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ICES CM 2002/V:14 **Unaccounted Mortality in Fisheries**

Some sources of variation in the assessment when introducing unaccounted mortality due to discarding practices. The case of Southern Four spot megrim stock.

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Abstract

Four spot megrim (*Lepidorhombus boscii*) is widely distributed in Atlantic waters form Iceland to Cape Bojador. In ICES Divisions VIIIc and IXa, Portuguese and Spanish ships captured this species as by-catch mainly in mixed bottom trawl fisheries. Only one exploitation unit of this species is assessed (from Divisions VIIIc and IXa) in the ICES Working Group of Hake, Monk and Megrim. Discard data are not used in the assessment of this species, though they are considered significantly high for younger ages. Discards data are available for Spanish trawlers for 1993, 1994, 1997, and the period from 1999 to 2001. A simulation using discard data was made to avoid the underestimation of mortality and recruitment. Due to the change in January 1990 in the minimum legal size for this species in this area, it was decided not to use historical information previous to this year, as it is supposed that this change could substantially affect the fleet discard pattern. Different options were considered as the way of raising: by effort (number of trips, hour of trawling) or by landings (in weight or in number). Reasons for the final choices are explained for all options considered. The way to introduce discards data in the VPA procedure for assessment was through the catch at age matrix since we considered that no fish of this species survive after being discarded. Differences in yield of Short-term and Medium-term projections were observed.

Keywords: discard mortality, assessment, simulation, *Lepidorhombus boscii*.

Introduction

In many fisheries, discards constitute a major contribution to fishing mortality in younger ages of commercial species. However, relatively few assessments in ICES stock working groups take discards into consideration. This happens mostly due to the long time series needed (not available for all the fleets involved in the exploitation of most stocks) but also to the large amount of research effort needed to obtain this kind of information.
Discard data are not essential to obtain the historic trends of Spawning Stock Biomass (SSB). Nevertheless, discard data are useful for tuning the assessment related to recruitment variability. Furthermore, estimation of commercial vessels' discard weight is essential when discarding may cause a reduction of the yield in medium and long-term projections and has effects on management measures and in the settlement of biological reference points which rely on recruitment variability (Lart *et al*., 2002).
Eluding the discard estimation could also cause a bias in the recruitment and fishing mortality (F) estimates of VPA (Virtual Population Analysis) in the assessment of mixed-fisheries in which discards have a high relevance. This is the case of the Spanish trawl fleets, noted for being mixed fisheries with continuous changes in the target species, and based on a large range of species (including horse mackerel, blue whiting, mackerel, hake, two species of anglerfish and

megrim, Norway lobster, pout or different cephalopods). These Spanish fleets represent approximately 90% of the total international landings of Southern four spot megrim stock (Divisions VIIIc and IXa).
Apart from the advantage of using discards in assessments, fisheries monitoring with observers on board increases the detail and accuracy of the basic information and also supports management decisions to improve the conservation of exploited stocks. The knowledge of discards and their use in stock assessment may also contribute, in co-operation with the industry, to refine fishing and management strategies (Kulka, 1999).
The aim of this paper is to compare the VPA results with and without discards for Southern four spot megrim stock (Divisions VIIIc and IXa). The use of discard information was implemented to improve the stock assessment and to compare results of trends in catches, mean F, SSB and recruitment and yield in a medium and long term projection. They would illustrate the need to use discard data in stock assessment.
The discard information has been obtained with observers on board and financial assistance of the Commission of the European Communities and the Instituto Español de Oceanografía (IEO). It covers the activities of some of the most important Spanish fleets (trawlers in ICES Divisions VIIIc and IXa)

Material and Methods

Southern four spot megrim (*Lepidorhombus boscii* in Divisions VIIIc-IXa, ICES CM, 2002), was chosen to explore different assessment options, with and without discards. VPA assessment (ICES CM, 2002) was tuned only with one fleet, a Spanish survey (in which information on discards it is not necessary), avoiding estimations of discards for commercial tuning fleets.

Data collection
The available discard information was obtained from consecutive international and national studies carried out with observers on board demersal heavy trawling vessels ("Baka" type) operating in ICES West and Central area of Division VIIIc and Northern area of Division IXa.
The information obtained by the observers covers discarded and retained catch in weight and numbers and length distributions for Southern four spot megrim, among other species, for the years 1993, 1994, 1997, 1999, 2000 and 2001. The sampling level in the years 1993 and 2001 is considered to be low. Allen *et al.* mentioned in 2002 that a need for sampling Baka trawlers of an average of seven hauls per trip requires either one trip of 39 vessels or two trips of 25 vessels to obtain a CV of 20%. Those values are far away from the 1993 and 2001 sampling levels, but achieving such a high level means a strong investment that has been only fulfilled in scarce occasions. Since 1999, age at length keys (ALKs) on discarded fish have also been available. From 1990 to 1997 the same ALKs were applied to discards and landings. In cases in which no otoliths were available for small discards sizes, the Spanish survey sampling otoliths were used.
With this information, it was possible to obtain discard rates calculated as mean discard per haul/mean retained catch per haul (in weight and number), for each of the years mentioned. The per year discards sampling level with observers on board is presented in Table 1.

Landings Data
Portuguese and Spanish information on landings (number and weight at age), landings and stock mean weights at age, mature proportion and natural mortality, came from the values estimated by the ICES Working Group on the Assessment on Hake, Monk and Megrim (WGHMM) (ICES CM, 2002).
Although the earlier ICES information for the assessment corresponds to 1986, only values from 1990 were used for the simulations. This was done in order to avoid the very likely change in the exploitation pattern (especially in short lengths, more affected by discarding) due to the 1990 change in the MLS from 25 cm to 20 cm (Regulation (CEE) n 4056/89). Selecting this year range also avoided the use of mean ALKs (ICES Working Group assessments for the years prior 1990).
Only abundance indices (ages 0 to 7) from the Spanish Demersal Survey (ICES CM, 2002) were used for the different Virtual Population Analysis (VPAs) in order to estimate Recruitment, SSB and F. This fleet was the only one used by the WGHMM for tuning the four spot megrim assessment (ICES CM, 2002).

Choosing the raising method

An important source of variation in the discard estimations would be choice of the raising method. Several raising options are generally considered in discard studies (ICES CM, 2000): raising by effort (in number of trips or hours of trawling) and raising by landings (in weight or numbers), etc. For the present study, the only effort estimator available was the number of trips that was considered to be too rough for raising purposes. On the other hand, there are evidences that there is no relation between discards and trawling hours (Trenkel *et al*., and Lema *et al*., 2002). In addition, Pérez *et al.* (1999) found that the highest difference in the discards estimation appeared when raising by effort was used. Thus, raising by effort methods were not used. The only choice was between raising by landings in weight method and raising by landings in number. Due to the fact that differences in the results between the discards values obtained with each of the raising methods (by weight or numbers) were probably smaller than the error associated to both methods due to high CVs, the importance of the option chosen is minor. Both raising methods (weight or number) gave similar results in most of the years, although differences between both raising ways seem to be higher when discards were concentrated in a few length classes. As the discards estimates obtained by raising by landings in weight resulted in these cases higher than raising by landings in number, this weight method was chosen for simulations; thus the differences between assessments with and without discards are more highlighted. This was also considered to be the most precautionary choice.

Length distributions of total discards were obtained multiplying the length distributions of sampled discards of each year by the factor obtained dividing the weight of the sample (obtained through the length/weight relationship (BIOSDEF, 1998) by the total weight of discards (obtained through the raising method selected before).

Discard Estimation for the years in which discards sampling was not available.

Since the main reason for discarding this species (67% of the occasions) is being below the minimum legal size (MLS) (Lart, 2002) it is probable that the amount of discards could be correlated with the abundance of small age fish.

Two different ways of discards estimation were used to calculate discards numbers at age for years in which no discard information was available.

1. The age range in which discard occurs is from age 0 to 4. As there are no landings at age 0 for this species in the landings matrix (ICES CM, 2002) an Extended Survivors Analysis (XSA) was run with zero values at this age. This XSA was run to obtain an estimation of the stock number at age (start of year) using the abundance indices of Spanish Demersal Survey, as tuning fleet.
   Then, the relationship between stock numbers obtained from XSA and discards in number estimated from observers on board sampling was studied for the available years. A correlation analysis was performed for each age using the age data of both variables.
2. The other option was to use directly the abundance indices available from the Spanish Demersal Survey to obtain estimates of discard at age for age ranges in which discard occurs (from age 0 to 4 since 1990 to 2001). To study the relationship between the Spanish abundance indices and the discards in number for the available years a correlation analysis was performed for each age using both variables data at age.

The XSA abundance estimates were not used for these purposes due to the lower Pearson's coefficients for older ages. Pearson's coefficients for both options are presented in Table 2. Both estimation ways give a very low correlation coefficient for age 2.

Introducing discards information in the assessment

New matrixes were obtained to be used in the Virtual Population Analysis.

A new catch at age matrix was built adding the whole discards estimates in number to the landings at age matrix. It was assumed that no fish of this species survives after being discarded due to the long duration of the hauls and to the fact that most of the individuals are caught deeper than 150 m and raised suddenly in the haul.

A new age is added to the catch at age matrix (age 0) when including discards. That age did not use to appear in the landings matrix just because it is totally discarded on board, if caught.

