass (ton)	Catch (ton)	Source
1970							200	Csirke 1986
1971							100	Csirke 1986
1972							100	Csirke 1986
1973							250	Csirke 1986
1974							200	Csirke 1986
1975							140	Csirke 1986
1976							129	Csirke 1986
1977							354	Csirke 1986
1978							911	Csirke 1986
1979							925	Csirke 1986
1980							1111	Csirke 1986
1981							631	Csirke 1986
1982							18452	Csirke 1986
1983							38256	Csirke 1986
1984							36450	Csirke 1986
1985							36430	Csirke 1986
1986								
1987	64063		101000	18484		202000	82547	
1988	48664		115000	5267		39000	53931	
1989	106186	33159	165000	11671	16881	46000	117857	RRAG-FIFD
1990	69078	24177	206000	13589	15713	104000	82667	RRAG-FIFD
1991	37336	13808	53000	16293	16610	146000	53629	RRAG-FIFD
1992	47407	15406	97000	35100	19291	264000	82507	RRAG-FIFD
1993	21814	16065	47000	28650	32950	90000	50464	RRAG-FIFD
1994	34741	19891	55000	30226	29687	116000	64967	RRAG-FIFD
1995	60759	10913	195000	37251	22365	141000	98009	RRAG-FIFD
1996	38729	16438	31000	22662	28420	130000	61392	RRAG-FIFD
1997	15973	16766	40000	10159	18486	82000	26131	RRAG-FIFD
1998	32774	16835	60000	17287	22762	<u>Failure</u>	50061	RRAG-FIFD
1999	22189	19642	44826	11596	18266	53737	33785	RRAG-FIFD
2000	38697	21034	63683	25723	18869	<u>Failure</u>	64420	RRAG-FIFD
2001	27611	20955	26000	25888	19841	162234	53499	RRAG-FIFD
2002	14194	20824	21000	9459	11570	<u>Failure</u>	23653	RRAG-FIFD
2003	15966	8494	40350	28301	16166	<u>Failure</u>	44267	RRAG-FIFD
2004	6669	8740	<u>Failure</u>	**17559**	**17024**	**37220**	24228	FIFD
2005	**24605**	**7292**	**117339**					FIFD

Table 2.- Effort and catch statistics of *Loligo* first season 2005 by fishing ground.

Fishing Ground (Area)	Total Catch (ton)	Effort (Vessel-Day)	Effort (hour)	Average CPUE ton/V-D	Average CPUE ton/h
Beauchene	24558	653	7285	37.609	3.371
Central	47	4	7	11.705	6.852
North	0	0	0		
Total	24605	657	7292	37.451	3.374

