Falkland Island Fisheries Department

Fishery Report

Loligo gahi, Second Season 2005

Fishery Statistics, Biological Trends and Stock Assessment

November 2005

SUMMARY

Results of stock assessment for the last three *Loligo* seasons are presented jointly in this report, starting with an introductory account of the innovations introduced since the Falkland Islands Fisheries Department started to assess this stock locally. The total catch in the second season (July/15-September/30, 2005) by the *Loligo* fleet was 29659 tons, the highest since 1996, and total effort was 17658 hours of trawling, close to average. Virtually all the catch was taken from the Beauchene and the North regions with negligible activity in the Central region. Biological trends in proportion of mature individuals showed that sexual maturation started earlier than in previous years and that the squid were of larger size. Initial biomass in the whole Loligo box was estimated as close to 47191, a rather low figure when compared to the previous two seasons. Only 8665 tons were estimated as spawning biomass. A sudden drop in catches and a concurrent drop in stock biomass was observed in Beauchene and North during mid-season. This fact as well as the early maturation of squid strongly suggest that migration to inshore waters started early. Therefore stock assessment results might have produced an overestimation of catchability and an underestimation of initial biomass. The initial biomass projected from the surveys was always lower than the biomass estimated from the fisheries-based stock depletion model but it correctly captured the general trends in abundance.

INTRODUCTION

From the second season of 2004 we have implemented new procedures for the stock assessment of the *Loligo gahi* stock, which have been in use for the last three seasons. In this report we present the results of these three season together in order to gain perspective on the merit of the new procedures as well as to present the situation of the stock in the second season of 2005. These new procedures have been introduced as stock assessment work on *Loligo* has been transferred from the Imperial College's Renewable Resource Assessment Group (RRAG) to the Falkland Island Government Fisheries Department (FIFD).

The following list describes the main differences between RRAG's methods and FIFD methods currently in use.

1) A new mathematical model has been introduced, the Biomass Projection Model (BPM), which uses the results of a survey performed before the season starts, plus information on squid growth rates that have already been published in the scientific literature (Arkhipkin and Roa-Ureta 2005). The BPM makes a short-term prediction of the biomass that will be observed at the start of the coming season from the date when the survey was carried out.
2) A new implementation of the Stock Depletion Model (SDM, also known as DeLury model, see Anon. 2004a) has been programmed in Automatic Differentiation Model Builder (ADMB) and is now in use instead of RRAG's program MSquid. The new SDM is more comprehensive than MSquid's SDM because the fit of the model is performed with respect to two parameters, initial abundance and catchability, whereas MSquid's SDM was only optimised in relation to initial abundance.

3) The old MSquid analysis assumed that there was a single depletion episode occurring in the whole *Loligo* box whereas the new SDM considers that there might be at least three separate depletion episodes occurring in different regions (North, Central, and Beauchene, **Fig. 1**). This seems to be more realistic since the fleet switches regions as the captains try to keep the highest possible catch rate.
4) The fit of the new SDM is performed using a better likelihood function than the one implemented in MSquid in the sense that it better preserves the uncertainty in the data.
5) The new SDM uses fishing effort units in vessel-days rather in hours of trawling, so that there is no statistical error in the independent variable and the statistical model is thus greatly simplified.
6) The new SDM ignores any internal structure in the fleet whereas MSquid was fixed to consider four GRT groups of vessels.
7) The new SDM uses a daily time step rather than a weekly time step as used previously in MSquid.
8) Both the BPM and the SDM depend on an unknown parameter related to natural mortality in the stock. Previous assessments by RRAG used the fixed value of 0.009 day^{-1} but that value appears to be inconsistent with the known longevity of *Loligo gahi* (~360 days). We have introduced a new fixed value using an empirical equation published in the scientific literature (Hewitt and Hoenig 2005) and that takes into account the known *L. gahi* longevity. The current value is 0.0133, ~48% higher than the previous one, so now squid are assumed to die naturally at a much higher rate.
9) The BPM is also used to project the biomass remaining at the end of the season into an assumed date of spawning (15/June for the first cohort and 15/October for the second cohort) so that there is a now a better concept of 'spawning biomass'.

There has been a change too in this season's assessment in relation to our two previous assessments. Because we separated the *Loligo* box into three main regions where separate depletion episodes took place, then the issue of what to do with days when in a given region the size of the fleet was small arisen naturally. This issue appeared important if there was a strong vessel-competition effect on daily catches. In the second season of 2004 we set an arbitrary threshold fleet size of 13 vessels to include a given day into the fit of the SDM. Days when the fleet was smaller in a given region were simply discarded. The problem with that solution is that many days of valuable data are lost to the model. The issue was unimportant in the first season of 2005 because the abundance was very high in Beauchene and the fleet did not move from that region. The latest season, second season of 2005 has given us a chance to look at that problem again. We have now arrived to the conclusion that it is better to ignore any possible vessel-competition effect so we can use all the data that the fishery generates to fit the SDM. Thus the SDM has been simplified by elimination of an arbitrary parameter and we have re-run the SDM for the second season of 2004 and the first season of 2005. The figures reported here for initial biomass and the other parameters in the model should be considered as superseding the previous figures (in Anon. 2004b, 2005).