A new mean weight at age matrix was built with the mean weights at age obtained from the age conversion of discards and landings.

Virtual Population Analysis
Two different options, with and without discards were run:
XSA without discard uses only ages 1 and older in the landings matrix and XSA with discards uses age 0 in the catch matrix and in the survey.
The two retrospective analyses were plotted to show any systematic pattern.

Projections
Short-term projections
For the catch/landings projections population numbers were taken from the final XSAs outputs. Stock size at age 1 for the following years was assumed to be GM90-99. The exploitation level or pattern used was the scaled average of 1999-2001. Mean weights in catch and stock were computed as averages for 1999-2001. The management options from the catch projection with and without discards and the short-term yield and SSB trends were estimated. The detailed output by age group was also estimated. Probability profiles of expected yield and SSB are also given.

Yield and biomass per recruit
The input data for projections are the same as used for the short-term. Results of the yield and SSB per recruit analysis are given and the stock-recruitment plot is shown.

Medium term projections
Medium-term projections were carried out for a period of 10 years (2002-2011) to estimate percentiles of the distribution of projected yield, SSB and recruitment at status quo F. A random bootstrapped recruitment over the whole period was used for estimating recruitment. Landings and SSB were projected. The percentiles that SSB<Bpa between 2002 and 2011, for F multipliers, were also estimated with both, landing and catch option.

Results

The discards sampling level for the years with observers on board vessels are presented in Table 1. Sampling was lowest in 1993 and 2001. Coefficients of Variation (CV) expressed as a percentage of the mean catch by haul of the discarded and retained catches by weight and number were estimated. In most years the discards showed high CVs. This was due to the seasonal variability in the catch composition over a year, and the variations between trips, ports and boats such as those described in Allen *et al*., 2002.
Discard data are not used in the this species assessment, though they are significant for younger ages (ICES, 2002). Discards of four spot megrim are estimated to be between 140 to 520 t every year while the discard rate in weight was between 13% to 33% (Table 3). Due to the fact that most individuals are young fish, this percentage reaching values between 39% and 74% when the discard rate is expressed in number.
Table 4 presents the discards and total catch estimations at age. Discard values are very high for age 1, especially before 1997. In 2001 discards estimation were very low for all ages. Null discards at age 0 in 1993 is in relation to the extremely low 1993 year classes (ICES, 2002).
Table 5 shows landings weight at age were taken from ICES GWHMM (ICES, 2002) and catches weight at age were taken from the values estimated.
Figure 1 shows the very low residuals for all the ages observed in the Spanish survey tuning fleet for the two XSA runs (with and without discards) and significant trends were not observed. In the XSA estimates, Spanish survey plays an essential role in the estimate of survivors of age 2 and older, while for age 1 (without discards) and age 0 (with discards) it has 59% and 51% of weight were respectively estimated. F shrinkage represents almost the rest of the weight. Survivors estimated at the end of the year with their associated maximum se are shown in Table 6.
Table 7 shows F and population numbers from XSA with and without discards. Differences in stock numbers are meaningful for ages 1 to 3 in which most of the discards occur.

The retrospective analysis shown in Figure 2, indicates the same pattern except for the recruitment in the option that includes discards. Recruitment without discards was estimated for age 1, while recruitment with discards was estimated for age 0.
The recruits, Spawning Stock in number (SS) SSB and F estimates obtained from XSA are shown in Figure 3. Patterns are similar for both options. Nevertheless, slight differences in the SSB estimates with discards were observed. The option with discards presents higher values at the beginning of the series than the option without discards and, on the contrary, lower values for recent years.
Figure 4 presents the short-term yield and trends in landings and catches, SS in number and SSB from 2002 to 2004 assuming status quo F, for both options (with and without discards). Differences are clear, especially in SS numbers.
Probability profiles of expected yield and SSB are shown in Figure 5. The 90% confidence interval of the expected yield, at status quo F, in 2003 is between 700 and 1,600 t (for projections without discard) and increases to 700-2,000 t when the discards are included. The differences in SSB are hogher: from 5,700 to 9,300 t without discards to 6,200 to 10,500 t with discards.
A random bootstrapped recruitment over the whole period was used for estimating recruitment for medium-term predictions. Results are summarised in Figure 6. Landings and SSB are predicted to increase gradually in both cases. The predicted increase in SSB is mostly due to the low status quo F (F_{2-4} had some of the series lowest values in the period 99-01) and to the higher recruitment estimated in the random bootstrap. Nevertheless, the projections including discard estimates are significantly higher than those made without discards.
Figure 7 shows the percentiles of SSB<Bpa (5,000 t) between 2002 and 2011, for F multipliers. At status quo F, the probability of SSB being below the proposed Bpa for all the period is virtually zero.
The results for long term projections are given in Figure 8. With the status quo exploitation, and assuming Geometric Mean 90-00 recruitment for both examples, the equilibrium SSB would increase from 7,000 t to 8,000 t when discards are taken into account.

Discussion

Four spot megrim is taken as by-catch in mixed bottom trawl fisheries by Portuguese and Spanish fleets and also in small quantities by the Portuguese artisanal fleet. As we said before, Spanish trawlers record the majority of catches of Four spot megrim (*L. boscii*) distributed in both ICES Divisions (VIIIc and IXa). Nevertheless the decreasing abundance of hake has modified the target species of the Spanish fleets that now are more focused on other species such as blue whiting, horse mackerel and mackerel. The resulting shift of the exploitation to pair trawlers and very high vertical open trawlers (VHVO), that do not catch megrims, has strongly reduced the effort on this species. This is clear in the reduction of total catches in the recent years.

There were different reasons for choosing four spot megrim as an example for the estimation of the overall mortality associated with an exploited fish population:
1. This species has a high level of discards, particularly at younger ages.
2. The discard sampling level is good for most of the period analysed.
3. Although the series with a discard estimation available is shorter than the landing series, it covers a period long enough to try the assessment and corresponds to a period without changes in the regulations.
4. Four spot megrim starts its reproduction at early ages and therefore a part of the discards corresponds to mature individuals. Discards in this case are expected to introduce an unaccounted source of mortality in mature ages.
5. Just a survey is used as tuning fleet by the ICES WGHMM (ICES CM, 2002). The Spanish survey provides good estimates for all ages and covers all the Spanish stock distribution area. This possibility avoids the need to estimate discards for commercial fleets in which samplings are not enough stratified in some cases.

However, some other difficulties have been observed during this study:
1. The sampling level in the years 1993 and 2001 is considered to be low. Nevertheless, as the CVs of the discard samples in weigh and number for these years were similar to those

years with a higher sampling level, they were considered suitable for use. The null catch of age 0 obtained in 1993 is in agreement with the weakness of this year class, confirmed by the Spanish survey indices (ICES CM, 2000). On the contrary, the discard decrease in 2001 cannot be related to the high 1999 and 2000-year classes.

2. There is a general decrease in discards in recent years, this decrease is also remarkable in the total catch. The explanation would be, as we mentioned before, the reduced effort on megrims due to a change in target species of the Spanish fleets as a result of reduced hake abundance.
3. As it was mentioned before, a source of variation in the estimation of discards would be the choice of raising method. As differences in results obtained with each of the raising methods (by weight or numbers) are probably smaller than the error associated to both methods due to high CVs, the importance of the option chosen is minor.
4. Other source of variation in the assessment would be the usage of the same ALKs for discards and landings from 1990 to 1997. Nevertheless, this does not produce any difference in the case of age 0 because the catches at this age came entirely from discards and the otoliths from the survey. The majority of age 1 individuals are also discarded. An overestimation of mean weight at age was expected in the mean weight at age matrix for the rest of the ages. Nevertheless, the differences between the mean weight at age in the mean ALK period and the separate ALK for landings and discards period were negligible.
5. Another variation in the assessment comes from the two different methods which could be used to obtain discards numbers at age for years in which no discards estimations were available. Both estimation ways give an extremely low correlation coefficient at age 2. The explanation would be that discards at this age are more variable between hauls as they are more influenced by Minimum Legal Size, in the middle of this age length distribution. However, the low standard error of the survivors estimated at this age observed from XSA, the tuning with the Spanish survey, and the fact that no trends where observed could be seen as a sign of good estimation of abundance by age for the years with no sampling.

Despite the difficulties found, especially due to the fact that discards sampling programmes were not carried out on a regular basis, some useful conclusions were reached.

The low catches of age 0 four spot megrim shows that this age is not completely recruited to this fishery, even taking discards into account. An important mortality of juvenile (1 year old) four spot megrim is caused by discarding practices. High catches are observed for age 1 in almost all years of first half of the series, have fallen during the recent years. That change in the catch structure could be related to the enforcement of the legal mesh size and to changes in the fleets' target species.

Slight differences were observed between SSB estimations with and without discards. In recent years, the option without discards shows SSB values slightly higher than the options with discards, due to the different F estimate between both options. The scenario is very different when we compare de SS in numbers. The estimation with discards is much higher due to the large number of individuals in younger ages.

The differences found in the population parameters between the two options (Recruits, F (2-4) SS numbers and SSB) cause significant differences in prediction. Those differences appear earlier in SS in numbers than in SSB. SSB predictions are clearly different after 3 years, since four-spot megrim starts to contribute strongly to SSB at age 2 (ICES, 2002).