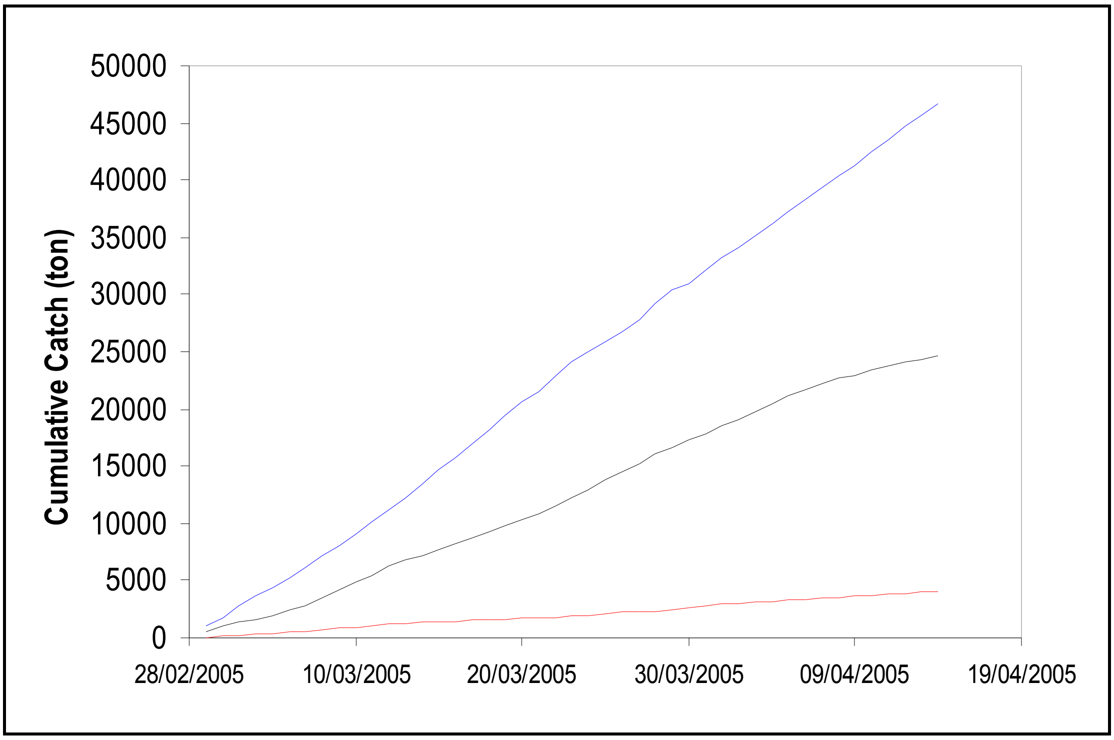

Fig. 2.- Cumulative catch versus date (mo/day/yr) in the first season of 2004 compared with the cumulative catch of the first seasons that yielded the highest and lowest historical catches on exactly the same date range.

Fleet Movement Dynamics, Catch and Catch Rate

During the whole season the fleet remained in the Beauchene fishing grounds (**Fig. 3a**). During the first few days the catch and the catch rate (in ton/vessel-day) decreased and then they increased substantially up to more than 40 ton/vessel-day (**Fig. 3b,c**). It seems that during the first few days the fleet was exploring the different fishing grounds in search for the specific spots where the catch rate was excellent. By mid March the catch rate declined again but the fleet remained in the fishing grounds until what appears to be a second wave of squid recruited from inshore waters into the fishing grounds (**Fig. 3b, c**). Then the catch and catch rate declined slowly until the end of the season, when part of the fleet simply abandoned the fishing activities apparently because some vessels saturated their hold capacity. Thus there seem to have been two depletion processes during the season.

PART 2 – BIOLOGICAL TRENDS

Biological trends of the stock were based on a sample of animals taken from the catch of a few vessels. Typically there was an observer on one vessel taking a sample of 200 animals from every other trawl, though sometimes this effort was doubled by the presence of another observer on a second vessel. Thus our results in this part are affected by sampling variation.

Hypothesis of a Second Wave of Recruits

In **Fig. 4** it can clearly be seen that in fact, there is also biological evidence for the second wave of recruits of larger body weight than the ones that had been fished up to about the 20th of March.