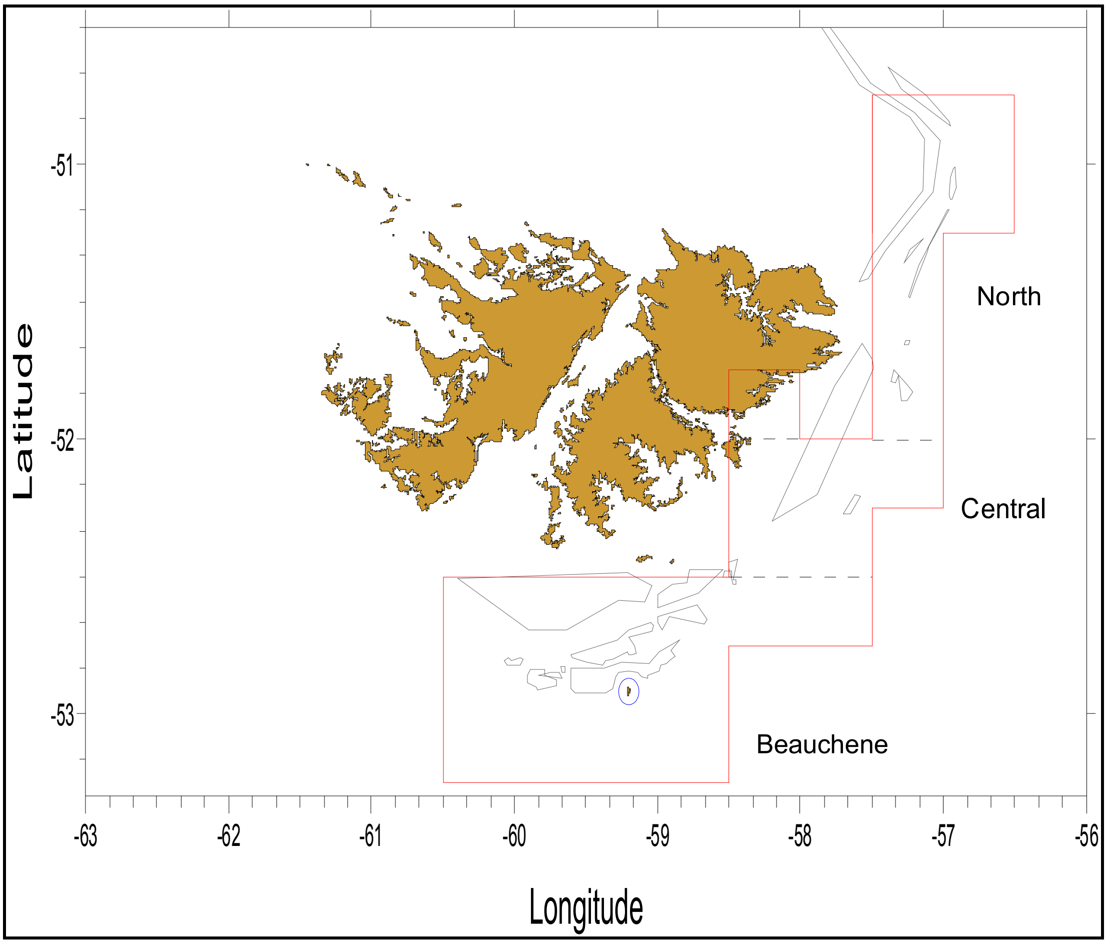

Fig. 1.- Fishing grounds and rocky bottom around the Falkland Islands. In red, the *Loligo* box, and in blue, the three-nm exclusion area around Beauchene Island.

PART 1 – FISHERY STATISTICS

Total Catch and Total Effort in Historical Perspective

Total catch in the second season of 2005 was the highest since 1996 whereas total effort in hours trawled was rather average (**Table 1**). The total catch was ~63% of the initial biomass and the latter was 75% of the initial biomass of the previous second season.

Table 1.- Fishery statistics and initial biomass for the known history of the *Loligo gahi* fishery of the Falkland Islands. 'Failure' indicates that stock depletion model could not produce a reasonable estimate of initial biomass. From 1970 to 1985 the source is Csirke (1986), from 1987 to the present the source is either RRAG (for initial biomass up to 2003) or FIFD (catch and effort and initial biomass from 2004).

Year	Semester 1			Semester 2			Year Total Catch (ton)
	Catch (ton)	Effort (h)	Initial Biomass (ton)	Catch (ton)	Effort (h)	Initial Biomass (ton)	
1970							200
1971							100
1972							100
1973							250
1974							200
1975							140
1976							129
1977							354
1978							911
1979							925
1980							1111
1981							631
1982							18452
1983							38256
1984							36450
1985							36430
1986							
1987	64063		101000	18484		202000	82547
1988	48664		115000	5267		39000	53931
1989	106186	33159	165000	11671	16881	46000	117857
1990	69366	24177	206000	13624	15713	104000	82990
1991	37353	13808	53000	16462	16610	146000	53815
1992	48157	15406	97000	35227	19291	264000	83384
1993	23567	16065	47000	28711	32950	90000	52278
1994	35502	19891	55000	30254	29687	116000	65756
1995	60293	10913	195000	37486	22365	141000	98409
1996	38679	16438	31000	22694	28420	130000	61373
1997	15962	16766	40000	10159	18486	82000	26121
1998	33379	16835	60000	18178	22762	Failure	51557
1999	22863	19642	44826	12008	18266	53737	34871
2000	38713	21034	63683	25781	18869	Failure	64494
2001	27624	20955	26000	25935	19841	162234	53559
2002	14198	20824	21000	9513	11570	Failure	23711
2003	18973	8494	40350	28447	16166	Failure	47420
2004	8609	8740	Failure	18229	17024	62732	26838
2005	28747	7292	114878	30047	17658	47201	58794

Catch and Effort per Fishing Ground and Cumulative Catch

Virtually all fishing was carried out in the Beauchene and North regions with negligible activity in the Central region (**Table 2**). The daily cumulative catch was very close to the best season on record though it flattened out in the last part of the season (**Fig. 2**).

Table 2.- Effort and catch statistics of *Loligo* second season 2005 (15/July to 30/September) by fishing ground by the *Loligo* fleet.

Fishing Ground (Region)	Total Catch (ton)	Effort (Vessel-Day)	Average CPUE (ton/vessel-day)
Beauchene	15434	583	26.473
Central	704	44	15.998
North	13521	559	24.188
Total	29659	1186	25.008

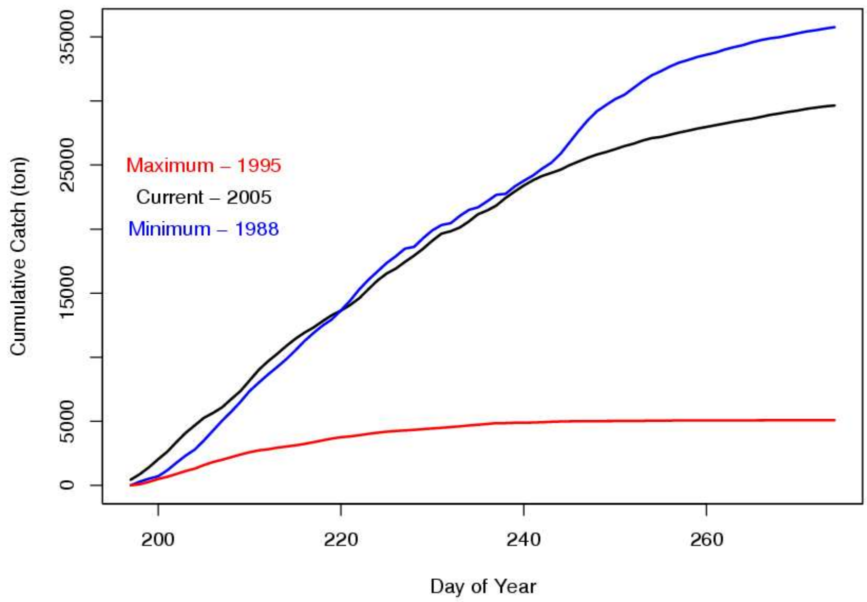

Fig. 2.- Cumulative catch versus date in the second season of 2005 compared with the cumulative catch of the second seasons that yielded the highest and lowest catches on exactly the same date range (displaced back 15 days to cover the same period of time).