Those differences in predictions are due to a combination of two factors: the number of recruits for predictions, that is significantly higher when the discards are included than when the discards are not considered, and the exploitation pattern effect.

The exploitation pattern results to be quite different between the two options (Figure 9), with higher mortality in younger ages (1, 2 and 3) for the "with-discards" option and the opposite (a lower mortality) for older ages. This high fishing mortality in younger ages is not enough to reduce recruits to a level that would compensate the high values of recruits estimates when discards are used. The lower mortality over age 4 and older increases the number of survivors and the SSB in older ages.

The picture would we probably different considering the possibility of a higher natural mortality affecting age 0 recruits, which sounds quite sensible, instead having a 0.2 for all ages.

The combination of both effects is on the base of the significant differences in long term predictions, when strong cohorts (with origin in strong recruitments) reach the ages with less fishing mortality (the older ages in the with-discards option).

Discards introduce more variation in predictions than any other sensible changes in XSA parameters and this demonstrates the importance of discard for TAC constriction recommendations in stock assessment. Nevertheless, no changes in Biological reference points based on recruitment variability are found in this stock as it is now far above Bpa.

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Table 1. Sampling level of discards on board "Baka" Spanish trawlers.

					CV			
			Length distribution samples		In weight		In Number	
	Trips	Hauls	Retained	Discarded	Retained	Discarded	Retained	Discarded
1993	6	17	15	11	0,82	1,62	0,64	1,04
1994	60	470	234	209	1,27	2,19	1,35	2,71
1997	57	395	241	207	1,24	1,81	1,30	2,02
1999	44	228	181	122	0,93	1,65	0,92	3,12
2000	70	368	311	248	0,99	1,72	0,97	1,58
2001	11	48	19	15	1,10	2,15	1,29	1,64

Table 2. Pearson´s coefficients of correlation by age between abundance indices from surveys or XSA abundance and discards per age with observers on board. All correlations are significant at $p < .05$

	Spanish Survey Indices	XSA Abundance
Age 0	0,08	0,32
Age 1	0,66	0,64
Age 2	0,01	0,01
Age 3	0,70	0,56
Age 4	0,53	0,27

Table 3. Total Spanish fleet Retained and Discarded Estimation and their respectively Discard/Total Catch rates.

	Tonnes			Number *10^3		
	Retained	Discarded	Discard rate	Retained	Discarded	Discard rate
1993	1384	499	26,5	10839	30040	73,5
1994	1403	276	16,5	12678	10564	45,5
1997	896	374	29,4	8026	14644	64,6
1999	1115	359	24,4	9881	14907	60,1
2000	1040	518	33,3	8614	14604	62,9
2001	927	137	12,9	8112	5071	38,5

Table 4. Input data for Four spot megrim (*L. boscii*) in Divisions VIIIc, IXa.

Discards numbers at age. Numbers*10^-3

Year/Age	1990*	1991*	1992*	1993	1994	1995*	1996*	1997	1998*	1999	2000	2001
0	481	1072	1084	0	1815	944	1441	317	423	4200	438	131
1	22709	4798	49323	27256	4360	23720	24764	4099	6830	5068	8093	3848
2	2939	3091	3228	2467	3166	3281	2899	7422	3040	2799	3196	993
3	304	691	1040	207	1104	1131	0	2512	2896	2634	2022	80
4	322	104	208	109	80	380	174	171	425	205	741	19
5					31			106			114	
6					6			17			1	
+gp					2			0				
Total	26755	9757	54884	30040	10564	29455	29278	14644	13614	14907	14604	5071

Catches numbers at age. Numbers*10^-3

Year/Age	1990*	1991*	1992*	1993	1994	1995*	1996*	1997	1998*	1999	2000	2001
0	481	1072	1084	0	1815	944	1441	317	423	4200	438	131
1	24153	5958	50169	27802	4443	24890	25161	4133	6875	5106	8125	4107
2	8123	6770	5895	4801	6081	4828	5036	8666	4244	3941	3761	2128
3	2189	4019	5040	2303	5619	6913	1267	5382	7131	5370	3517	1320
4	4151	2015	5387	3908	2348	6558	3988	915	3366	4053	3609	2320
5	2311	2650	2200	1151	1643	1420	1896	1730	698	1392	2057	1867
6	1383	1028	738	635	845	839	204	1083	829	236	893	964
+gp	803	479	64	278	448	342	551	443	349	491	819	346
Total	43594	23991	70577	40878	23242	46734	39544	22669	23915	24789	23219	13183
Tons Catch	2636	1934	3333	1883	1679	2413	1854	1270	1475	1474	1558	1064

* Years without discards sampling on board

Table 5. Input data for Four spot megrim (*L. boscii*) in Divisions VIIIc, IXa.

Landings weights at age (kg)

Year/Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
0												
1	0,028	0,033	0,032	0,023	0,033	0,041	0,038	0,032	0,033	0,036	0,037	0,046
2	0,065	0,073	0,073	0,074	0,069	0,069	0,062	0,056	0,063	0,070	0,085	0,070
3	0,106	0,117	0,110	0,118	0,092	0,092	0,074	0,080	0,086	0,091	0,083	0,092
4	0,141	0,125	0,125	0,143	0,121	0,094	0,112	0,097	0,112	0,102	0,097	0,107
5	0,156	0,166	0,161	0,178	0,153	0,143	0,137	0,126	0,142	0,149	0,129	0,122
6	0,184	0,191	0,226	0,220	0,181	0,169	0,213	0,180	0,180	0,200	0,163	0,162
+gp	0,273	0,264	0,359	0,297	0,245	0,256	0,232	0,252	0,294	0,276	0,224	0,249

* Age 0 was not used in the assessment

Total catch weights at age (kg).

Year/Age	1990*	1991*	1992*	1993	1994	1995*	1996*	1997	1998*	1999	2000	2001
0	0,005	0,005	0,005	0,000	0,005	0,005	0,005	0,004	0,005	0,006	0,006	0,004
1	0,020	0,022	0,020	0,014	0,021	0,021	0,020	0,016	0,020	0,020	0,025	0,025
2	0,055	0,057	0,053	0,056	0,052	0,047	0,048	0,029	0,044	0,044	0,053	0,056
3	0,098	0,105	0,097	0,112	0,083	0,085	0,074	0,062	0,071	0,071	0,066	0,089
4	0,135	0,122	0,123	0,141	0,120	0,092	0,110	0,091	0,106	0,100	0,091	0,107
5	0,156	0,166	0,161	0,178	0,152	0,143	0,137	0,123	0,142	0,149	0,126	0,122
6	0,184	0,191	0,226	0,220	0,181	0,169	0,213	0,178	0,180	0,200	0,163	0,162
+gp	0,273	0,264	0,359	0,297	0,244	0,256	0,232	0,252	0,294	0,276	0,224	0,249

* Years with no sampling on board discards estimation

Table 6. Terminal year survivor with both options and maximum se.

	XSA Survivors Without Discard	Max s.e	XSA Survivors With Discard	Max s.e
Age 0			31662	0,39
Age 1	22771	0,23	29456	0,20
Age 2	16674	0,19	19572	0,18
Age 3	8315	0,18	8421	0,17
Age 4	7074	0,15	7874	0,15
Age 5	4389	0,14	4615	0,14
Age 6	2310	0,14	2129	0,15

Table 7. Four spot megrim (*L. boscii*) in Divisions VIIIc-IXa. Fishing mortality (F) at age and Stock number at age (start of year)

Terminal Fs derived using XSA (Without Discards)

Year/Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	FBAR 99-01
0	0,057	0,071	0,024	0,018	0,009	0,050	0,014	0,001	0,002	0,002	0,001	0,010	0,005
1	0,258	0,203	0,231	0,086	0,128	0,241	0,120	0,054	0,059	0,065	0,043	0,060	0,056
2	0,208	0,263	0,355	0,287	0,238	0,403	0,319	0,236	0,264	0,184	0,114	0,127	0,142
3	0,512	0,337	0,847	0,682	0,578	0,594	0,511	0,314	0,404	0,409	0,300	0,258	0,322
4	0,788	0,833	0,827	0,449	0,706	0,914	0,363	0,426	0,549	0,340	0,373	0,326	0,346
5	0,594	1,054	0,583	0,605	0,703	1,056	0,304	0,357	0,402	0,360	0,381	0,321	0,354
6	0,594	1,054	0,583	0,605	0,703	1,056	0,304	0,357	0,402	0,360	0,381	0,321	
+gp	0,326	0,268	0,478	0,351	0,315	0,413	0,317	0,201	0,242	0,220	0,153	0,148	
FBar (2- 4)	0,326	0,268	0,478	0,351	0,315	0,413	0,317	0,201	0,242	0,220	0,153	0,148	