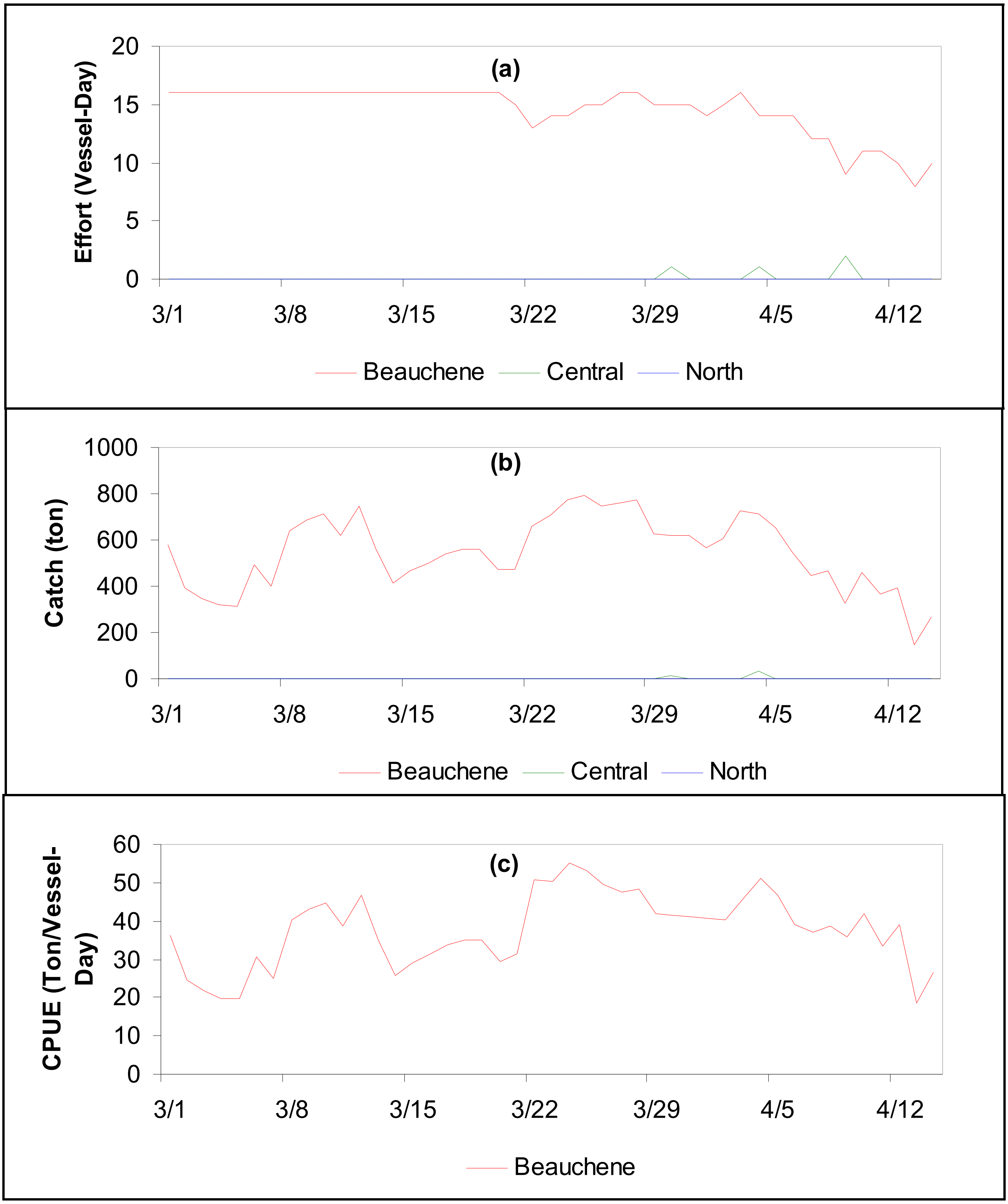

Fig. 3.- Daily evolution of effort (a), catch (b), and average catch per unit of effort (c) in the *Loligo* fishery during the first season of 2005.

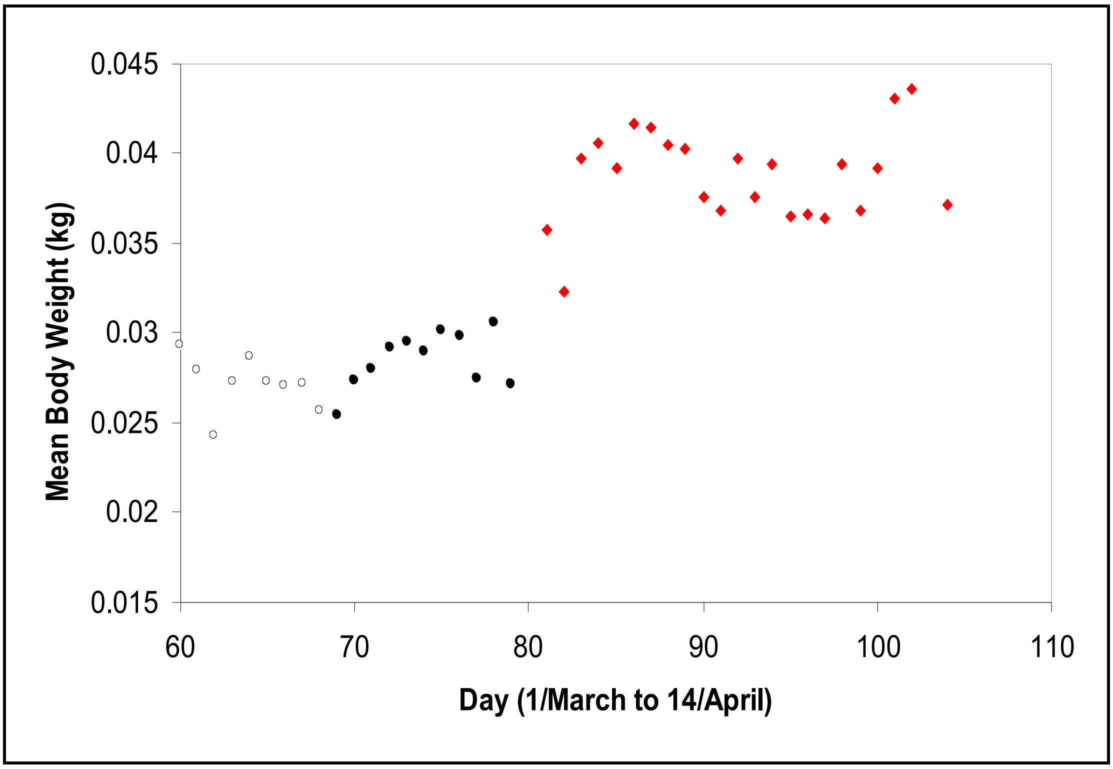

Fig. 4.- Daily evolution of mean body mass of squids sampled from the catch. Open circles: period of exploration; closed black circles: first depletion process; closed red diamonds: second depletion process.

Comparison of Daily Mean Biological Characteristics with Recent Years

The proportion of sexually mature squid in the catch closely followed trends observed in the previous five years (**Fig. 5**). Most females were immature or maturing during the whole season, with weak signs of sexual maturation by the end of the season. Conversely, males showed early signs of sexual maturation though still a majority remained immature. The sex ratio showed high variability but remained around the 0.5 value, as in most previous seasons (**Fig. 6**). The evidence for the second wave of recruits is also visible in the evolution of daily mean length separated for each sex (**Fig. 7**). It is also evident that this is not the first time that the second wave of recruits has entered in mid-season; see 1999 and 2001 in **Fig. 7**.