Fleet Movement Dynamics, Catch and Catch Rate

During the season the fleet showed a very dynamic spatial behaviour switching between Beauchene and North (**Fig. 4**, top). During the first 25 days the catch was taken mostly from the North but then it dropped sharply and the fleet moved to Beauchene (**Fig. 4,** middle). The catch in Beauchene fell sharply too by the end of August and the last month the fleet was equally allocated between the two regions and the catch was low (**Fig. 4,** middle). Given that the total effort remained relatively constant (**Fig. 4**, top) and the catch suffered sudden decliness (**Fig. 4**, middle) the catch rate presented the same decline as the catch in Beauchene and North (**Fig. 4,** bottom). These declines were stronger than in the previous second season of 2004, when the decline of catch rates was gradual, as expected from a depletion process with relatively constant effort, implying that in this recent second season some other processes, like early emigration, affected the stock in the fishing grounds.

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 were two observers on two different vessels taking a sample of 200 animals from every other trawl. Thus our results in this part are affected by sampling variation.

The proportion of sexually mature squid in the catch shows that both females (**Fig. 5**, top) and males (**Fig. 5**, middle) started maturing rather early in the second season. The proportion of females in sex ratio decreased gradually during the second season though it recovered to a balanced proportion in the last few days (**Fig. 5**, bottom).

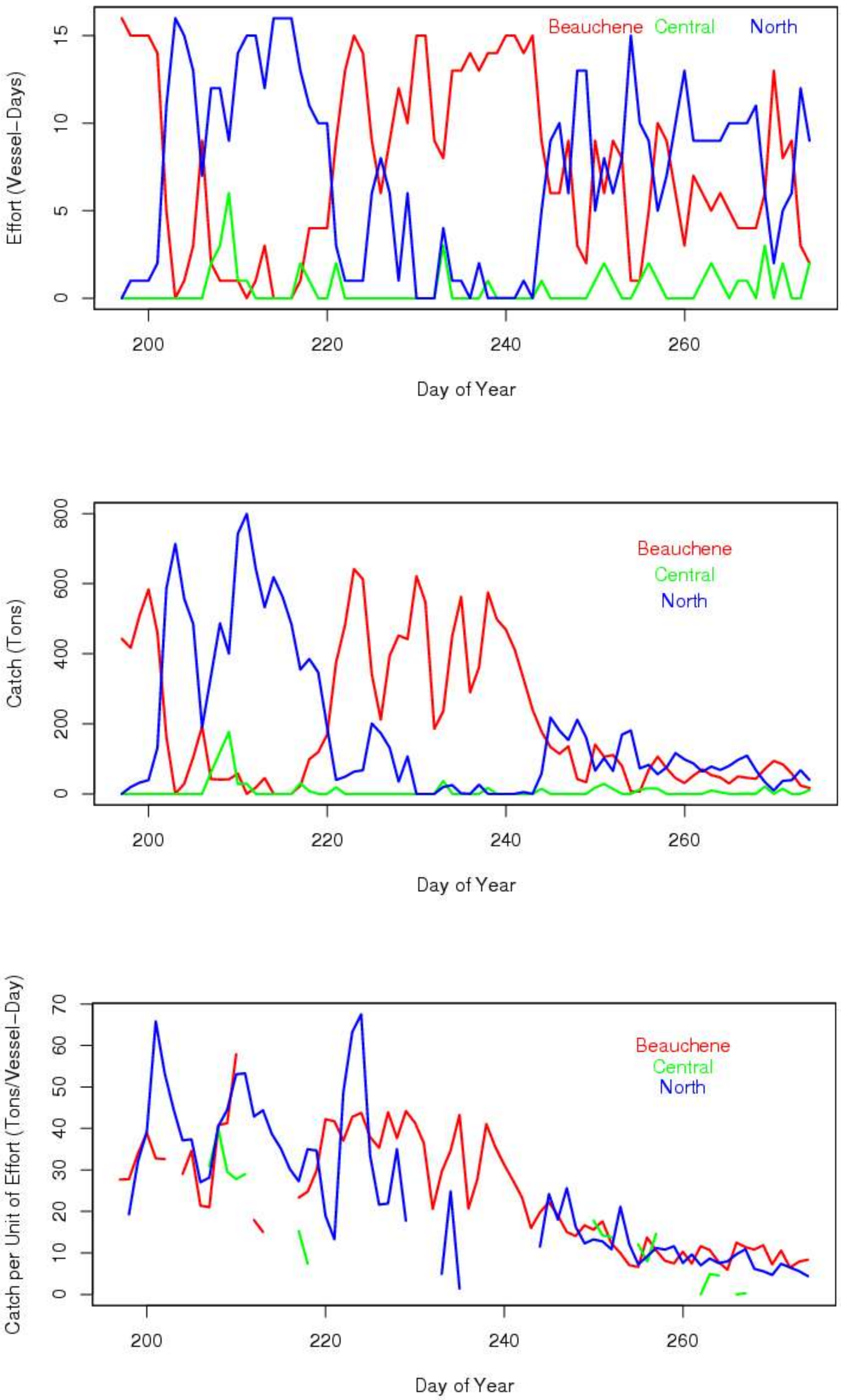

Fig. 4.- Evolution of the effort, the catch, and the catch rate in the three major regions.