Stock number at age (start of year). (Without Discards). Numbers*10^-3

Year/Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	GMST 90-99	AMST 90-99
0															
1	28637	18736	39297	33278	9831	26717	32192	28472	24429	17995	26440	28095	0	24382	25959
2	25166	22140	14290	31408	26752	7974	20816	25997	23279	19960	14699	21618	22771	20547	21778
3	11108	15914	14798	9287	23603	19265	5129	15110	20159	17970	15310	11523	16674	14098	15234
4	10562	7389	10018	8496	5707	15239	10541	3053	9774	12672	12236	11182	8315	8634	9345
5	4685	5183	4320	3516	3518	2620	6887	5179	1826	5342	6893	7423	7074	4048	4308
6	3412	1744	1845	1546	1837	1422	860	3923	2771	864	3114	3886	4389	1801	2022
+gp	1958	798	158	669	964	569	2308	1618	1157	1783	2837	1385	3133		
Total	85528	71903	84727	88200	72212	73807	78732	83351	83395	76586	81528	85112	62355		

Table 7. (Continued) Four spot megrim (*L. boscii*) in Divisions VIIIc-IXa. Fishing mortality (F) at age and Stock number at age (start of year)

Terminal Fs derived using XSA (With Discards)

Year/Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	FBAR 99-01
0	0,015	0,010	0,014	0,000	0,027	0,011	0,030	0,007	0,014	0,089	0,010	0,004	0,034
1	0,591	0,259	0,816	0,578	0,293	0,598	0,468	0,111	0,206	0,223	0,247	0,119	0,196
2	0,361	0,323	0,443	0,160	0,235	0,603	0,226	0,289	0,159	0,174	0,255	0,094	0,174
3	0,236	0,305	0,425	0,309	0,284	0,458	0,308	0,402	0,410	0,310	0,232	0,133	0,225
4	0,552	0,356	0,878	0,698	0,599	0,632	0,526	0,383	0,475	0,434	0,354	0,236	0,341
5	0,799	0,856	0,843	0,457	0,730	0,932	0,372	0,456	0,570	0,367	0,411	0,312	0,363
6	0,629	1,092	0,617	0,629	0,734	1,109	0,315	0,378	0,413	0,382	0,426	0,343	0,384
+gp	0,629	1,092	0,617	0,629	0,734	1,109	0,315	0,378	0,413	0,382	0,426	0,343	
FBar (2- 4)	0,383	0,328	0,582	0,389	0,373	0,564	0,353	0,358	0,348	0,306	0,280	0,154	

Stock number at age (start of year). (With Discards). Numbers*10^-3

Year/Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	GMST 90-99	AMST 90-99
0	35742	122586	86665	23587	76646	91973	54787	50318	34958	54778	49968	38814	0	56531	63204
1	59813	28828	99395	69974	19311	61110	74447	43552	40910	28239	41048	40514	31662	47037	52558
2	29598	27116	18211	35983	32134	11791	27511	38186	31917	27274	18500	26256	29456	26672	27972
3	11507	16883	16075	9576	25116	20807	5285	17968	23422	22292	18764	11743	19572	15450	16893
4	10809	7440	10186	8601	5756	15479	10780	3180	9841	12724	13392	12180	8421	8771	9480
5	4643	5093	4268	3465	3506	2588	6739	5217	1776	5011	6750	7699	7874	3978	4231
6	3275	1710	1772	1504	1796	1384	834	3802	2706	822	2843	3666	4615	1745	1961
+gp	1879	782	152	651	939	553	2238	1543	1130	1697	2585	1306	2888		
Total	157266	210439	236725	153341	165204	205685	182622	163766	146661	152838	153851	142178	104488		

Figure 1. Four spot megrim. Division VIIIc and IXa

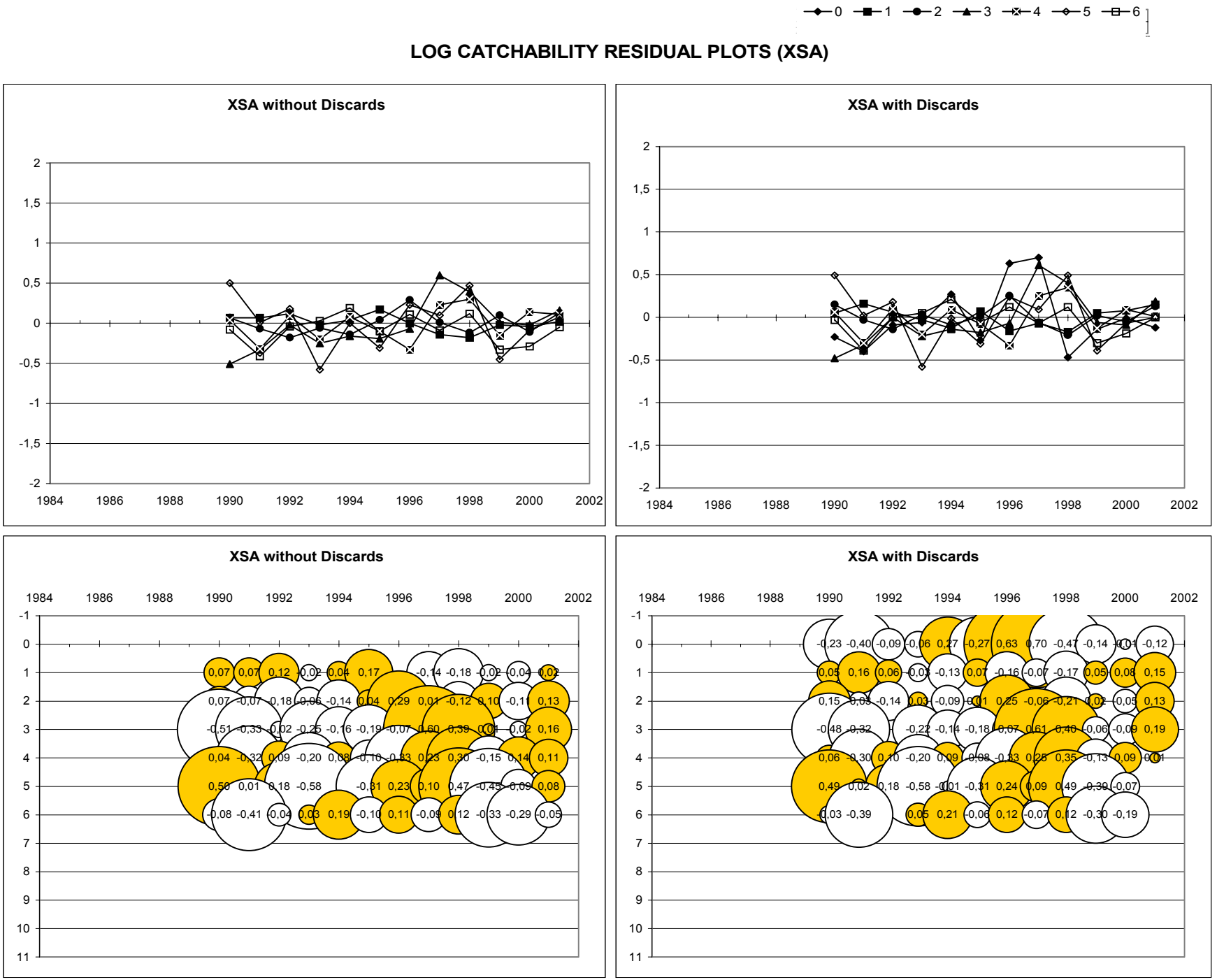
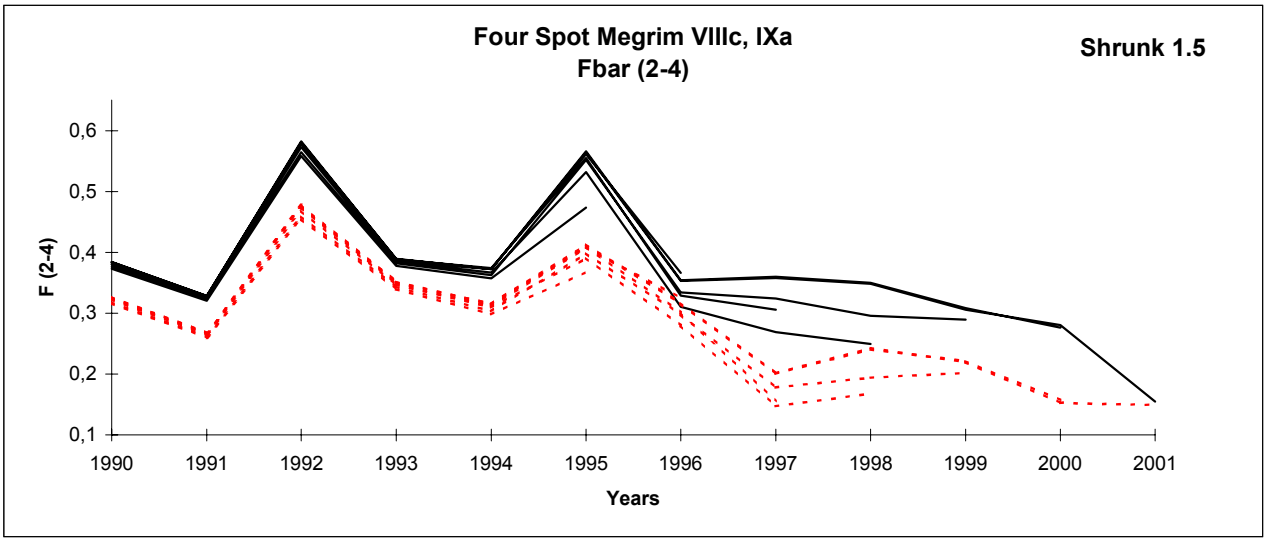
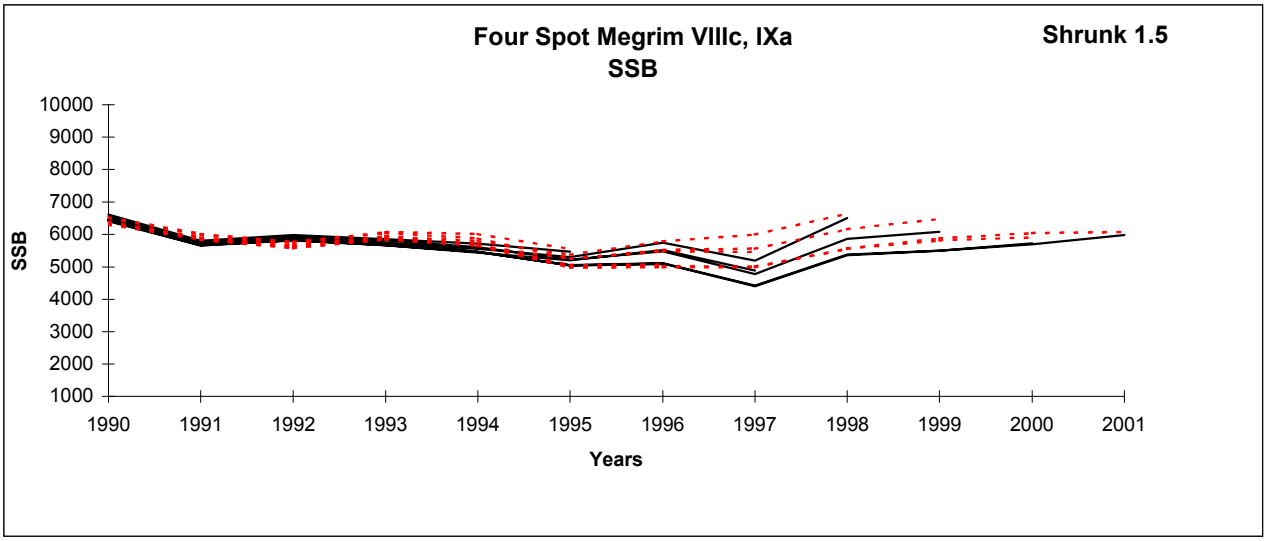