Full Daily Evolution of the Squid Size Spectrum in the Sample

Fig. 8 shows the information from every single squid measured by observers for the whole season (23556 females and 20846 males). Once again the break in the daily evolution induced by the second wave of recruits becomes evident. It is also clear that the increase squid size was not the result of increased size range. This suggests that the first and second wave did not overlap in the catch.

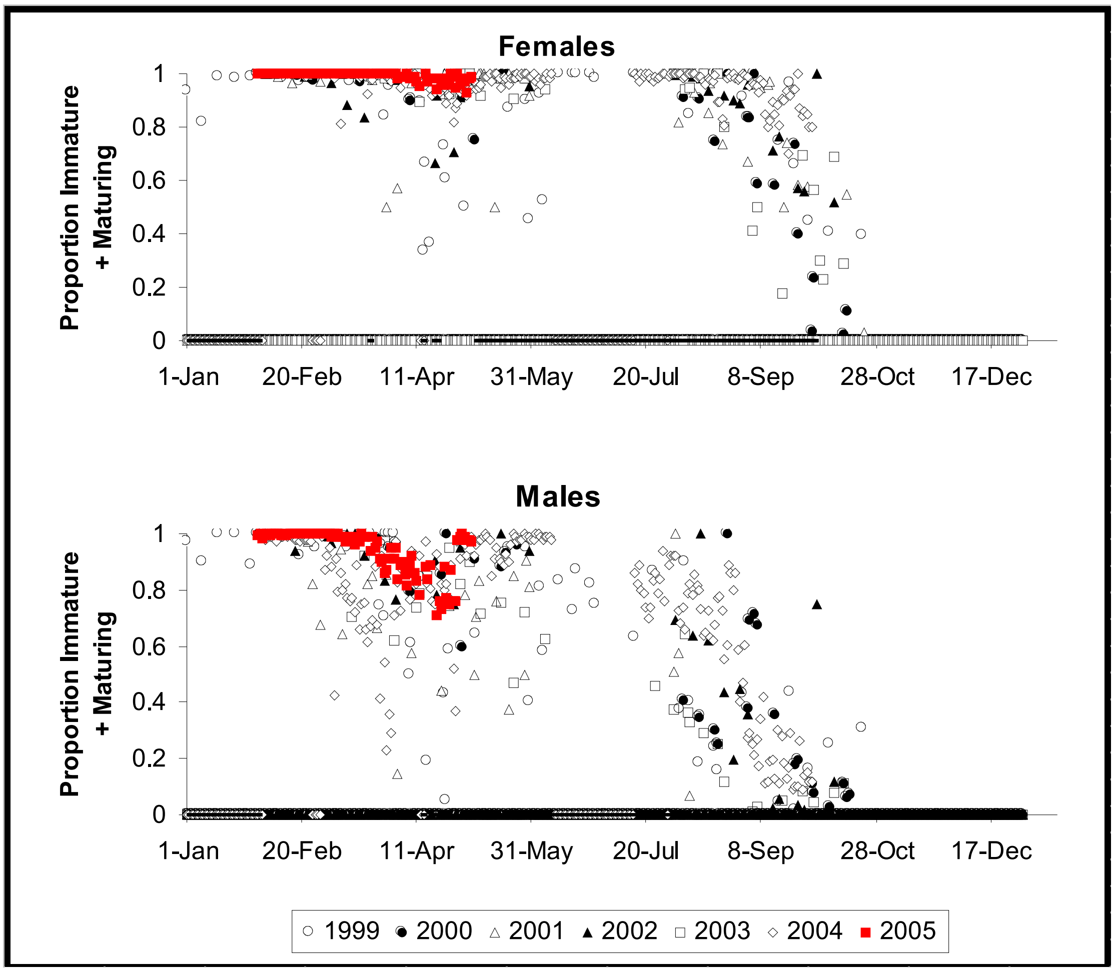

Fig. 5.- Current year trends in the proportion of sexually immature squids in the catch, compared with six previous years.