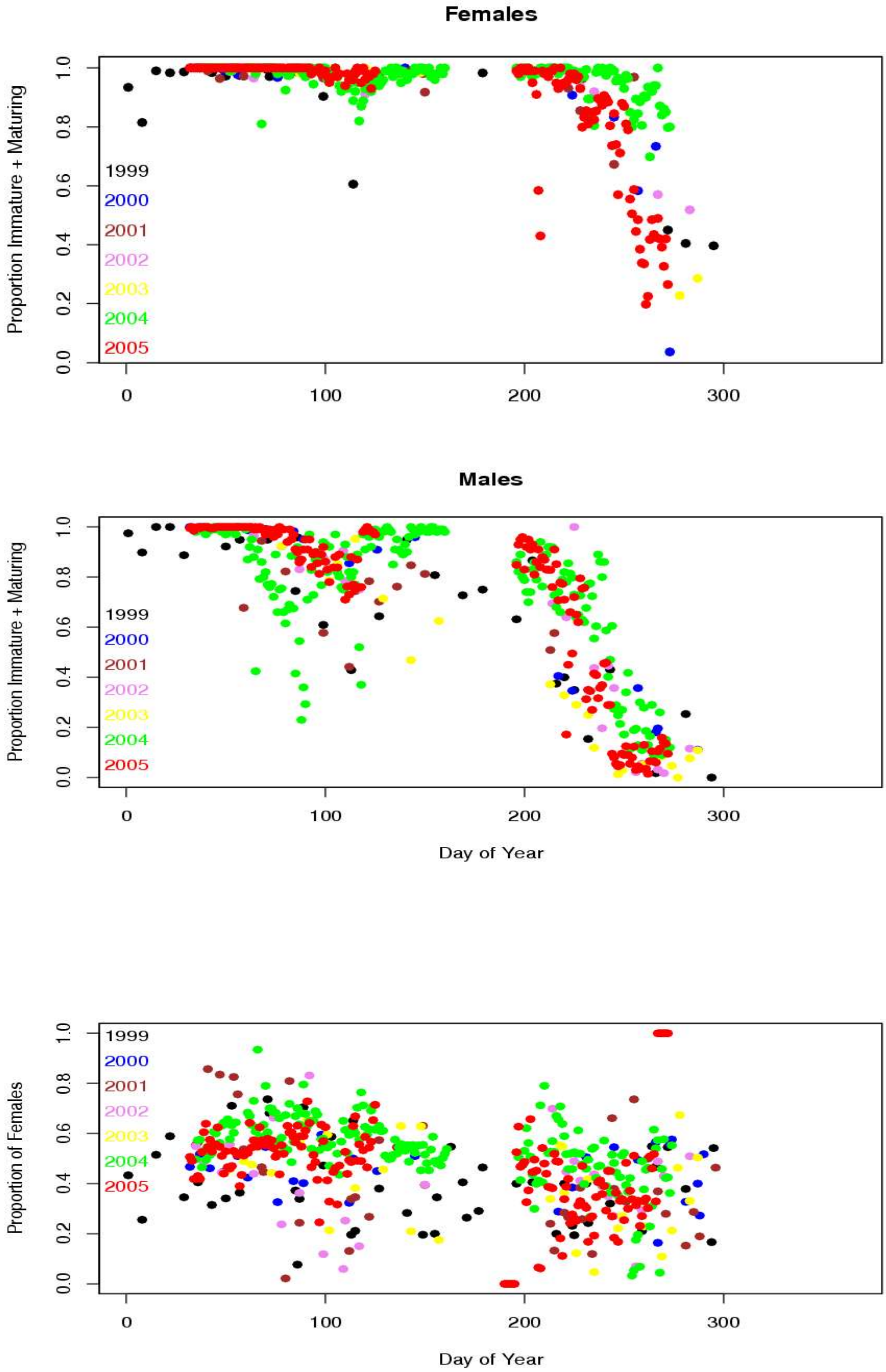

Fig. 5.- Evolution of the proportion of sexually immature females, males, and evolution of the proportion of females in the whole year in the last 7 years.

Squids of both sexes were consistently of bigger size than in previous second seasons (**Fig. 6**). Larger squid appeared by the end of the season in both sexes and in males the spread of mantle lengths also increased towards the end of the seaso (**Fig. 7**).

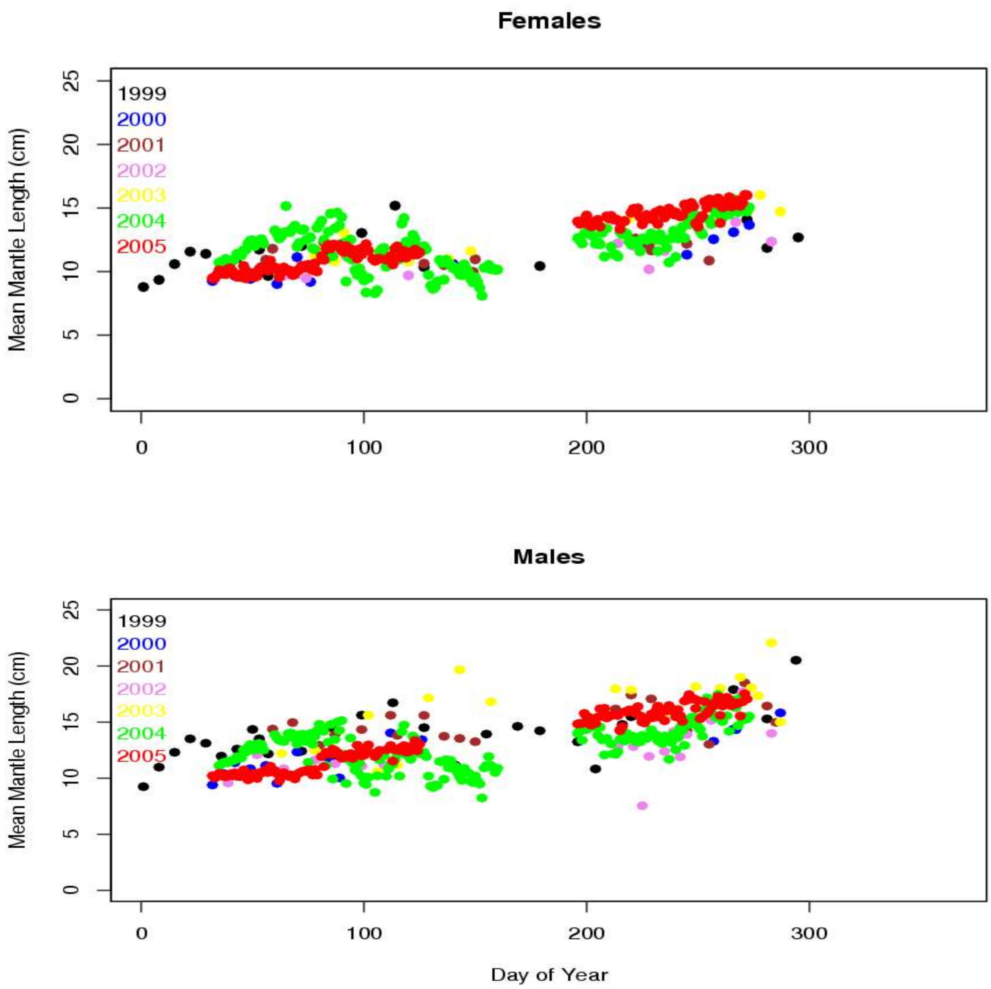

Fig. 6.- Evolution of the daily mean mantle length of females and males in the whole year for the last seven years.