Figure 2. Four Spot Megrim in Division VIIIc, IXa. Retrospective XSA
Without Discards -------
With Discards ———





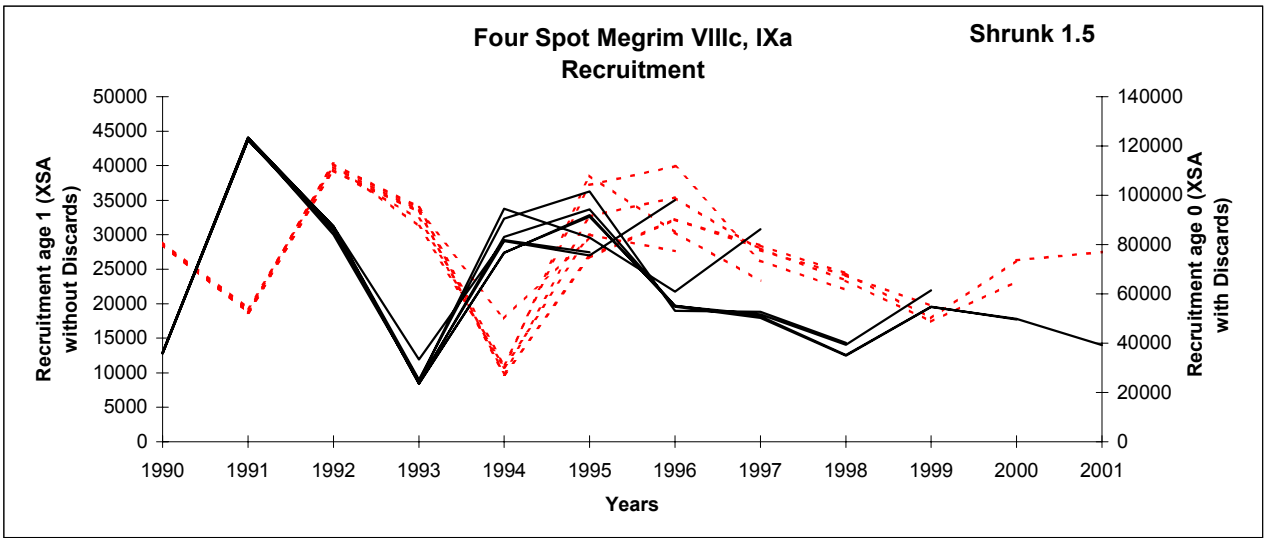
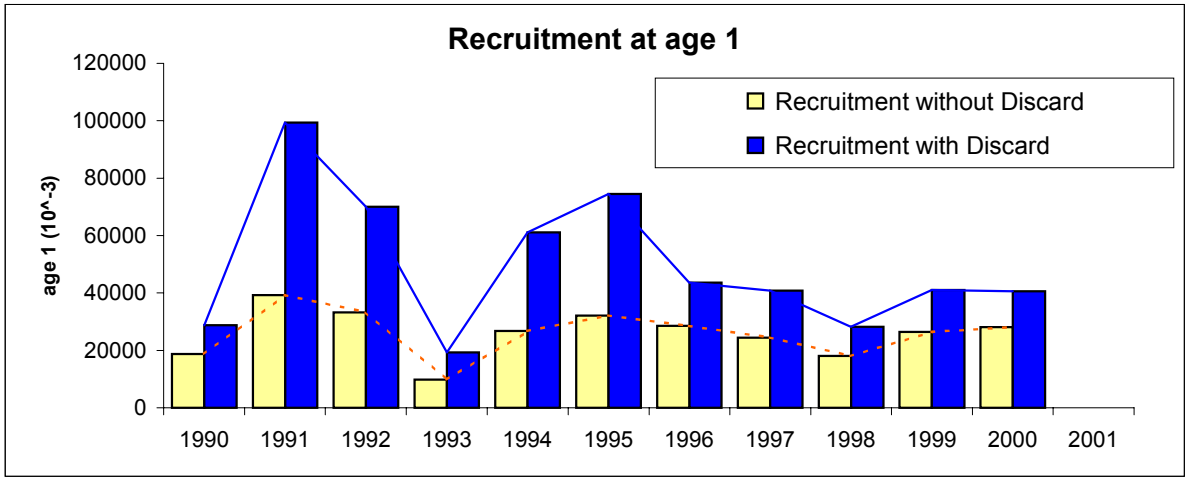
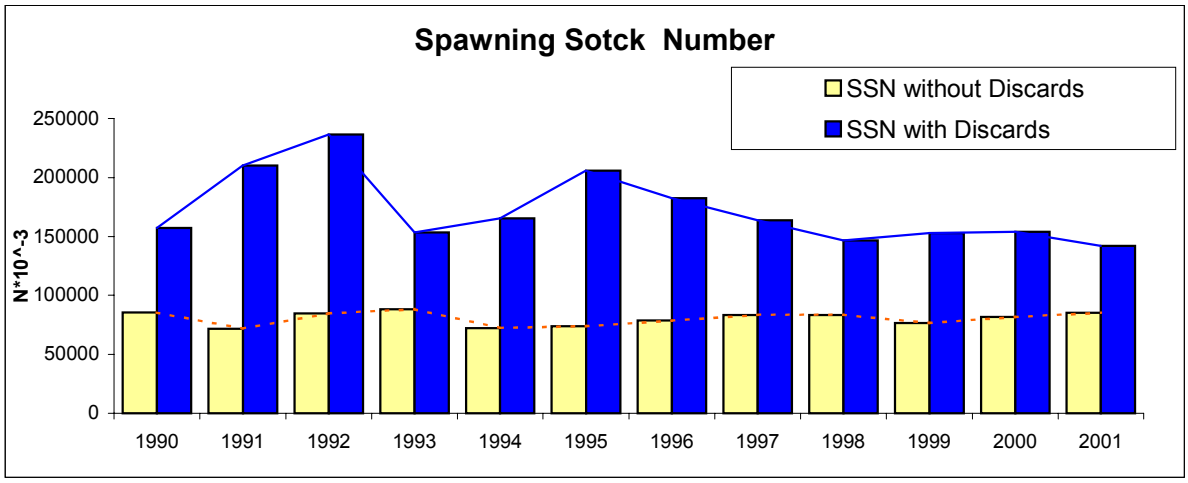
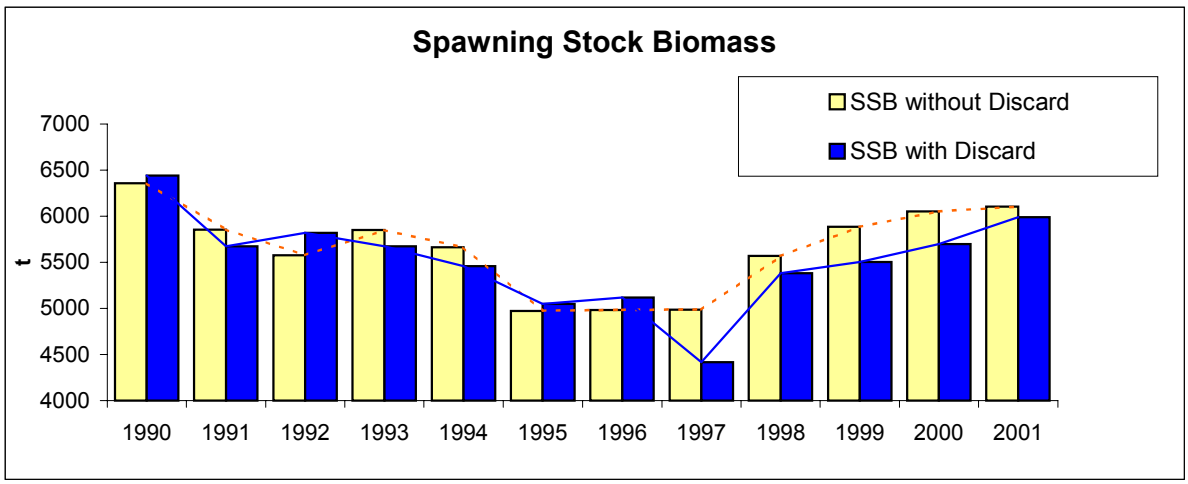