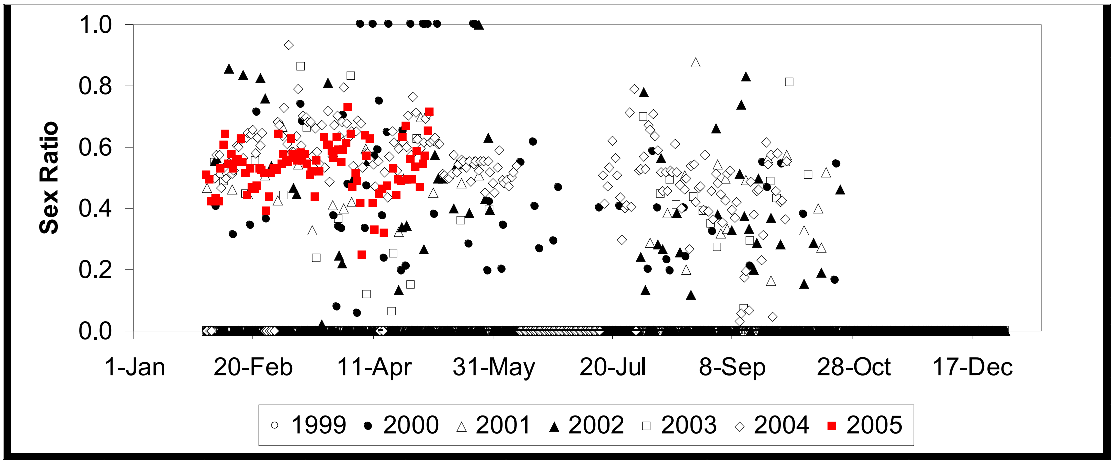

Fig. 6.- Current year trends in the daily evolution of the proportion of female squids in the catch, compared with six previous years.

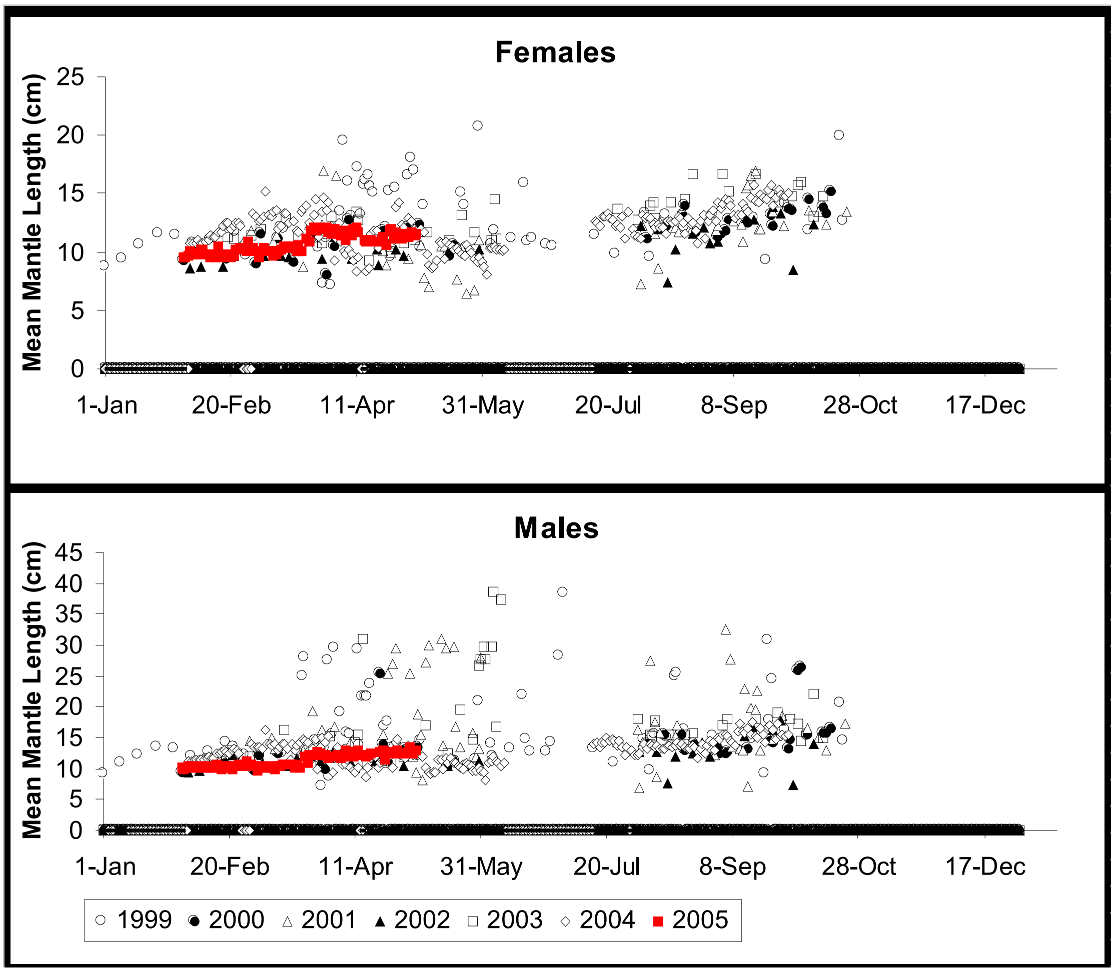

Fig. 7.- Current year trends in the daily evolution of the proportion of female squids in the catch, compared with six previous years.