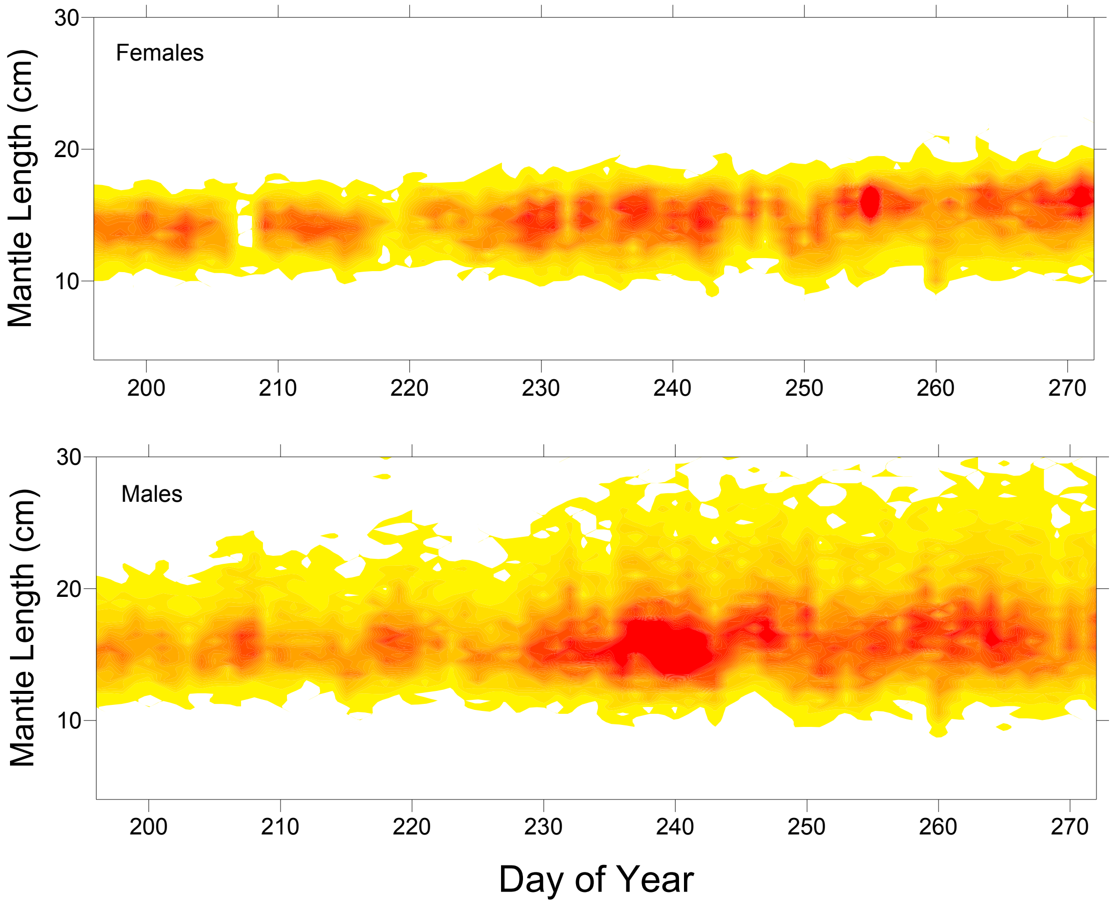

Fig. 7.- Full daily evolution (19578 females and 33426 males) of the squid size spectrum in the sample during the second season 2005.

PART 3 – STOCK ASSESSMENT

The elimination of an arbitrarily-fixed parameter in the stock depletion model, namely the minimum size of the fleet to include a given day of data in the stock depletion model, has produced a significant change in the results of the assessment in the second season of 2004. Thus in this report we have collected the results for all three seasons that have been studied under the new methods (second season 2004, first season 2005, and second season 2005). For completeness, we also compile here the results of the survey-based biomass projection model.

The model predicted ~30 thousand tons at the 15th of July 2004 for the whole fishing grounds, ~38 thousand tons at the 1st of March 2005 for the Beauchene region, and ~19 thousand tons at the 15th of July 2005 for the whole fishing grounds (**Table 3**). In relation to the last result, it must be taken into account that females were under-represented and probably have not yet fully migrated into the fishing grounds. Carrying over the sources of uncertainty for the three total biomass projections indicates that these estimates are not very precise (**Table 3**).

Table 3.- Abundance input and output of the *Loligo gahi* biomass projection model from three surveys. Numbers in parentheses are the measures of statistical precision as percentage of the estimate; the lower this number the more precise the estimate.

	Survey 1 2nd Cohort 2004	Survey 2 1st Cohort 2005	Survey 3 2nd Cohort 2005
Survey Dates	2/May to 12/May	1/Feb to 14/Feb	28/Apr to 14/May
Season Dates	15/7 to 30/9	1/3 to 14/4	15/7 to 30/9
Vessel	Argos Vigo	Capricorn	Robin M. Lee
Number of trawls	34	49	53
Number of spatial observations	300	328	277
Estimate of the Number of Females (10^6)	570.5 (75.07)	668.7 (85.73)	263.7 (64.42)
Estimate of the Numbers of Males (10^6)	490.2 (77.19)	559.8 (89.53)	525.3 (61.81)
Initial Projection Date	8/May	10/Feb	6/May
Estimate of Total Initial Biomass (ton)	26776 (54.22)	36025 (62.30)	28711 (48.58)
Final Projection Date	15/Jul	1/Mar	15/Jul
Estimate of Total Projection Biomass (ton)	29628 (54.53)	38196 (62.32)	19963 (52.01)