Figure 3. Terminal Recruits, SS Number, SSB and Mean Fs from XSA with and without Discards.







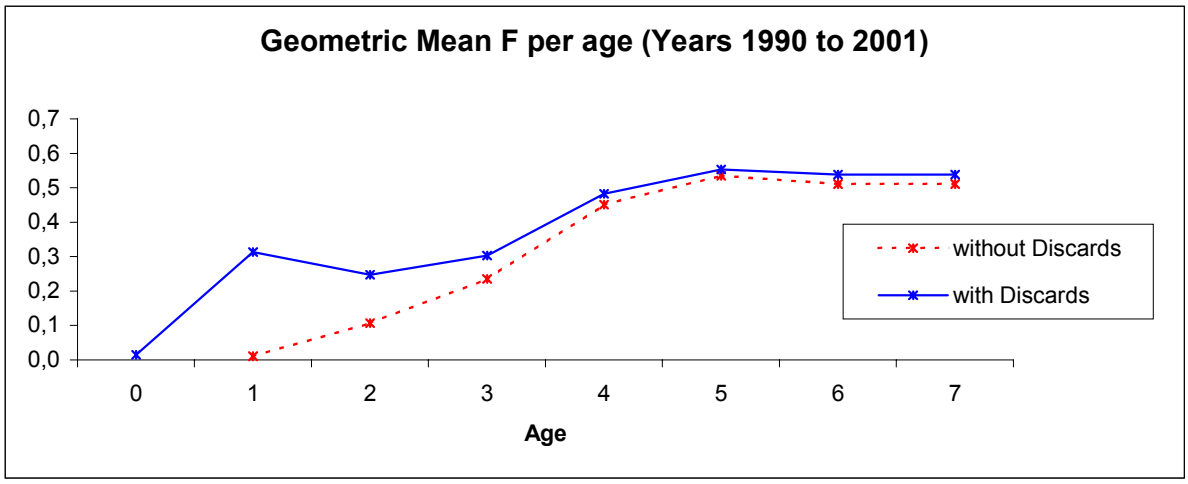
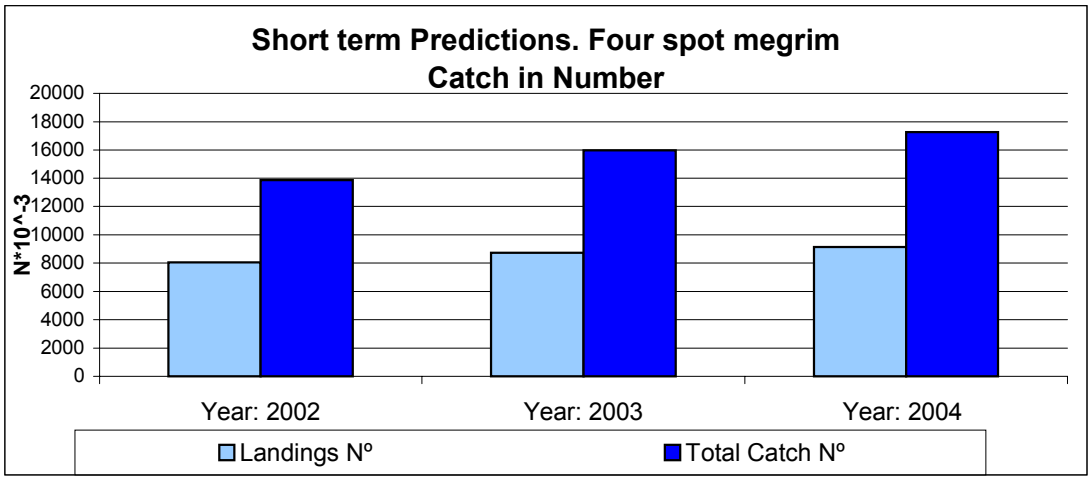
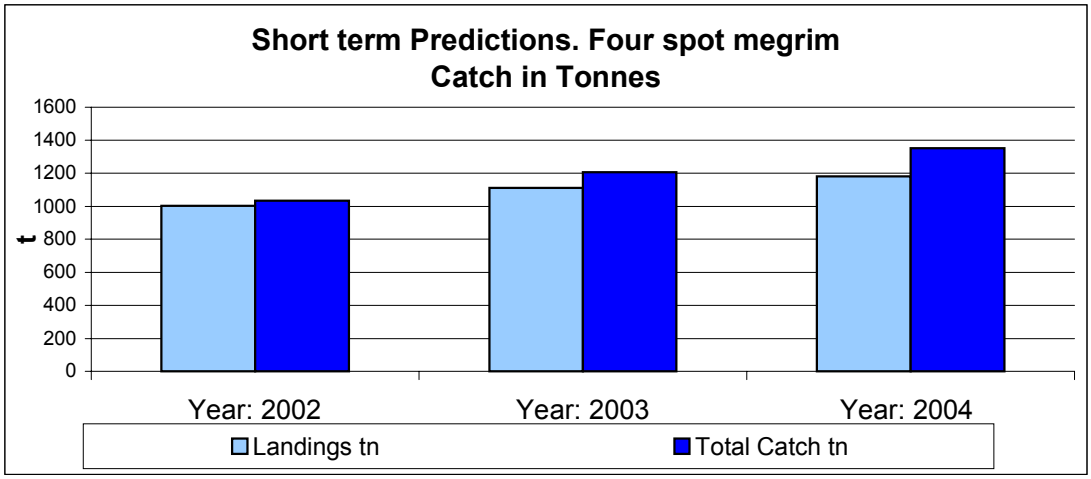
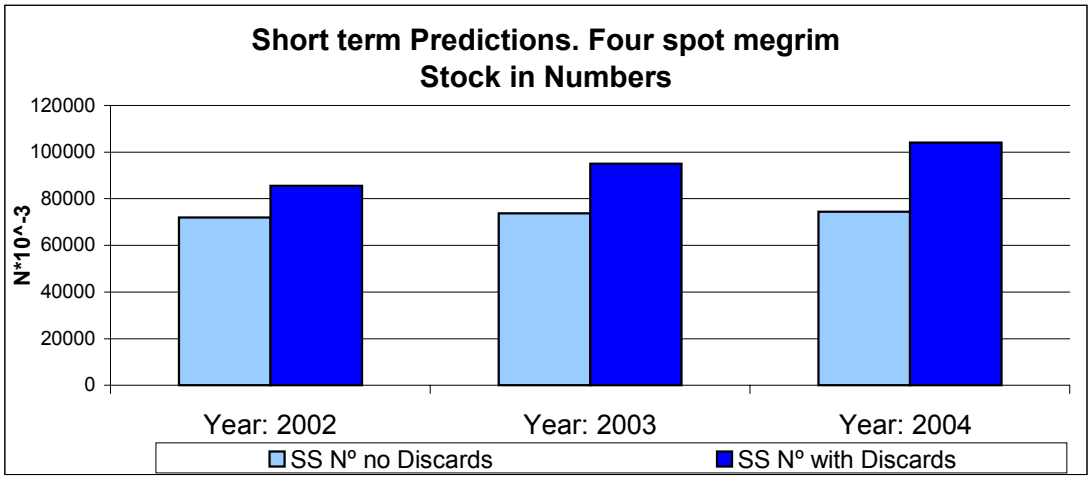


Figure 4. Four spot megrim in Divisions VIIIc and IXa. Short term prediction.