PART 3 – STOCK ASSESSMENT

Given the fisheries and biological evidence suggesting two processes of depletion over two waves of recruits, we have to contemplate the question of whether there can be two separate assessments done independently or whether they have to be connected mathematically, statistically and computationally. If the first wave of recruits was mixed with the second wave in the catch of the second period, then the assessments have to be connected and this introduces additional complications. Fortunately, the biological evidence points in the direction of two separate episodes of depletion. If the two waves of recruits were mixed we would expect that the increase in mantle length brought about by the influx of the second wave be accompanied by an increase in the *range* of mantle length. In fact, in **Fig. 8** we see that there was no significant increase in the range of mantle length. Thus our interpretation of the population and fishing process is as follows. The first wave of recruits was harvested up to the point in which the second wave appeared far enough offshore to be caught without interference from the *Munida* lobster, which inhabits the inshore part of the Beauchene fishing grounds. Once this happened the fleet abandoned the first wave obviously because the incoming recruits were more abundant and of larger size. Under this scenario, the assessments of the two depletion episodes can be done separately.

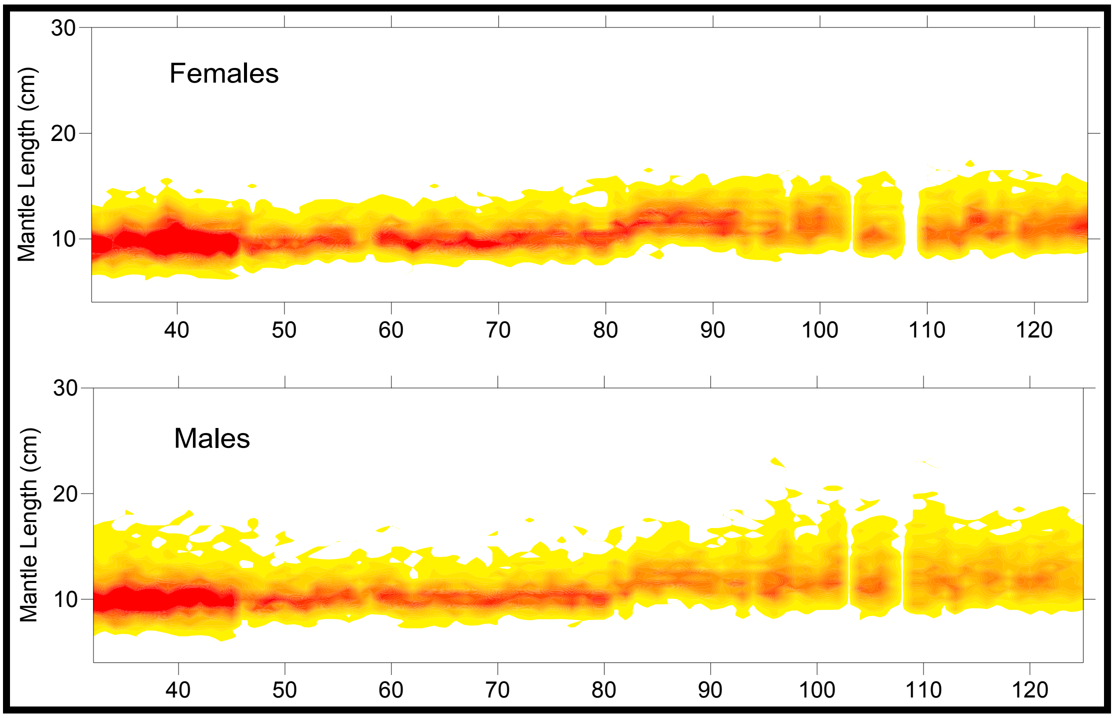

Fig. 8.- Time series of histograms of body size distribution of squid in the catch during the first season, 2005.

Table 3.- Results of stock assessment of Beauchene area using Delury method implemented in ADMB, both for the date indicated as Starting Date (percentage coefficients of variations in parentheses for estimated parameters), and the biomass projection model implemented in Octave. mle: maximum likelihood estimator. Parameters *M*: natural mortality rate, N_0: initial abundance in numbers, *q*: catchability, B_0: initial biomass. Func. Invar.: functional invariance property, allowing the secondary computation of maximum likelihood estimates.