During the second season of 2004 the highest abundance was estimated in the Beauchene region (**Table 4**). The initial biomass projected from the survey-based estimate was 47% of the initial biomass in the fisheries-based model (**Tables 3, 4**). A gradual decline of daily catch was observed in the three regions (**Fig. 8**). The stock biomass declined gradually along the season and arrived at similar low values in Central and North (**Fig. 9**). The spawning biomass was dominated by males (**Table 5**). During the first season of 2005 the fleet fished exclusively in the Beauchene region. During the first 21 days the fleet fished mostly inshore of the Beauchene Island but also offshore, and thereafter they fished exclusively offshore Beauchene Island. The last 12 days of the 21-days period yielded a variable but consistent depletion trend for the first depletion episode (**Fig. 10**). The final 24 days of the season yielded a clear though weak depletion process (**Fig. 10**). The abundance of the stock was very high (**Table 4**). The initial biomass projected from the survey was 33% of the initial biomass from the fisheries-based model (**Tables 3, 4**). The stock biomass was barely affected by fishing (**Fig. 11**). The spawning biomass was very high with homogeneous parts for both sexes (**Table 5**). During the second season of 2005 the estimated abundance was the lowest of the three seasons (**Table 4**). The contribution of the North region was more important than in the previous second season and relatively similar in magnitude to Beauchene (**Table 4**). The initial biomass projected from the survey was 42% of the initial biomass estimated by the fisheries-based model (**Tables 3, 4**). Both regions had similar final biomass at the end of the season and there was a rather sudden drop in stock biomass at different moments in Beauchene and North (**Fig. 12**). The spawning biomass was dominated by males (**Table 5**). The sudden drop in catch and biomass, as well as the early maturation in both sexes, strongly suggests that the migration to inshore waters started earlier. Therefore, the catchability reported hare can be overestimated and the initial biomass underestimated.

Table 4.- Stock assessment of *Loligo gahi* in the Falkland Islands by a stock depletion model. Numbers in parentheses are the measures of statistical precision.

	2nd Season 2004			1st Season 2005		2nd Season 2005		
Parameter	Beauchene	Central	North	Beauchene Inshore	Beauchene Offshore	Beauchene	Central	North
Starting Date	15/07	16/08	28/07	10/03	22/03	10/08	25/07	21/07
Final Date	30/09	30/09	30/09	21/03	14/04	30/09	30/09	30/09
N° of days	66	16	58	12	24	52	25	39
Period (days)	78	56	65	12	24	52	68	73
Catchability	5.9×10^{-4}	3.4×10^{-3}	2.7×10^{-3}	1.6×10^{-3}	5.6×10^{-4}	2.3×10^{-3}	3.7×10^{-2}	2.1×10^{-3}
(1/vessel-day)	(5.4)	(9.9)	(14.9)	(2.9)	(5.5)	(1.2)	(703.5)	(25.6)
Initial numbers	8.5×10^{-1}	1.4×10^{-1}	2.7×10^{-1}	8.8×10^{-1}	2.6	3.2×10^{-1}	1.6×10^{-2}	4.1×10^{-1}
(billions)	(23.0)	(50.3)	(3.0)	(10.7)	(2.5)	(5.4)	(363.5)	(8.3)
initial biomass	42239	6983	13510	22155	92723	20417	1070	25714
(ton)	(39.6)	(61.2)	(34.0)	(44.8)	(37.4)	(30.2)	(365.7)	(32.0)
Final Numbers	2.2×10^{-1}	3.3×10^{-2}	4.4×10^{-2}	5.6×10^{-1}	1.6	6.2×10^{-2}	1.4×10^{-3}	5.6×10^{-2}
N_T (billions)	(31.1)	(100.9)	(21.0)	(14.2)	(3.1)	(13.9)	(2778.4)	(53.5)
Final Biomass	15191	2229	3009	15828	60047	5203	112	4505
(ton)	(49.2)	(107.8)	(43.6)	(43.7)	(36.9)	(39.8)	(2778.6)	(56.4)

Table 4.- Biomass of squid projected from the end of the season with starting numbers as estimated from the stock depletion model. The numbers in parentheses are the measures of statistical precision.

	Dates	Females	Males	Total
Second Season 2004	30/09 to 15/10	6199	14522	20721
		(29.7)	(32.3)	(24.3)
First Season 2005	21/03[1] and 14/04[2] to 15/06	35801	42307	78108
		(12.8)	(7.2)	(7.0)
Second Season 2005	30/09 to 15/10	2818	5847	8665
		(43.7)	(52.2)	(38.0)

[1]Inshore Beauchene and [2]Offshore Beauchene

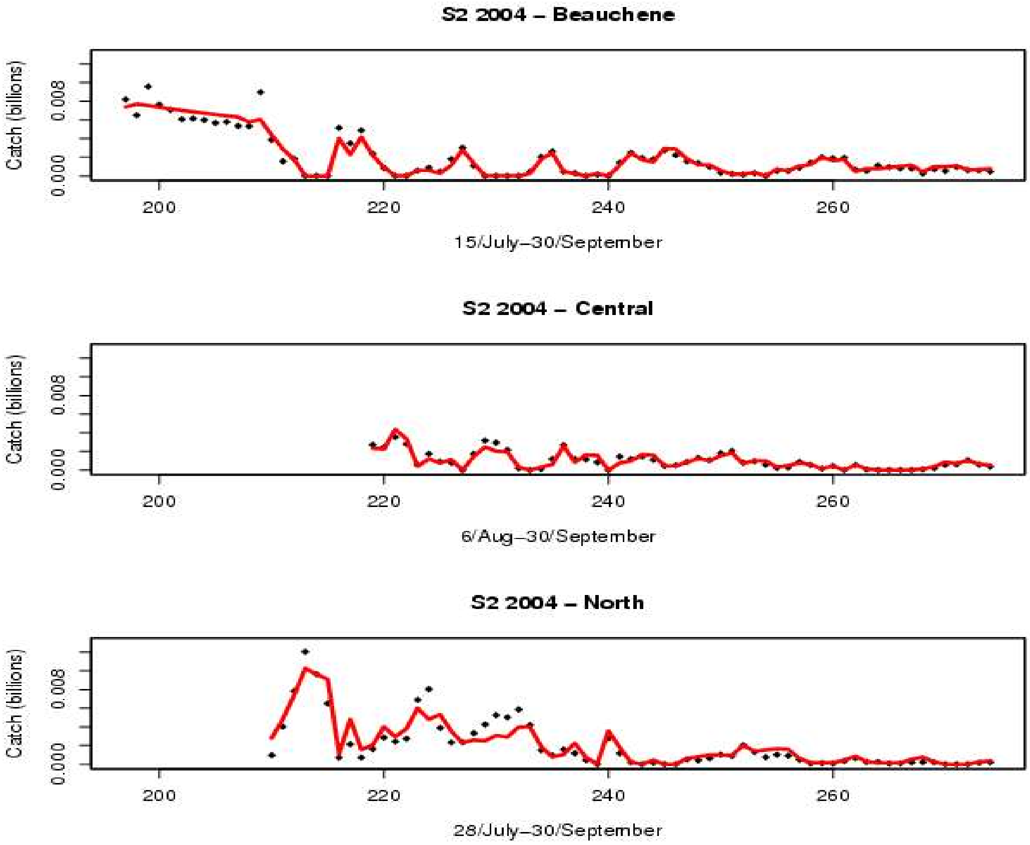

Fig. 8.- Observed daily catch in numbers (dots) and predicted daily catch in numbers by the stock depletion model in the 2nd season of 2004.