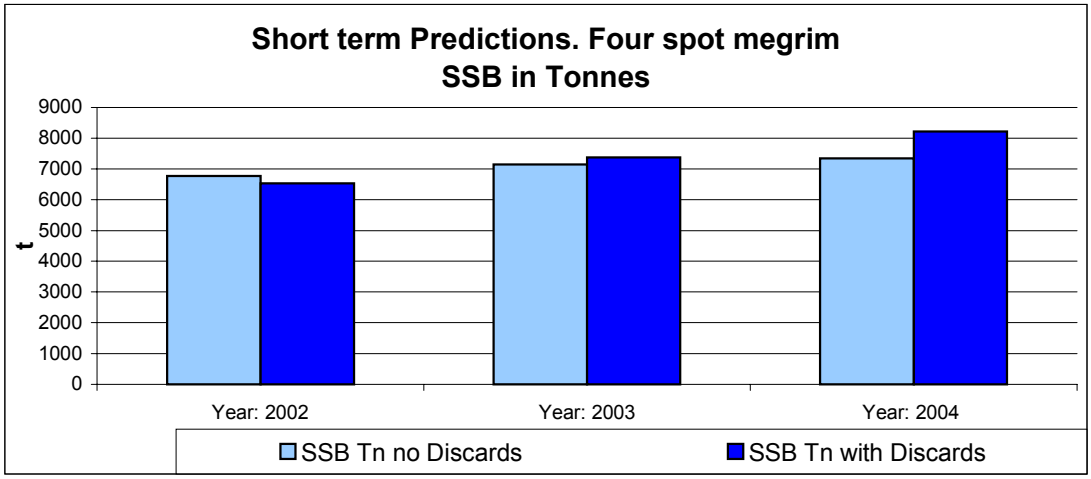
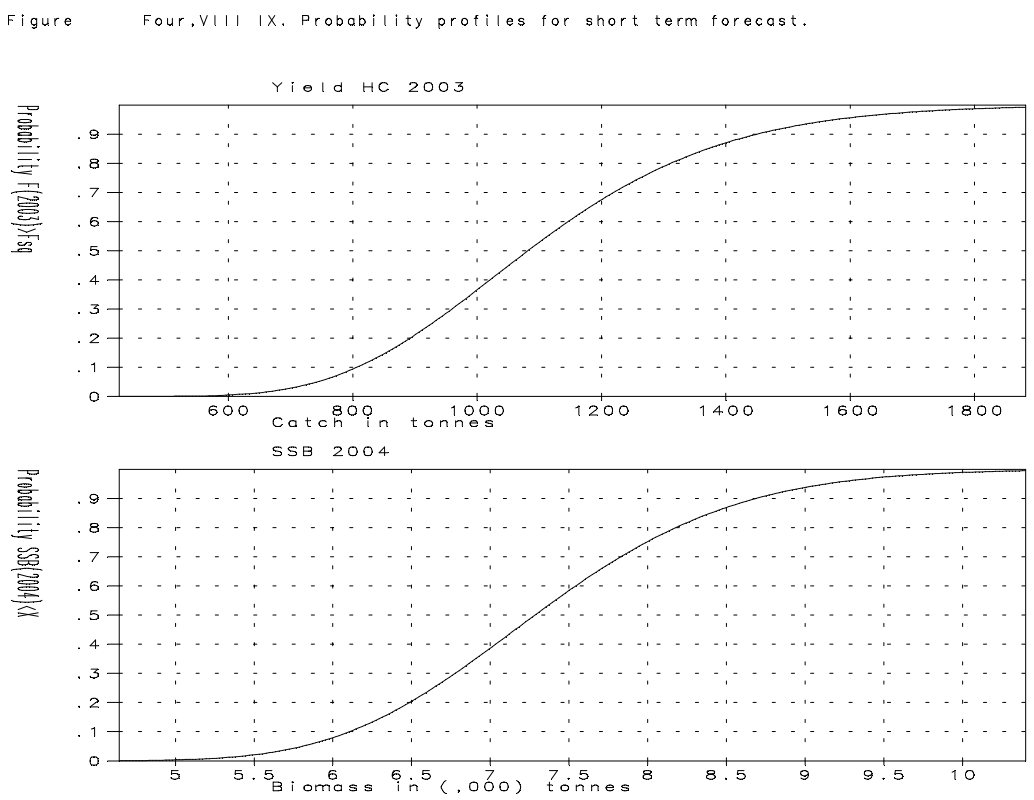


Figure 5. Four spot megrim VIIIc & IXa. Probability profiles for short term forecast.
a) without discard, b) with discards

a)



b)

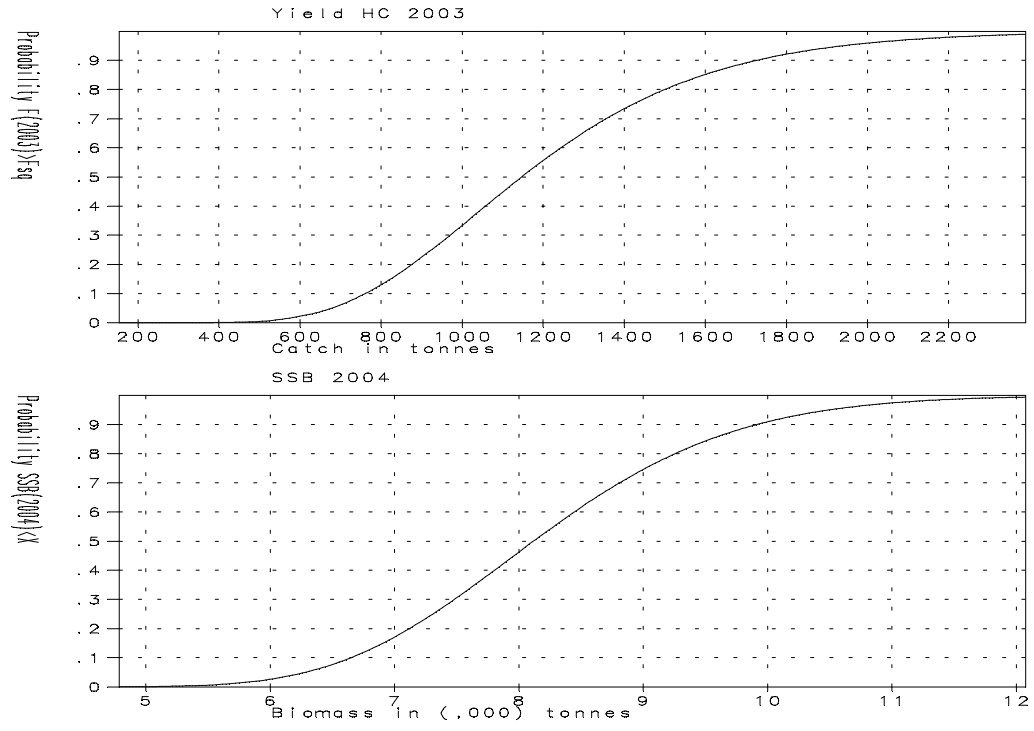


Figure 6. Four spot megrim (*L. boscii*) Div. VIIIc, IXa. Medium term projections. Random stock-recruitment