Parameter	Status	First Wave	Second Wave	Total
Longevity	Known	352	352	
M (1/day)	Known	0.0133	0.0133	
N0 (billions)	Estimated	0.93 (5.5)	2.62 (2.5)	
q (1/vessel-day)	Estimated	0.0015 (2.6)	0.00051 (13.4)	
Starting Date	Known	10 of March	22 of March	
Starting day	Known	69	81	
Last Date		21 of March	14 of April	
Last day	Known	80	104	
Number of days	Known	12	24	36
Period Length	Known	12	24	
Min. Fleet Size	Known	15	8	
σ Fleet (billions/√day)	Nuisance	0.0035	0.0017	
Biomass Starting Date (ton)	Funct. Invar.	23610	93730	
Catch Up to Last Date(ton)	Known	10794	13764	
Biomass Last Date (ton)	Funct. Invar.	17208	60775	
Date of Spawning	Known	31 of May	31 of May	
Spawning Stock Biomass (ton)	Funct. Invar.	18596	67548	86144

Using the mathematical and statistical models detailed in Anon. (2004a) and the computer code shown as **App. 1** in Anon. (2004b), we estimated initial biomass and the catchability coefficient for each wave of recruits of the first season 2005. The first wave started at 23610 tons and 17208 tons were left when the fleet started to harvest the second wave. This second wave started at 93730 tons and its harvest was stopped when there were 60775 tons left in the sea.

The model did not provide a very good fit to the catch of the first wave of recruits mostly because of instabilities in the depletion process and two few data points (too few days) (**Fig. 9**), but it did provide a good fit of the larger second wave of recruits (**Fig. 9**).

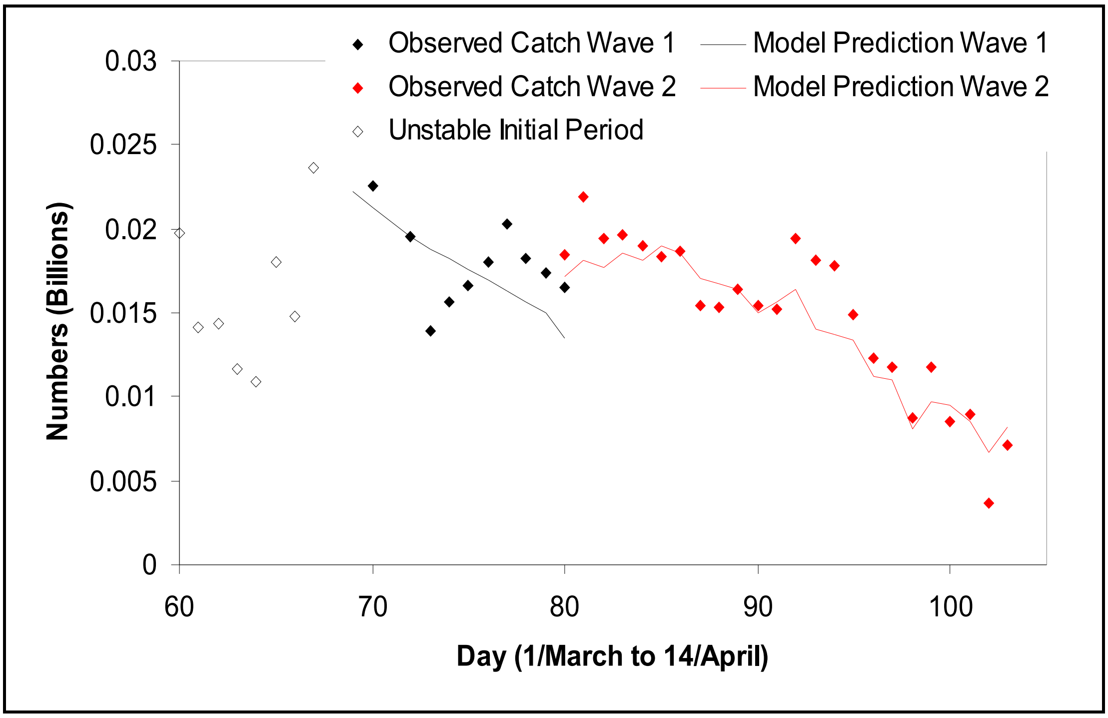

Fig. 9.- Observed catch in numbers by the Loligo fleet and predicted by DeLury depletion model as implemented in Anon. (2004b).

In Anon. (2004c) we had predicted –based on a survey carried out in February and a biomass projection model– that the starting biomass in a polygon covering the Beauchene, Central and North areas by the 1st of March would be ~32 thousand tons. To compare these results with the estimates in this report we have to consider only the first wave (the second wave was invisible to the survey) and move the prediction in the future, to the 10th of March. There is still the problem that the survey-based prediction was made for the three major areas while the fisheries-based estimation in this report only covers the Beauchene area. Therefore we have re-run the survey-based biomass projection model using the survey results only for the area of the polygon including the Beauchene area. We have kept the mean squid density estimated for the whole polygon (Beauchene, Central and North, ~4 ton/km^2). The survey-based biomass projection model predicts ~20 thousand tons for the first wave in Beauchene up to the 10th of March, whereas the fisheries-based Delury estimation of the first wave of recruits for the Beauchene area was ~24 tons. Recall that in the report of the second season 2004 (Anon. 2004b) the survey-based biomass projection model predicted ~20 thousand tons for the Beauchene area whereas the fisheries-based Delury model estimated 17 thousand tons. We see then that the two methods of assessment that we have developed and that are based on different data and mathematical models, give broadly coincident results. In particular, the survey-based methodology cannot of course predict events such as a second wave of recruitment in mid season. A more complex mathematical model connecting historically the spawning biomass with recruitment and environmental variables would be required for such an enterprise.