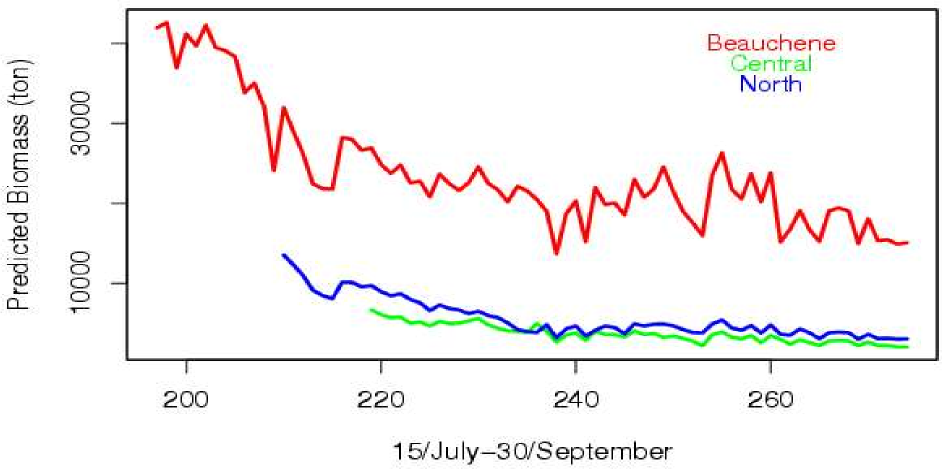

Fig. 9.- Biomass trajectory in three major regions during the 2nd season of 2004.

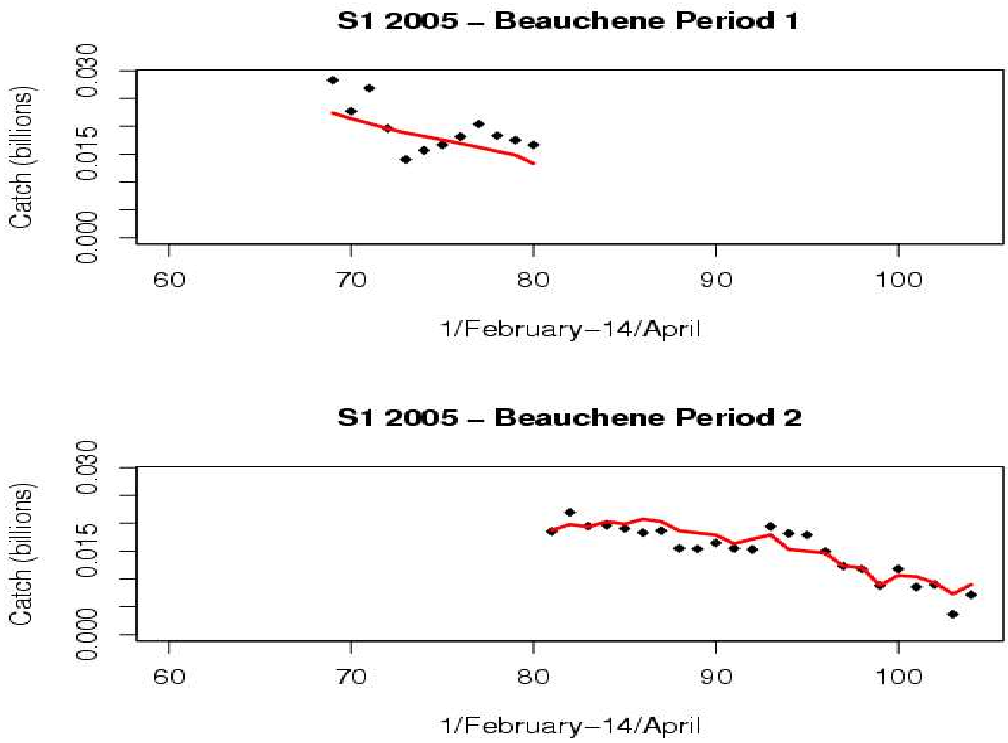

Fig. 10.- Observed daily catch in numbers (dots) and predicted daily catch in numbers by the stock depletion model in the 1st season of 2005.

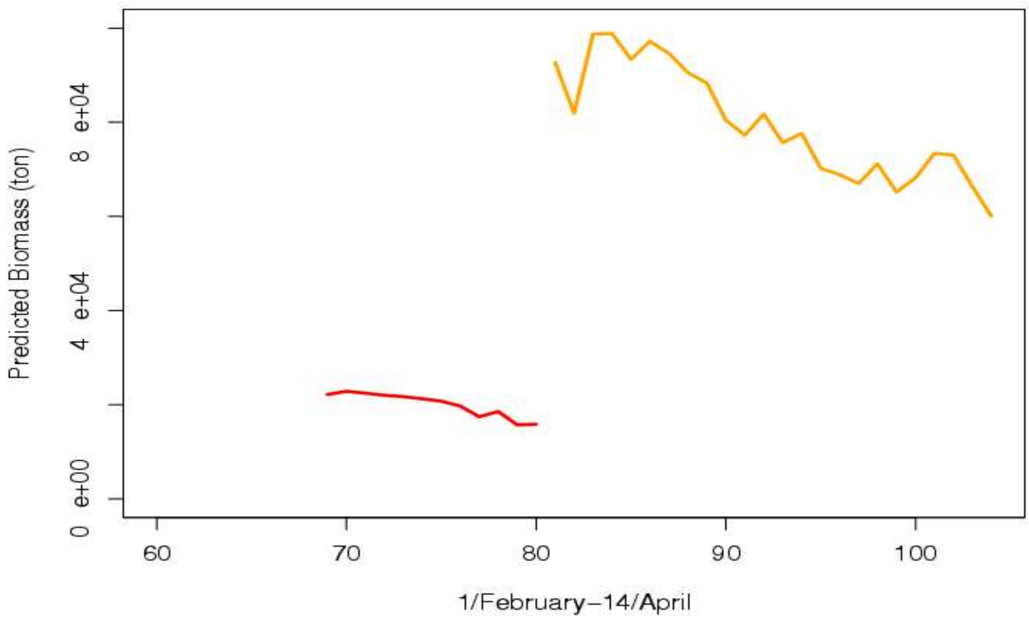

Fig. 11.- Biomass trajectory of two pulses of recruits in Beauchene during the 1st season of 2005.