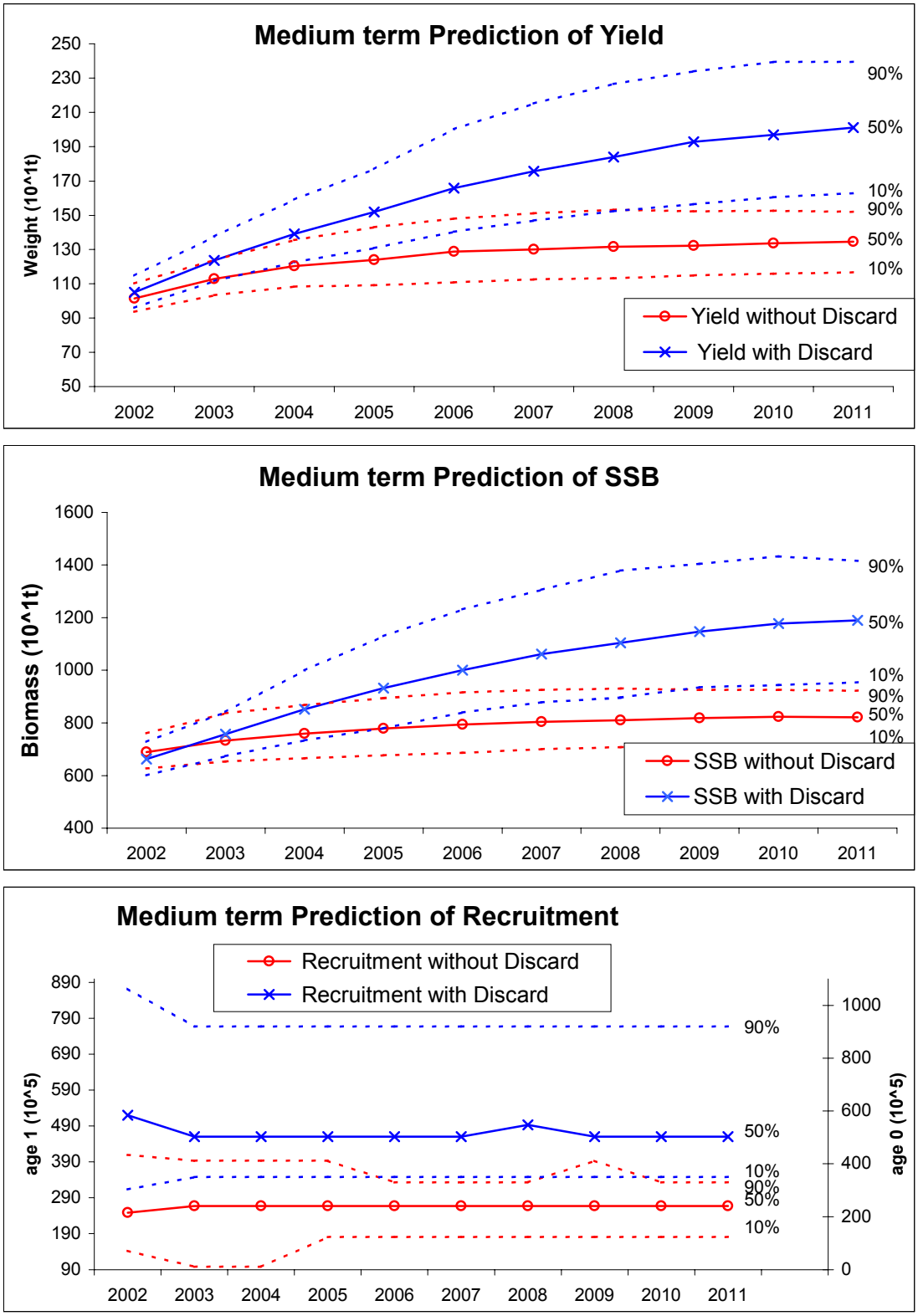
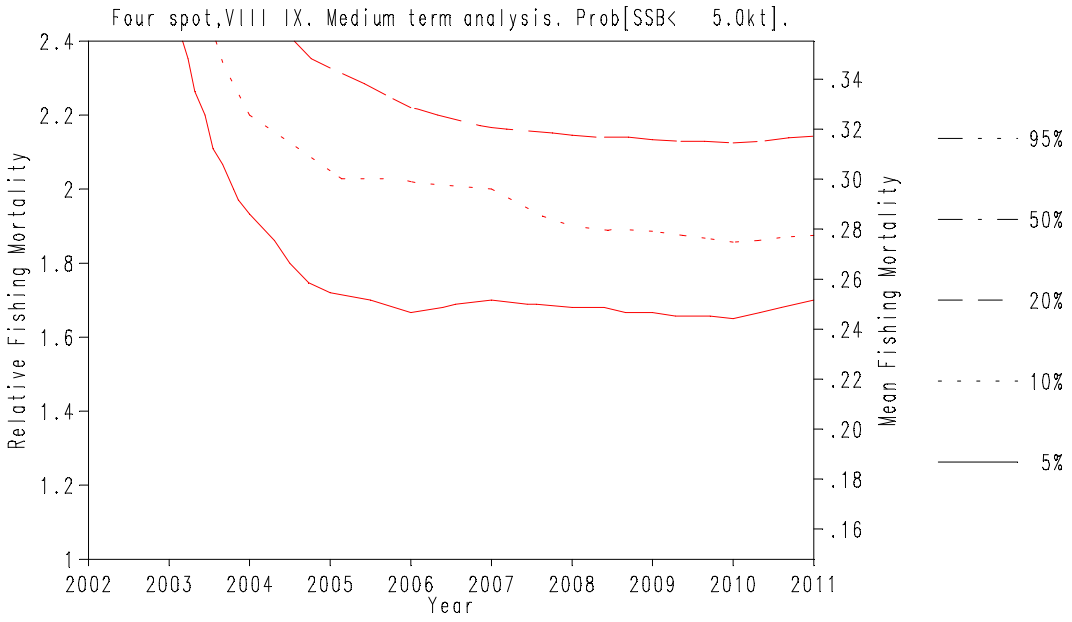


Figure 7. Four spot megrim in Divisions VIIIc and IXa. Medium term analysis. Lines show 5,10,20,50, and 95 percentiles.
b) without discard, b) with discards

a)



b)

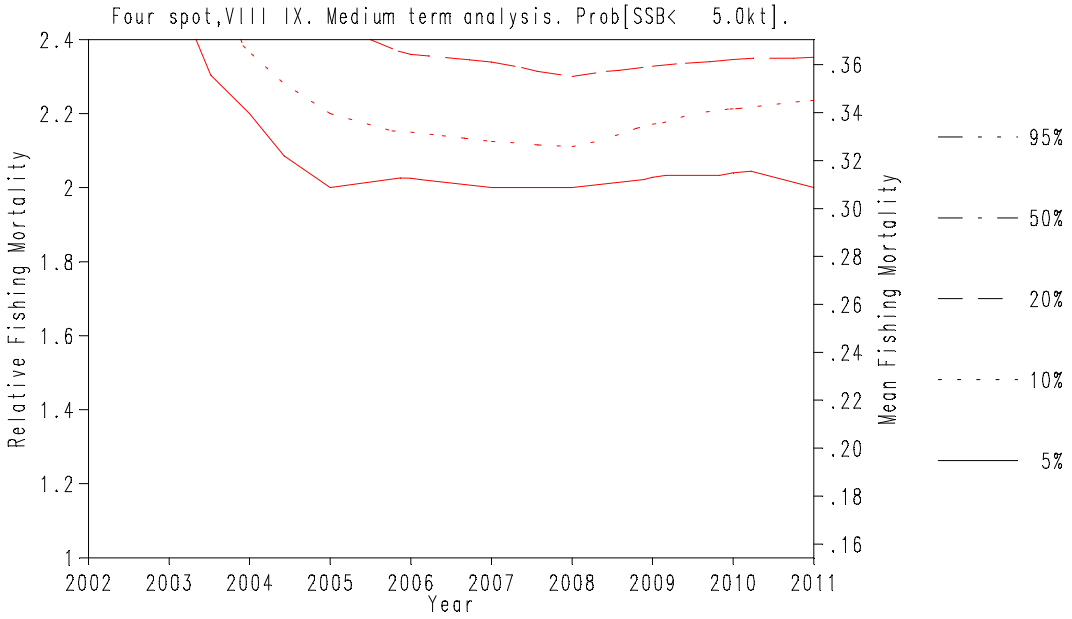


Figure 8. Four spot megrim in Divisions VIIIc, IXa. Yield per recruit results with different F multiplier

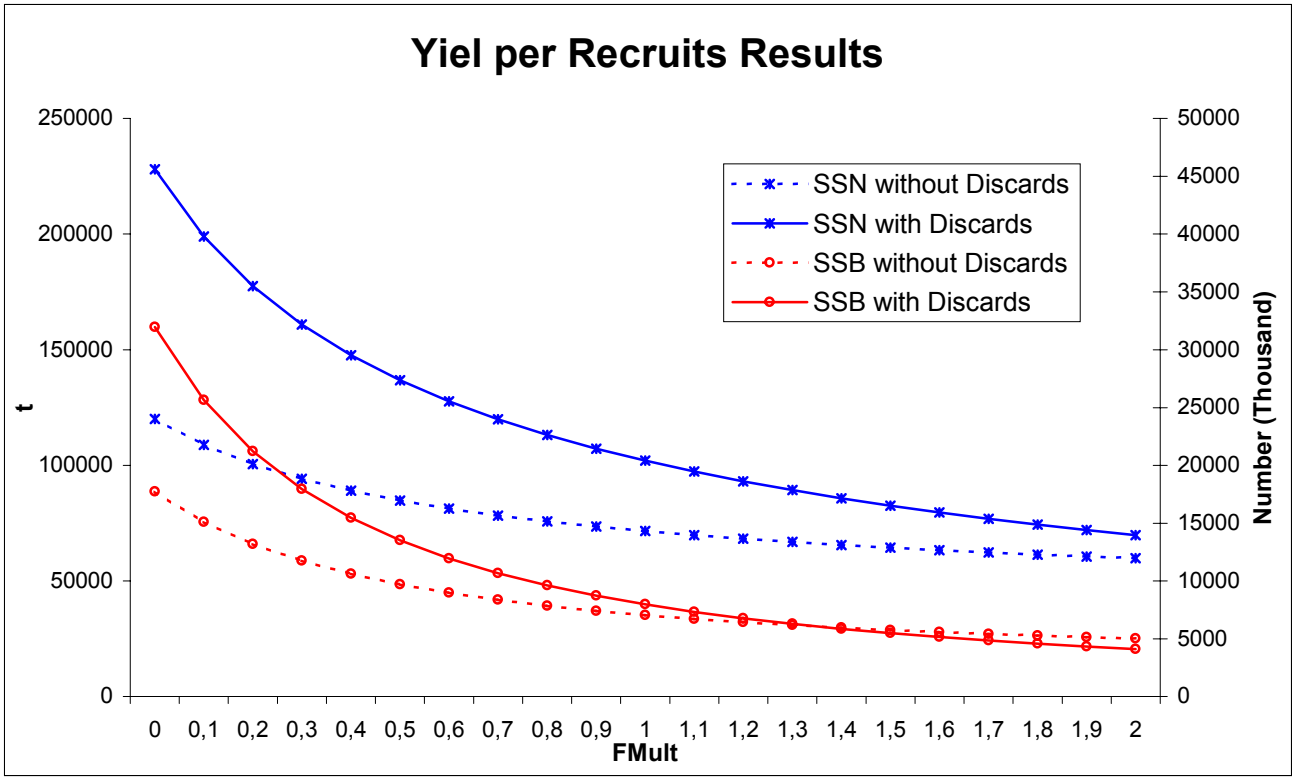


Figure 9. Fs from XSA (scaled average of 1999-2001) with and without discards used for Predictions.