In this report we introduce a new procedure to calculate the spawning stock biomass. We have defined a fixed spawning date as the 30th of May and then we have used the biomass projection model of Anon. (2004c) to project the biomass left for each wave up to the spawning date. This projection is shown in Fig. 10. It is seen that by the chosen date the age of maximum biomass productivity of the cohorts have passed and they have started to decline. It is expected that after this date the biomass will collapse as many animals die after spawning. The spawning stock biomass is estimated as 86144 tons.

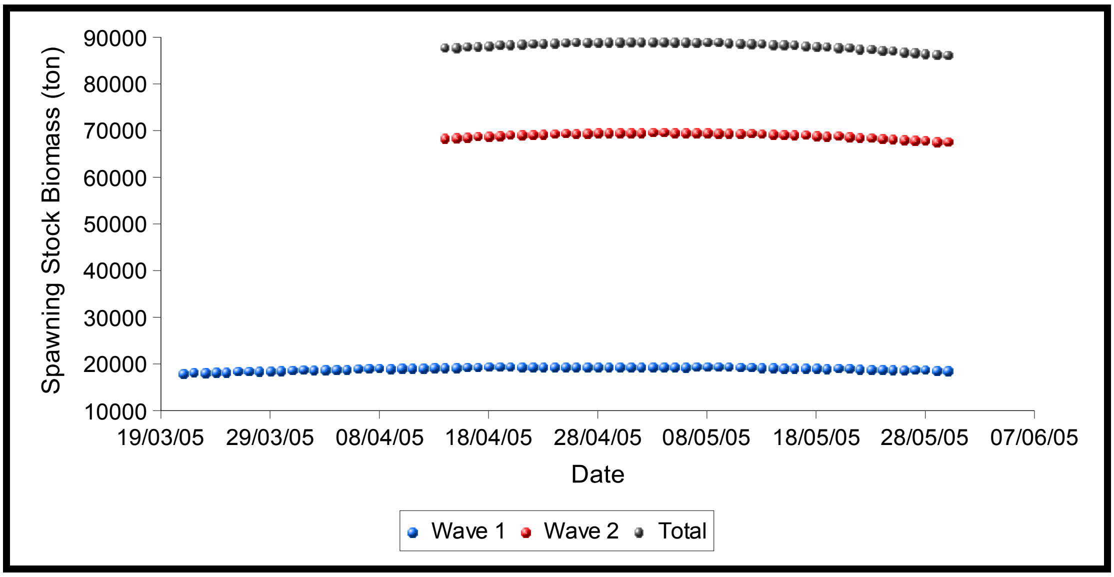

Fig. 10. Loligo biomass projected to the assumed fixed spawning date using the biomass projection model of Anon. 2004c.

CONCLUSIONS

1) Total catch (24605 tons) was closer to the highest values on record for the last 10 years although total effort (7692 hours of trawling) was the lowest on record.
2) Two waves of recruitment were observed, and the second one was comprised of larger individuals.
3) Initial biomass of the first wave of recruitment was estimated as ~24 thousand tons whereas initial biomass of the second wave was estimated as ~94 thousand tons.
4) The spawning biomass left after the season was estimated as ~86 thousand tons so that the management target of 10 thousand tons was amply met.

REFERENCES

Anon. 2004a. Review and Modified Implementation of Rosemberg et al. DeLury Model. Technical Memo, Falkland Islands Fisheries Dept.

Anon. 2004b. Loligo gahi, Second Season 2004. Fishing Statistics, Biological Trends and Stock Assessment. Technical Document, Falkland Islands Fisheries Dept.

Anon. 2004c. 2004. Loligo stock assessment survey. Technical Document, Falkland Islands Fisheries Department.

Arkhipkin AI, Roa-Ureta R. In Press. Identification of growth models for squids. Marine and Freshwater Research.

Csirke J. 1986. Review of the state of the fishery resources in the south-west Atlantic with particular reference to the Patagonian offshore fisheries. Mimeo.

Hewitt DA, Hoenig JM. 2005. Comparison of two approaches for estimating natural mortality based on longevity. Fish. Bull. 103:433-437.

Hoenig JM. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82:898-903.