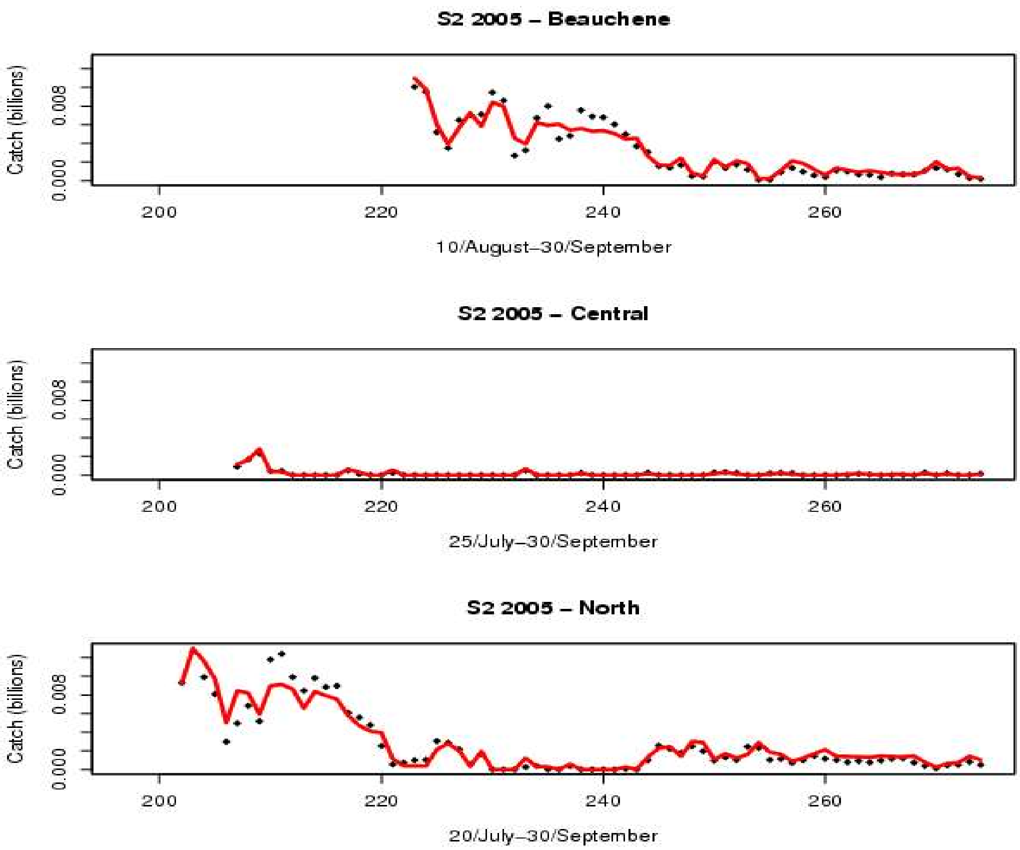

Fig. 12.- Observed daily catch in numbers (dots) and predicted daily catch in numbers by the stock depletion model in the 2nd season of 2005.

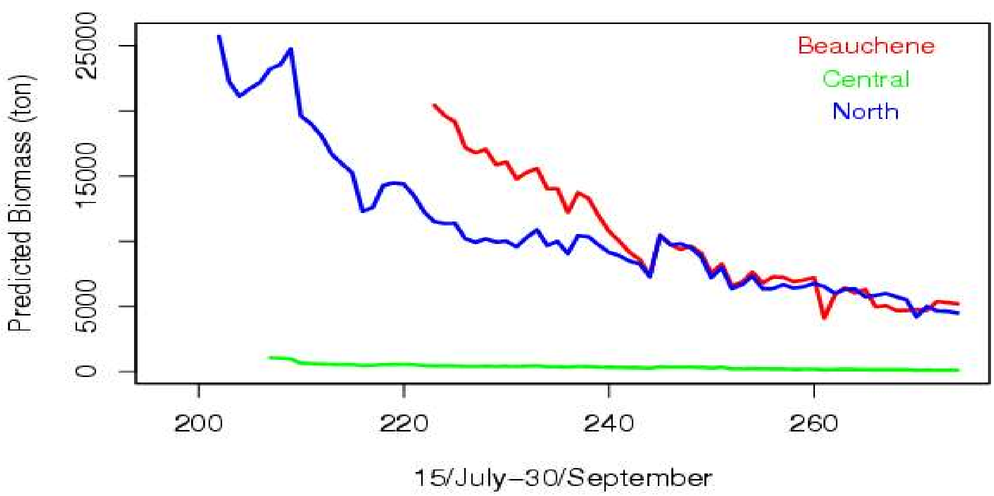

Fig. 13.- Biomass trajectory in three major regions during the 2nd season of 2005.

CONCLUSIONS

1.- Total catch (29659) in the second season of 2005 was the highest for a second season since 1996 whereas total effort (17658 hours) was average.

2.- Squid became sexually mature earlier and were of bigger size than in previous years.

3.- Sudden drops in catch and stock biomass during the season and early sexual maturation of squids suggest that migration had started during the season. Thus it is possible that the stock depletion model over-estimated catchability and under-estimated initial biomass because in its current stage of development, the model does not account for migration.

4.- The estimated initial biomass (~47191) was rather low but this estimate might have been affected by early emigration of the squid.

5.- Both the biomass at the end of the season and the spawning biomass were under the 10 thousand tons management target but these figures probably are under-estimates due to the effect of early migration on the stock depletion model.

6.- The second *Loligo* season of 2005 has shown that the stock depletion model developed by FIFD in the last two years need to be extended to include the possibility of early migration during the second season.

7.- The biomass projected from the pre-season survey is always lower (from one half to one third) than the biomass estimated from the fisheries-generated data but the general trend of abundance (highest for the first cohort of 2005, intermediate for the second cohort of 2004, and lowest for the second cohort of 2005) was correct..

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